A Comparative Study of College Age Female Beginning, Competitive (Speed), and Synchronized Swimmers in Measures of Arm Strength, Flexibility, Kinesthesis, and Percent of Total Body Fat

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A COMPARATIVE STUDY OF COLLEGE AGE FEMALE BEGINNING, COMPETITIVE (SPEED), AND SYNCHRONIZED SWIMMERS IN MEASURES OF ARM STRENGTH, FLEXIBILITY, KINESTHESIS, AND PERCENT OF TOTAL BODY FAT

by

Mary Jo De Boer

A Thesis Submitted to the Faculty of The Graduate College in partial fulfillment of the Degree of Master of Arts

Western Michigan University Kalamazoo, Michigan August 1977

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Mary Jo De Boer
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Aquatics, particularly swimming, is an integral part of today's physical education programs. At the college level, a wide range of swimming ability exists among students from beginners through advanced. Often an individual's lack of swimming ability can be traced to a lack of exposure to an aquatic environment and instruction in swimming during the formative years. Those individuals who are fortunate enough to learn to swim early in life often go on to swim competitively (for speed) and/or join specialized clubs, such as water polo or synchronized swimming.

Historically, skill in swimming goes as far back as man. The earliest time in which the ability to swim is known to have been acquired, utilized, and recorded was on wall paintings dated about 9000 B.C. At that time, pictures portraying the actions of swimmers were inscribed on the rock walls of caves of the Wadi Sori in the Libyan Desert.¹ Children learned to swim from one another or from their elders, much in the same way as they learned to walk. Swimming was considered as a "natural" part of

life and not previously thought of as a sport. In America, Benjamin Franklin, who had experimented with paddles attached to the hands of swimmers, recommended that swimming be part of the curriculum of schools in the United States. In 1827, Francis Leiber established a swimming school in Boston. In 1855, the first YMCA swimming pool was built in Brooklyn, New York. Formal swimming competitions were not evident until the late 1800's.

Synchronized swimming is a creative form of swimming often expressed in water shows or aquatic art. Involved are the elements of stunts, pageantry, and group swimming formations. Stoerker, in a study of The Origin and Development of Synchronized Swimming in the United States, points out that there were water activities of this type in the United States as early as 1910. Toler pointed

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out that, "water stunts were designed to perfect water­
manship, muscle control, confidence in water, and to use
these skills as a means for entertaining others." Syn­
chronized swimming has been known by many names such as
water ballet, ornamental swimming, formation swimming, rhythmic swimming and figure swimming.\(^7\) In 1941, the
Amateur Athletic Union recognized synchronized swimming
as a competitive sport.

Swimming exercise contributes significantly to the
physical development of the body. Muscular development
and strength, circulorespiratory endurance, flexibility,
and co-ordination are benefits from or through swimming.
Torney\(^8\) stated that:

"symmetrical development, the acquisition of
grace and strength, the improvement of pos­
ture through the strengthening of muscles
utilized in swimming, and its development
and improvement of endurance are additional
benefits obtained."

Much has been written about the specificity of flex­
ibility and the amount of flexibility needed for various
activities. Many investigators have also studied kines­
thesis or the part that "muscle sense" plays in perform­
ing various movements.

We know that the buoyancy of any given individual

\(^7\) Ibid.

depends on his/her individual physical make-up (composition); muscle and bone are dense in structure and do not aid in flotation, whereas fat, which is much less dense, is easily supported by the upward force exerted by the water. There may exist a difference in the amount of arm strength swimmers have.

The aim of this study was to investigate which factors lead to success in swimming. Do differences exist between the groups in measures of flexibility? Is the degree of "muscle sense" enhanced among any of the groups? What differences exist in the arm strength of beginning, synchronized, and competitive (speed) swimmers? Do the amounts of total body fat vary between the three groups? All of these aspects were investigated in this study.

Statement of the Problem

The problem in this investigation was to compare measures if flexibility, percent of total body fat, arm strength, and kinesthetic sense among college age, female, beginning, competitive (speed), and synchronized swimmers.

Purpose of the Study

The purpose of this study was to determine whether differences exist between beginning, competitive (speed), and synchronized swimmers in measures of flexibility, percent of total body fat, arm strength, and kinesthetic
sense. It is also the first step in isolating those factors which contribute to success in swimming.

Definition of Terms

**Kinesthesis.**—Kinesthesis is defined in this study as follows:

"that sense which enables the person to perceive the position and movement of the total body and of its parts. It is the basis for balance, both dynamic and static, for knowing the gradations of effort put into a movement and for the duplication of movements previously performed."\(^9\)

**Flexibility.**—Flexibility is the range of motion of a particular joint action.\(^10\) Flexibility is used in this study as a measure of hip flexion, hyperextension of the spine, and flexion and extension of the ankle.

**Arm Strength.**—Arm strength "is the power to resist force"\(^11\) as measured by a hand grip dynamometer.

**Percent of Total Body Fat.**—Percent of total body

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fat is "body tissue with a density of less than 1.0" as opposed to lean body mass measured in the underwater weighing techniques using Chatillion scales.

**Beginning Swimmers.**—Beginning swimmers are identified as "persons who have reached youth or adulthood without being able to swim or survive by their own efforts in deep water." Subjects in this study were enrolled in a general physical education class in beginning swimming during the Winter 1977 term at Western Michigan University.

**Synchronized Swimmers.**—Synchronized swimmers are identified as:

"persons involved in stunt and figure competition and/or routines performed to music demanding quality swimming, acute timing, breath control, co-ordination, and strength. They express ideas through aquatic movements."

Members of the Western Michigan University Aqua Sprites (synchronized swim club) participated in this study.

**Competitive Swimmers.**—Competitive swimmers are identified as "persons in swimming events that include

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the four basic strokes swum at various distances both as individual and relay races."¹⁵ This investigation included members from the Women's Intercollegiate Swim teams from Western Michigan University and Kalamazoo College.

Delimitations

This study was delimited to female college students who (1) were attending either Michigan Institutions; Western Michigan University or Kalamazoo College during the Winter Semester 1977; (2) were between the ages of eighteen and twenty-two years; (3) who had no physical deficiencies that might have affected participation in the study; and (4) who volunteered to participate in this study.

Significance of the Study

Very little research has been completed establishing the physical characteristics of women participants in various aquatic ability groupings. Women's athletics are developing at a rapid rate. It is hoped, therefore, that the findings of this study will lead to further

research in the area of women's participation in aquatic activities.
CHAPTER II

REVIEW OF LITERATURE

This chapter is devoted to reviewing past studies related to kinesthesis, flexibility, percent of total body fat, and arm strength in college women swimmers. A brief summary of the findings is included at the end of the chapter.

Kinesthesis

There have been many definitions of kinesthesic or kinesthesia. Scott\(^1\) defined kinesthesia as the

"sense which enables us to determine the position of segments of the body, their rate, extent and direction of movement, and the position of the entire body and the characteristics of total body motion."

Rasch and Burke\(^2\) defined kinesthesia as "the perception or consciousness of muscular movement and the position of one's body parts in space." They further point out that the data kinesthetic receptors furnish is necessary for efficient movements and "in combination with the sensory organs, they enable the body to make the changes in posi-


tion necessary to maintain balance and to execute body movements."

According to Scott and French, kinesthesis "is the basis for balance, both dynamic and static, for knowing the gradations of effort put into a movement, and for duplicating movements previously performed." Scott also stated that:

"kinesthesis is believed to hold at least a partial answer to the secret of individual differences in motor accomplishment and learning rate. It can give the physical educator a tool with which to instruct and serve as an aid in understanding, guiding, and motivating individuals."

The components of kinesthesia are many and most authors agree that there is no one specific test to measure general kinesthetic sensibility (2, 3, 4). Bass investigated kinesthetic tests of static balance in "which the equilibrium is maintained for one position of the body" and dynamic balance that is "concerned with keeping one's equilibrium while in motion or while changing from one balanced position to another." She devel-

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oped a Stepping-Stone Test for dynamic balance and a Balance-on-a-Stick test for static balance. She stated that "balance is a general kinesthetic response or sensitivity factor which is probably less used when the eyes are open." Later this test was used by Gross and Thompson who investigated the relationship of dynamic balance to speed and ability in swimming. They obtained a .75 correlation coefficient between the Bass test and speed in the 30-yard crawl, and a coefficient of .65 with judges' ratings of nine strokes. They drew the following conclusions:

1. In general, individuals who have better dynamic balance, as determined by the Bass Test, can swim faster than individuals who have poor dynamic balance.

2. Individuals with better swimming ability, as determined by experts' judgements, tend to have better dynamic balance than individuals with poor swimming ability.

3. Dynamic balance, as measured in this study, was not a chance factor and may be an important factor in the speed and ability in swimming.

Scott attempted to establish tests for the measurement of kinesthesis. She measured 100 college women in

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twenty-eight measures of kinesthesis and two of motor ability. Her purpose was to analyze the quality of the test items and the inter-relationship of tests. Although the tests were adequate in reliability, no single test was sufficient to use as a single measure of kinesthesis. She concluded that "kinesthesis is composed of a series of specific functions."

A balance test, two arm positioning tests, and a weight shifting test were combined by Roloff. The resulting correlation of .88 denotes a good battery to be used to measure kinesthesis for college women.

Many experiments have been conducted trying to find the relative importance of tests of kinesthesis to various motor tasks and sport skills. Spears stated that:

"body awareness takes place through kines-thesia or the ability to 'feel' a body position or movement. It is essential in synchronized swimming to be aware of every part of the body at all times and to utilize the body as an expressive tool...some swimmers do not 'know' or 'feel' when their feet are out of the water, when their ankles are flexed or extended, or when their knees are straight. Space orientation is also an important aspect of body awareness."

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According to Scott, "precision of perception of movement is higher in the small muscles of the hand than in larger segments."

Tests of kinesthesis that were most related to performance of synchronized swimming stunts were adapted by Toler so that they could be administered in the water. Female college students (34) with no previous synchronized swimming experience were given kinesthetic tests of arm positioning, leg positioning, and orientation in space, which were adapted to the water by use of a transparent chart of angles suspended over the water. She also used a test of balance and tests of flexibility of the hip and spine. Following a 16-week course in beginning synchronized swimming, student ability was determined by three judges' ratings of skills categorized into movement patterns and body positions. Correlations made between each test of kinesthesis and measures of flexibility were not, however, significant enough to be of predictive value.

In measuring college women of varying swimming abil-

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ities using measurements of kinesthesis for hand and arm function and sculling ability tests, Fisher\(^\text{12}\) found no relationship between measures of kinesthesis and sculling ability. However, a correlation between rated sculling and timed sculling did exist.

Stevens\(^\text{13}\) attempted to determine if individuals who were trained in motor movements showed a more highly developed sense of kinesthesis than those who were untrained. She also sought to learn if higher skilled performers with the same amount of motor training, showed a higher developed kinesthetic sense than the less skilled. She tested forty female physical education major students and 100 non-major students dividing the major students into high and low motor ability groups. The kinesthesis tests she selected were different arm and leg positioning tests, extent of arm and leg force, hand force, arm swing, arm precision and pathway through an arc. She found that:

"individuals who are trained in motor movements or have had more motor experience show more highly developed kinesthetic sense than those who are untrained but, when the training


is held constant, more highly skilled in motor ability do not show a more highly developed kinesthetic sense."

Steinhaus\textsuperscript{14} emphasized that:

"too much of modern life is limited by two dimensions. The third dimension comes to use from muscle and joint senses, i.e., the proprioceptive system. Too much is just seeing pictures and reading the printed page. It is short on muscle and joint experience."

This was supported by Smith\textsuperscript{15} who stated that "man is capable of fine kinesthetic perception, but he does not ordinarily attend to the precise feedback, because he is too highly oriented toward external cues." Chew\textsuperscript{16} found that kinesthetic cues were equally effective as more familiar visual and verbal cues and stressed the importance of providing information to the subject during the learning of a skill. Contrary to previous findings, the results of Chew's study support the use of kinesthetic error feedback in early stages of learning.


Flexibility

The specificity of flexibility has been investigated by several authors (17,18,19,20) and they have all come to the conclusion that flexibility is very specific to the different joints of the body.

Cureton17 stated that:

"tests (of flexibility) do not correlate significantly with each other and are therefore fairly specific which means that flexibility is not some general quality which causes all tests of it to vary alike."

When he investigated flexion and extension of the wrists and ankles of fifty male college students, Dickinson18 found all intercorrelations failed to show significant relationships among the measures.

Specificity of flexibility in girls was investigated by Hupprich and Sigerseth,19 and after administering twelve tests of flexibility they correlated each measure. They found a generally low correlation among the measures.

In her factor analysis of flexibility, Harris20

17Cureton, Thomas K., "Flexibility As an aspect of Physical Fitness." Research Quarterly, Xii (May 1941), 381.


studied two types of flexibility measures: single joint action and composite joint action. She compared 147 college women in fifty-three variables; thirty-eight of which were single joint actions, thirteen composite joint actions, and two anthropometric measures. The major conclusion reached was:

"there is no evidence that flexibility exists as a single general characteristic of the human body. Thus no one composite test or no one joint action measure can give a satisfactory index of the flexibility characteristics of an individual."

Scott and French stated that "flexibility is desirable only as it contributes toward some other ability or freer movement."

Several investigations have been made which compare flexibility and motor skills. Cureton made investigations which compared the athlete vs. the non-athlete. In the sport of swimming, he considered that "a swimmer with relatively flexible ankles has the possibilities of more effective force for propulsion on every down beat of the foot." He also stated that:

"...in the use of the arms and shoulders, and

---


22Cureton, Thomas K., "Flexibility as an Aspect of Physical Fitness." Research Quarterly, XII (May 1941), 381.
chest in respiration, suppleness is a great asset because the movements may be made more easily without disturbing the all-important aspect of body balance, necessary for minimum resistance. There is no doubt that better speed and endurance swimming performances parallel greater flexibility in the joint: trunk extension, trunk flexion, ankles and shoulders."

Cureton tested this hypothesis on Japanese and American Olympic swimmers in 1932. The four Japanese who broke the world record in the 880-yard relay averaged 31.3% better on trunk flexion than the losing American team. He also showed that twenty-one Olympic swimmers were superior on an average to 100 college competitive swimmers by 11.4% in the ankles and 7.7% in trunk flexion.

Flexibility in relation to weight, jumping, performance on an obstacle course, and amount of physical activity of 130 college women was investigated by McCue. McCue tested this hypothesis on Japanese and American Olympic swimmers in 1932. The four Japanese who broke the world record in the 880-yard relay averaged 31.3% better on trunk flexion than the losing American team. He also showed that twenty-one Olympic swimmers were superior on an average to 100 college competitive swimmers by 11.4% in the ankles and 7.7% in trunk flexion.

Flexibility in relation to weight, jumping, performance on an obstacle course, and amount of physical activity of 130 college women was investigated by McCue. For the comparisons she used a Leighton Goniometer to measure twelve different joint movements. She found that individuals who had a past history of more activity tended to be better in trunk flexion, total back and neck extension, and in ankle flexion and extension. The superior jumpers and those fastest in the obstacle course had greater mean flexibility scores in hip flexion and trunk flexion. McCue found that hip flexion for underweight

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23McCue, Betty, "Flexibility in Relation to Weight, Jumping and Performance on an Obstacle Course." Research Quarterly, XXIV (October 1953), 316.
individuals was significantly greater than for overweight individuals. She also found that overweight individuals had significantly greater lumbar extension.

Rasch and Burke\textsuperscript{24} stated that "children from ages 10-16 show a generalized pattern of decreasing flexibility." This was supported by Hupprich and Sigerseth's\textsuperscript{25} study of 300 girls, age 6-18, involving twelve measurements of flexibility. They found

"the evidence indicated clearly that the areas of the girls bodies, for the most part, become progressively more flexible from childhood to adolescence and then they become progressively less flexible after adolescence."

In a test battery to determine if there were differences in trunk, hip, shoulder, and ankle flexibility in springboard divers, gymnasts, and swimmers, Gardiner\textsuperscript{26} used a Leighton Flexometer. The swimmers were found to have less hip flexibility than both the gymnasts and divers.


\textsuperscript{25}Hupprich, Florence L. and Sigerseth, Peter O., "Specificity of Flexibility in Girls." Research Quarterly, XXI (March 1950), 25.

Steffens\(^{27}\) studied twenty-five university football players and concluded that higher values of body fat did not affect hip flexibility or cardiovascular fitness.

**Percent of Total Body Fat**

Several methods of evaluating body composition have been used including height-weight charts, somatotyping, skinfold tests, and underwater weighing. Whether one is testing for the purpose of determining nutritional states, metabolic activity, or performance factors, the objective is to analyze the metabolically active and relatively inactive constituents of the body. The method has evolved into estimates of fat-free body weight (lean body mass) and the percentage of the body weight that is fat. The percent fat is predicted from body density and the fat-free weight is calculated from this estimate.

A simple and economical measurement of fatness is the skinfold test. A double thickness of skin and subcutaneous fat is lifted and measured by a caliper. In addition to a table for determining "Ideal Body Weights for Women," Sinning\(^{28}\) stated that the:

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"ideal body weight was computed on the assumption that the average value of 23 percent fat commonly found for college-age women represents a desirable value for all adult women. It is also assumed that a woman reaches physical maturity at about college age and subsequent weight gains are due to fat accumulation rather than muscle and bone development. No ideal weight computations were made for women who are less than 23 percent fat since it is felt that as long as a person receives adequate nutrition and is in good health, it is not possible to be underweight."

Underwater weighing has been the most widely used method of determining body density. Total body volume is determined by subtracting the weight in water from the weight in air (Archimedes' principle with an additional correction for the residual air in the lungs and air passages. Body density is then the weight in air divided by the body volume (see Appendix B)). Zuti compared hydrostatic weighing with several equations for estimating body composition and selected anthropometric measures for determining body density. He found that density obtained from underwater weighing had a high correlation with five of the individual body measurements, the height-weight methods, and several of the equations for the estimation of body composition.

Many investigations have sought to determine the

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effects that various motor and sport activities have on percent of body fat in individuals. Mayhew and Gross evaluated the effects of high resistance weight training on the body composition of seventeen college women and found significant increases in total body potassium, lean body mass, flexed biceps and forearm girths, and shoulder width resulted from the weight training. Relative fat and chest depth were significantly decreased by the weight training program while skinfold thicknesses and body weight were unaffected.

The effects of weight training on strength, endurance, girth, and body composition in college women were investigated by Price. Groups involved in physical training revealed significant (1) increases in strength and muscle endurance, and (2) decreases in all skinfold measurements, three of seven girth measurements and present body fat.

Katch found that percent fat and lean body weight

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were related to distance running scores in women. "There was a tendency for fatter subjects to have poorer performance scores although body weight was unrelated to how far a girl would run."

Track and field athletes were measured by Pipes in total body weight, lean body weight, fat weight, body density and relative body fat according to their event. The lowest value for relative body fat in women was 9.0% found in the sprinters. The highest value was in women shot-putters who had 27% relative body fat. Pipes stated that:

"investigators usually cite the relative body fat of normal individuals at 15% for men and 23% for women. Changes in body compositions associated with training programs may include alterations in total body weight, body fat, and lean body mass."

He cited that the frequency, intensity, and duration of training will determine the magnitude of these changes. Pipes also suggested that body type is a combination of both genetic and training regimes.

Women basketball players, according to Sinning, tended to be slightly leaner than college women in general,

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33Pipes, Thomas V., "Body Composition Characteristics of Male and Female Track and Field Athletes." Research Quarterly, XLVIII (March 1977), 244.


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although they were on the average heavier and taller. Changes in body composition during the competitive season were small.

Brown and Wilmore\(^3^5\) reported female swimmers followed champion gymnasts and track runners (both short and long-distance) in percent of body fat:

"champion gymnasts were found to average 13% fat, but a low of 9% was reported for Russian Olympic competitors. Track sprinters and runners had a mean of 18% although reported values have been as low as 6% for long distance runners. Swimmers followed with 19% fat."

A comparison of female gymnasts and swimmers, according to Sprynarova and Pariskova,\(^3^6\) found swimmers having a greater amount of lean body mass as well as fat. College female swimmers (15) were assessed by Wade\(^3^7\) for body composition and skinfolds at the beginning and end of nine weeks of training. A significant increase in body density (1.052-1.054 g.cm\(^{-3}\)) resulted in significant


\(^3^7\)Wade, Charles E., "Effects of a Seasons' Training on the Body Composition of Female College Swimmers." Research Quarterly, XLVII (May 1967), 292.
decreases in absolute body fat (12.7-12.1 kg.) and relative fat (20.4-19.6%). Skinfolds of the triceps, supra-iliac, and subscapula also decreased significantly, suggesting the fat loss was mainly subcutaneous.

Katch\(^{38}\) found no significant changes in body composition during training of female college-age swimmers and tennis players.

It was concluded by Bloomfield and Sigerseth\(^{39}\) that both male and female contemporary distance swimmers have smaller fat deposits than their predecessors. They attribute the "reduction of fat deposits" to the increased tempo of interval training and the increased relative speed of the distance swimmers. Although plausible, both the assumption of a reduction and the hypothesis as to its cause are not substantiated by data.

**Grip and Arm Strength**

Measures of grip strength have been widely used to assess the physical performance capability of individuals and often grip strength is one factor comprising physical performance.


\(^{39}\)Bloomfield, John and Sigerseth, Peter, "Anatomical and Physiological Differences Between Sprint and Middle Distance Swimmers at the University Level." Journal of Sports Medicine and Physical Fitness, V (March 1965), 76-81.
fitness test batteries. A number of electrical and mechanical devices have been used to assess grip strength. There is evidence to suggest that grip strength scores may be affected by a number of factors, such as width of the hand grip, body position of the subject, and type of device used to measure the grip strength.

Cotten\textsuperscript{40} studied the T-5 Cable Tensiometer, which is designated for adjustment to five grip span sizes, to determine if varying the span settings of the adjustable grip attachment would affect the grip strength measures of thirty-six college women. She also sought to determine an optimum setting for general use in testing. Her conclusion was,

"it appeared that an individual will probably attain very close to her highest strength reading at the medium-small setting regardless of her grip size. It is also apparent that in strength testing it is essential to use the same span setting each time an individual's strength is measured. Otherwise, changes in grip strength may be due to changes in the setting rather than a training program."

The Stoelting Hand Grip Dynamometer (mechanical) and the Linear Voltage Differential Transformer (electrical) are both used to measure static muscle strength. In his

\textsuperscript{40}Cotten, Doyice J. and Bonnell, Lorraine, "Investigation of the T-5 Cable Tensiometer Grip Attachment for Measuring Strength of College Women." \textit{Research Quarterly, XL} (December 1969), 848.
comparison of the two methods, Heyward found that maximal grip strength may be influenced by the type of device used to assess grip strength. In comparison with the LVDT, the Stoelting Dynamometer registers lower maximal strength values. The difference between grip strength values, as assessed by the two instruments, is greater for high strength individuals than for low strength individuals. Therefore differences in instrumentation should be considered when comparing the strength of a sample to establish group norms.

Connolly tested three groups (slender, average, and heavy) of college women in arm strength measures and found that persons of varying body builds perform differently on four selected measures of arm strength. Total Cable Tensiometer strength, flexed arm hang, modified push-ups and pull-ups, do not vary within the slender build. The only arm strength measure significantly related to total Cable Tensiometer strength is the flexed arm hang for the average build.

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41 Heyward, Vivian, McKeown, Barry and Geeseman, Ralph, "Comparison of the Stoelting Hand Grip Dynamometer and Linear Voltage Differential Transformer for Measuring Maximal Grip Strength." Research Quarterly, XLVI (May 1975), 262.

A parallel between grip strength and temperature was indicated in Wright's studies. There was a marked increase in strength of grip from 6:00 a.m. to 9:00 or 10:00 a.m.; and then a gradual decrease until 1:00 p.m. and a great decrease at night. She stated that, "the results of this study suggest that diurnal variation of grip is a manifestation of a fundamental body rhythm and is paralleled to some extent by variation of temperature."

Montoye and Lamphiear investigated more than 6,000 people, age 10-69, in a total community (Tecumseh, Michigan) who were given grip and arm strength tests. Grip strength was measured with an adjustable Stoelting Grip Dynamometer. The best of two scores was taken. The results showed that from ages twenty to fifty, there is little decrease in absolute grip strength, arm strength or strength index. Peak strength for females was in the mid-twenties.

Summary

Kinesthesis is a sense which enables the human to "feel" his or her body position, muscle movement, balance

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44 Montoye, Henry J. and Lamphiear, Donald E., "Grip and Arm Strength in Males and Females, Age 10 to 69." Research Quarterly, XLVIII (March 1977), 109.
and orientation in space. No one test can measure kines-
thetic sensibility. Tests have been adapted for use in
the water. Correlations made between each test of kines-
thesis and measures of flexibility have not been of pre-
dictive value. Individuals with more experience in motor
movements show more highly developed kinesthetic sense.
We have failed to develop kinesthetic sense to its poten-
tial as we rely often on visual and aural cues instead.

Flexibility is specific to the different joints of
the body and thus flexibility does not exist as a single
general characteristic of the body. Swimming ability
(speed and endurance) seems to be positively correlated
with flexibility in the trunk (flexion and extension),
ankles, and shoulders. Flexibility increases until
puberty and then gradually decreases.

The average percent of body fat in college age women
is about 23%. Female swimmers tend to have more density
and a percent fat ratio of around 19% on the average.
Underwater weighing is an accurate technique of estimating
lean body mass against fat content in the body. Weight
training and athletic participation tend to decrease the
amount of body fat in individuals. Women athletes may
achieve lower percents of body fat as their training
programs become more intense and demanding.

Grip strength is often used as an indicator of per-
formance capability. There have been studies which inves-
tigate the equipment used in grip testing. Grip strength may be affected by body build, temperature, time of day, and age factors. There are no set norms for grip strengths and virtually no studies which relate grip strength to overall performance, specifically swimming.
CHAPTER III

DESIGN AND METHODOLOGY

This chapter contains four sections: (1) the general procedures adopted to collect the data; (2) description of the subjects; (3) instrumentation and method of administering the tests; and (4) an explanation of data analysis.

General Procedures

This study was designed to compare three groups of college age, female aquatic participants; beginning, competitive (speed), and synchronized swimmers. All of the participants were volunteers from one of two Michigan Colleges; Western Michigan University and Kalamazoo College.

The testing took place on two consecutive Monday nights during March 1977 between 6:30 and 9:30 p.m. at the Western Michigan University Gary Center Pool. Two staff members and five upperclassmen aided in the testing. They received previous instructions on how to administer one particular test and each remained at the same station throughout the entire testing. All of the students followed the same sequence when participating as measurements were taken at six stations in the following order:
1. Underwater (hydrostatic) Weighing
   a. height
   b. weight
   c. vital capacity
2. Hand Grip Test
3. Wells Modified Sit and Reach Test
4. Bridge-up Test
5. Left Arm Positioning Test
6. Right Leg Positioning Test
7. Right Ankle Flexibility Test
8. Left Ankle Flexibility Test

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4. loc. cit., p. 73.
6. Ibid.
7. Johnson, op. cit., p. 76
8. Ibid.
Subjects

The beginning swimmers were members of a general physical education class for beginning swimming at Western Michigan University during Winter semester, 1977. The synchronized swimmers were all members of Western Michigan University's Aqua Sprites—the synchronized swim club. The competitive (speed) swimmers were members of Women's Intercollegiate Swim Teams from both Western Michigan University and Kalamazoo College. All of the subjects were females of college age, between eighteen and twenty-two years.

From three separate pools of volunteers representing beginning, synchronized, and competitive (speed) swimmers, ten subjects from each pool were randomly selected for participation in the measurement situation.

Instrumentation

The purpose of this study was to compare the three groups of swimmers in measurements of flexibility, arm strength, kinesthesis, and percent of total body fat. The following tests were selected to measure each area:

**Flexibility Tests**

The flexibility tests selected were specific to three areas of the body: hip flexion, back hyperextension, and ankle flexion and extension. Johnson and
Nelson\(^9\) include these three test items in a battery containing several flexibility measurements. The Wells Modified Sit and Reach Test\(^{10}\) measures flexion of the hip and back as well as elasticity of the hamstring muscles. The Bridge-up\(^{11}\) measures hyperextension of the spine, and the Average Ankle Flexibility Test\(^{12}\) measures the ability to flex and extend the ankle.

- **Arm Strength** was measured with Neilson and Jensen's Hand Grip Test.\(^{13}\)
- **Kinesthesia** was measured with Toler's Left Arm Positioning and Right Leg Positioning Tests.\(^{14}\)
- **Percent of Total Body Fat** was measured using the Underwater (hydrostatic) Weighing technique.\(^{15}\)

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\(^9\) Johnson, loc. cit., pp. 70-87.
\(^{10}\) loc. cit., p. 71.
\(^{11}\) loc. cit., p. 73.
\(^{12}\) loc. cit., p. 76.
\(^{13}\) Neilson, op. cit.
\(^{14}\) Toler, op. cit.
\(^{15}\) Shaver, op. cit., p. 76.
<table>
<thead>
<tr>
<th>Test Item</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Underwater Weighing</td>
<td>Percent of Total Body Fat</td>
</tr>
<tr>
<td>2. Hand Grip Test</td>
<td>Arm and Grip Strength</td>
</tr>
<tr>
<td>3. Wells Modified Sit and Reach Test</td>
<td>Flexion of the Hip and Back and elasticity of the hamstring muscles</td>
</tr>
<tr>
<td>4. Bridge-up Test</td>
<td>Hyperextension of the Spine</td>
</tr>
<tr>
<td>5. Left Arm Positioning</td>
<td>Kinesthesia</td>
</tr>
<tr>
<td>6. Right Leg Positioning</td>
<td>Kinesthesia</td>
</tr>
<tr>
<td>7. Average Right Ankle Flexibility</td>
<td>Ankle Flexibility</td>
</tr>
<tr>
<td>8. Average Left Ankle Flexibility</td>
<td>Ankle Flexibility</td>
</tr>
</tbody>
</table>

**Test Item 1—Underwater Weighing (Figures 1 and 2)**

**Equipment.**—Chatillion scales, physician's scales, and Propper spirometer (see Appendix A), weight belt, nose clip, scale support frame, and scale "T" bar.

**Procedures.**—(1) The subject was weighed in a swim suit on a physician's scales.

(2) Measure of Vital Capacity was taken with the Propper spirometer. The best effort of three trials was used as the score.

(3) The weighing apparatus was assembled on the diving board in the swimming pool prior to the test session, i.e. support frame, "T" bar, and scales.
Fig. 1  Physician's scale, Propper spirometer and Chatillion scale

Fig. 2  Subject prepared to immerse for underwater weighing
(4) The weight belt and "T" bar are attached to the scale and weighed prior to the testing.

(5) The weight belt is placed around the subject's waist.

(6) The subject enters the pool and straddles the bar.

(7) The "T" bar is adjusted so that the subject's mouth and nose are above the water line as she sits on the bar.

(8) Nose clips (plugs) are placed on the subject's nose.

(9) The subject takes a deep breath and then bows her head so that the body is completely immersed in the pool.

(10) The subject then exhales as much air as possible underwater. After exhaling completely, the subject continues to hold.

(11) The scales are read after the subject has exhaled completely and the scale needle settles down.

(12) The procedure was repeated five times for each subject.

The formulas used to compute vital capacity and percent of total body fat are located in Appendix B.

Test item 2—Hand Grip Test (Figures 3 and 4)

Equipment.—A Lafayette Hand Grip dynamometer was used (see Appendix A).

Procedure.—The student places the grip dynamometer in the palm of her right hand (with the dial toward the palm) so that the convex edge is between the first and
Fig. 3 Lafayette hand grip dynamometer

Fig. 4 Arm strength measurement
second joints of the fingers and the rounded edge is against the base of the hand. She bends her elbow slightly and raises arm upward; she then moves arm forward and downward, gripping with maximum force. At the same time, she is careful not to touch her body or any object. The subject then repeats the test using the left hand.

**Scoring.**—Each subject had two trials with each hand. The better of the grips was recorded in kilograms.

**Test item 3—Wells Modified Sit and Reach Test** (Figures 5 and 6)

**Equipment.**—A Preston Shoulder Breadth Caliper was used (see Appendix A).

**Procedure.**—The shoulder breadth caliper is placed on a bench which is firmly against the wall. The subject assumes a sitting position with legs extended along the floor so that the caliper is centered outward from the legs. The subject's heels should line up with the near edge of the 1-inch mark and not more than 5 inches apart. The subject then bobs forward three times and on the fourth bob pushes the ruler, with the fingertips of both hands, forward as far as possible.

**Scoring.**—The score is indicated at the farthest point where the near side of the ruler is lined up as a result of the push with the fingertips. The best measure
Fig. 5 Preston shoulder breadth caliper

Fig. 6 Wells modified sit and reach test

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of three trials is recorded to the nearest quarter inch.
Note: An assistant must be used to press against the
subject's knees to ensure that they do not bend during the
reach forward. The reach forward must be a steady reach.
Jerking forward or quick pushing action against the ruler
is not allowed.

Test item 4—Bridge-up Test (Figures 7 and 8)

   Equipment.—A yardstick is the only equipment nec­
   essary.

   Procedure.—The subject places the toes of her feet
   against the base of a wall. The tester places the zero
   end of the yardstick against the subject's heel. The
   subject sits down and assumes a supine position over the
   yardstick. From the supine position on the floor, with
   knees bent, feet flat on the floor, and hands on the
   floor with the thumbs next to the ears, the subject
   raises the hips, and walks with the hands as close to the
   heels as possible and then hesitates at that point.

   Scoring.—When the performer hesitates in the hyper­
   extended position, the tester quickly reads the distance
   between the subject's fingertips and heels. The score is
   the distance noted to the nearest quarter inch. The
   shorter distance is the better score. Three trials are
   allowed with the best trial used as the score. Note:
   Be certain the subject keeps her heels (and feet) flat on
Fig. 7 Bridge-up test for back hyperextension

Fig. 8 Bridge-up test for back hyperextension
the floor as she walks her hands toward the heels. If the subject is too weak to lift her head and back off the floor, the head and hands may be used for support and the measurement made to the fingertips. A piece of chalk should be used to mark the fingertips' line when the subject cannot reach the 36-inch mark. The measurement in inches is then taken from the heels to the chalkmark.

Test item 5—Left Arm Positioning—55 degrees (Figures 9, 10 and 11)

Equipment.—A plastic-coated chart showing a stick figure with the left arm raised to a 55-degree angle, a 4-foot by 8-foot transparent protractor chart of angles (see Appendix A) suspended six inches above the water, a plastic "egg" type flotation, and a blindfold.

Procedure.—The subject, who is wearing the flotation device on her abdomen, is held in a floating position on her back with the axis of the shoulder under the center of the chart of angles. She is shown a stick figure with the arm abducted 55-degrees. The subject then is blindfolded and instructed to abduct her arm, keeping the palm down and on the surface of the water, until it is in the same position as the figure. The subject indicates by voice when she feels she is in the correct position. The leading edge of the wrist is used to measure the nearest angle as seen through the transparent
Fig. 9 Transparent chart of angles (protractor) for use in tests of kinesthesia
Fig. 10  Kinesthesis arm positioning test

Fig. 11  Kinesthesis arm positioning test with recorder
chart.

**Scoring.**—The scorer stands above the chart and marks where the leading edge of the wrist is when the subject indicates her position by voice. The subject repeats the test three times. The score is the sum of deviations from 55-degrees.

**Test item 6—Right Leg Positioning** (Figure 12)

**Equipment.**—A plastic-coated chart showing a stick figure with the right leg raised 35-degrees, a 4 by 8 foot transparent chart of angles suspended six inches above the water (see Appendix A), plastic "egg" flotation device, and a blindfold.

**Procedure.**—The subject, who is wearing the "egg" flotation device on her right side, is held in a floating position on her left side with her right hip under the axis in the chart of angles. She is shown a stick figure with the leg flexed to 35-degrees. The subject is then blindfolded and instructed to flex her leg, keeping it on the surface of the water, until she thinks it is in the same position as the stick figure. The subject indicates by voice when she feels she has reached the correct position. The leading edge of the ankle was used to determine the nearest degree.

**Scoring.**—The scorer stands above the protractor and records the score when the subject indicates by voice that
Fig. 12 Kinesthesia leg positioning test
she is in position. The subject repeats the test three times and the score is the sum of the deviation from 35-degrees.

**Test item 7—Average Ankle Flexibility** (Figures 13 and 14)

**Equipment.**—Thirty cardboard squares (18" by 18"), long pencils, a ruler, and a protractor.

**Procedures.**—The subject sits on the floor with the back of the knee touching the floor. Keeping the heel stationary, she dorsiflexes the foot as far as possible. The tester traces the outline of the foot (keeping the pencil horizontal) from just above the ankle to just beyond the big toe on a sheet of cardboard placed at the side of the foot. The subject then extends (plantar-flexes) the foot as far as possible, and the outline is again traced on the same sheet of cardboard. The angle of each of the lines from the horizontal is measured with a protractor.

**Scoring.**—The score is the measurement in degrees taken from the protractor for each foot. (The left and right feet are drawn on opposite sides of the cardboard.) An average score for the feet is then figured.

**Method of Instruction**

Each item was explained to the subjects, verbally, at each station of the test. In addition, direction
Fig. 13 Left ankle flexibility test
ankle extension

Fig. 14 Left ankle flexibility test
ankle flexion
charts were also posted for the subjects to read. The investigator made comments only to correct a subject when any of the rules was being violated. No words of encouragement or discouragement were used.

Experimental Design and Statistical Analysis

The data were analyzed at the computer center of Western Michigan University. The raw scores of each test item were coded by different characteristics (variables) to enable the investigator to separate the data for the purpose of comparison.

A research design similar to one described by Weber and Lamb as a "single variable manipulated, one observation per subject for R>2 groups"¹⁶ was selected for the study. The variation in aquatic experience; beginning, competitive (speed), and synchronized, of the three groups represented the independent variable in this descriptive study. The measured characteristics; arm strength, flexibility, kinesthesis, and body composition (percent of total body fat), represented the dependent variables. The design was replicated for each dependent variable measured. Table 2 is an example of the design used to determine the significance of arm strength as a factor in

aquatic experience.

TABLE 2. Experimental Design for the Analysis of Arm Strength Measures ($X_n$)

<table>
<thead>
<tr>
<th>Beginning</th>
<th>Competitive (speed)</th>
<th>Synchronized</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_{11}$</td>
<td>$X_{21}$</td>
<td>$X_{31}$</td>
</tr>
<tr>
<td>$X_{12}$</td>
<td>$X_{22}$</td>
<td>$X_{32}$</td>
</tr>
<tr>
<td>$X_{13}$</td>
<td>$X_{23}$</td>
<td>$X_{33}$</td>
</tr>
<tr>
<td>$X_{1n}$</td>
<td>$X_{2n}$</td>
<td>$X_{3n}$</td>
</tr>
</tbody>
</table>

The one way fixed affects, randomized groups, analysis of variance technique was used to test the null hypothesis concerning the mean performances of the three groups in the measured dependent variables. The five percent level of confidence was selected to determine the significance of the computed $F$ statistic.

The ANOVA technique is based upon a number of basic assumptions which must be met to ensure its validity. The assumptions are:

1. That the selection of subjects was random and independent.
2. The dependent variable was measured on the interval scale.
3. The population from which the samples were drawn was random.
4. That homogeneity of variance was evident.
In this study, the assumption of randomness and independence was controlled by the process by which subjects were selected for participation. All subjects were randomly selected from pools of volunteers.

By inspection it was determined that all data were collected on the interval scale and were normal in distribution.

The assumption of homogeneity of variance was determined statistically utilizing Hartley's $F_{\text{max}}$ statistic.\(^{17}\)

If the analysis of variance of a dependent variable proved significant at the .05 level of confidence, the Newman-Keuls technique for the multiple comparisons of more than two means was used to determine which group means were different from each other.\(^{18}\)


CHAPTER IV

ANALYSIS AND INTERPRETATION OF DATA

The main purpose of this study was to determine if any significant differences existed between college age, female, beginning, competitive (speed), and synchronized swimmers in measures of arm strength, flexibility, kinesthesi­thesis, and percent of total body fat. Specifically, the investigation compared the performance of beginning, competitive (speed), and synchronized swimmers in the following test items: (1) Underwater Weighing\(^1\) (percent of total body fat); (2) Hand Grip Test\(^2\) (arm strength); (3) Wells Modified Sit and Reach Test\(^3\) (hip and trunk flexion); (4) Bridge-up\(^4\) (hyperextension of the back);

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\(^4\) loc. cit., p. 73.
(5) Arm Positioning⁵ (kinesthesia); (6) Leg Positioning⁶ (kinesthesia); (7) Right Ankle Flexibility⁷ (average ankle flexibility); (8) Left Ankle Flexibility⁸ (average ankle flexibility).

The data collected in this study were analyzed and comparisons were made. The one-way, fixed affects, randomized groups, analysis of variance technique was used to test the null hypothesis concerning the mean performances of the three groups. The assumption of homogeneity of variance was determined statistically utilizing Hartley's $F_{\text{max}}$ statistic.⁹ If the analysis of variance of a dependent variable proved significant at the .05 level of confidence, the Newman–Keuls¹⁰ technique for the multiple comparison of more than two means was used to determine which group means were different from each

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⁶ibid.

⁷Johnson, op. cit., p. 76.

⁸ibid.


The results of these analyses are presented below, in the order the tests were administered, with tables and discussions.

The Analysis of Percent of Total Body Fat
Underwater Weighing Technique

The beginning, competitive (speed), and synchronized swimmers were tested for percent of total body fat using the Underwater Weighing technique. Table 3 presents the groups, sample sizes, means, standard deviations, and variances utilized to evaluate percent of body fat.

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>X</th>
<th>S.D.</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>10</td>
<td>28.33</td>
<td>7.572</td>
<td>57.342</td>
</tr>
<tr>
<td>Competitive (speed)</td>
<td>10</td>
<td>21.75</td>
<td>4.535</td>
<td>20.564</td>
</tr>
<tr>
<td>Synchronized</td>
<td>10</td>
<td>25.58</td>
<td>6.677</td>
<td>44.576</td>
</tr>
</tbody>
</table>

As was previously stated, it is necessary to determine whether the data meet the assumption underlying the analysis of variance technique. Hartley's $F_{max}$ statistic,

\[\text{Hartley's } F_{\text{max}}\]  

\[\text{Shaver, op. cit.}\]
suggested by Winer,\textsuperscript{12} was used to test for homogeneity of variance. The results of the test for homogeneity of variance are presented in Table 4.

\begin{table}[h]
\centering
\caption{Summary of Hartley's Test for Homogeneity of Variance for Percent of Body Fat Measures}
\begin{tabular}{lccc}
\hline
Treatment groups & d.f. & Sums of squares & Mean squares variance \\
\hline
Beginning & 9 & 516.07 & 57.342 \\
Competitive & 9 & 185.07 & 20.564 \\
(speed) & & & \\
Synchronized & 9 & 401.183 & 44.576 \\
\hline
F_{max} computed & & & 2.788 \\
F_{max} required & & & 5.340 \\
\hline
\end{tabular}
\end{table}

The null hypothesis that the group variances were equal was tested. With nine degrees of freedom involving the comparison of three variances, an $F_{max}$ of 5.34 was required for significance at the five percent level of confidence. An $F_{max}$ of 5.34 or greater would occur by chance alone only five percent of the time. Since the computed $F_{max}$ was 2.788, no evidence for rejecting the null hypothesis was provided.

No evidence was found that indicated the basic assumption for the analysis of variance had not been met.

The null hypothesis that the group means were from a common population was tested. The results of that

\textsuperscript{12}Winer, op. cit.
analysis are presented in Table 5.

TABLE 5. Analysis of Variance of the Percent of Total Body Fat Score of Beginning, Competitive (speed), and Synchronized Female Swimmers

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sums of squares</th>
<th>d.f.</th>
<th>Mean squares</th>
<th>F*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>218.240</td>
<td>2</td>
<td>109.1</td>
<td>2.673</td>
</tr>
<tr>
<td>Within</td>
<td>1102.334</td>
<td>27</td>
<td>40.83</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1320.573</td>
<td>29</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*F required at 5% level equals 3.35.

With 2 and 27 degrees of freedom, an F of 3.35 or larger was required for significance at the five percent level of confidence. Since the computed F was 2.673, no evidence was provided to reject the null hypothesis. Thus the data provided no evidence that the percent total body fat of the three groups differed significantly. (Although a difference did exist, as shown by the means, a statistically significant difference did not exist.

The Analysis of Arm Strength Scores
Hand Grip Test

The beginning, competitive (speed), and synchronized swimmers were tested for arm strength utilizing a Hand Grip Dynamometer. Table 6 presents the groups, sample size, means, standard deviations, and variances utilized

^13^ Neilson, op. cit.
to evaluate arm strength performance.

**TABLE 6. Summary of the Performance of Beginning, Competitive (speed), and Synchronized Swimmers in Arm Strength**

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>X</th>
<th>S.D.</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>10</td>
<td>30.10</td>
<td>4.982</td>
<td>24.822</td>
</tr>
<tr>
<td>Competitive (speed)</td>
<td>10</td>
<td>33.15</td>
<td>5.207</td>
<td>27.114</td>
</tr>
<tr>
<td>Synchronized</td>
<td>10</td>
<td>29.30</td>
<td>4.436</td>
<td>19.677</td>
</tr>
</tbody>
</table>

As was previously stated, it is necessary to determine whether the data meet the assumption underlying the analysis of variance technique. Hartley's $F_{\text{max}}$ statistic, suggested by Winer, was used to test homogeneity of variance. The results of the test for homogeneity of variance are presented in Table 7.

**TABLE 7. Summary of Hartley's Test for Homogeneity of Variance for the Arm Strength Measures**

<table>
<thead>
<tr>
<th>Treatment groups</th>
<th>d.f.</th>
<th>Sums of squares</th>
<th>Mean squares (variance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>9</td>
<td>223.399</td>
<td>24.822</td>
</tr>
<tr>
<td>Competitive (speed)</td>
<td>9</td>
<td>244.025</td>
<td>27.114</td>
</tr>
<tr>
<td>Synchronized</td>
<td>9</td>
<td>177.099</td>
<td>19.677</td>
</tr>
<tr>
<td>$F_{\text{max}}$ computed</td>
<td></td>
<td></td>
<td>1.378</td>
</tr>
<tr>
<td>$F_{\text{max}}$ required</td>
<td></td>
<td></td>
<td>5.340</td>
</tr>
</tbody>
</table>

\[^{14}\text{Winer, op. cit.}\]
The null hypothesis that the group variances were equal was tested. With nine degrees of freedom involving the comparison of three variances, an $F_{\text{max}}$ of 5.34 was required for significance at the five percent level of confidence. An $F_{\text{max}}$ of 5.34 or greater would occur by chance alone only five percent of the time. Since the computed $F_{\text{max}}$ was 1.378, no evidence for rejecting the null hypothesis was provided.

No evidence was found that indicated the basic assumptions for the analysis of variance had not been met.

The null hypothesis that the group means were from a common population was tested. The results of that analysis are presented in Table 8.

**TABLE 8. Analysis of Variance of the Arm Strength Score of Beginner, Competitive (speed), and Synchronized Female Swimmers**

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sums of squares</th>
<th>d.f.</th>
<th>Mean squares</th>
<th>$F^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>82.550</td>
<td>2</td>
<td>41.28</td>
<td>1.729</td>
</tr>
<tr>
<td>Within</td>
<td>644.525</td>
<td>27</td>
<td>23.87</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>727.075</td>
<td>29</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$F^*$ required at 5% level equals 3.35

With 2 and 27 degrees of freedom, an $F$ of 3.35 or larger was required for significance at the five percent level of confidence. Since the computed $F$ was 1.729, no
evidence was provided to reject the null hypothesis. Thus the data provided no evidence that the mean arm strength of the three groups differed significantly.

The Analysis of Hip and Trunk Flexion
Wells Modified Sit and Reach Test

The beginning, competitive (speed), and synchronized swimmers were tested for hip and trunk flexibility using the Wells Modified Sit and Reach Test. Table 9 presents the groups, sample sizes, means, standard deviations, and variances utilized to evaluate hip and trunk flexion.

TABLE 9. Summary of the Performance of Beginning, Competitive (speed), and Synchronized Swimmers in Hip and Trunk Flexion

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>X</th>
<th>S.D.</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>10</td>
<td>5.775</td>
<td>1.511</td>
<td>2.284</td>
</tr>
<tr>
<td>Competitive (speed)</td>
<td>10</td>
<td>8.900</td>
<td>1.444</td>
<td>2.086</td>
</tr>
<tr>
<td>Synchronized</td>
<td>10</td>
<td>6.700</td>
<td>1.756</td>
<td>3.081</td>
</tr>
</tbody>
</table>

As was previously stated, it is necessary to determine whether the data meet the assumption underlying the analysis of variance technique. Hartley's $F_{max}$ statistic, suggested by Winer, was used to test for homogeneity of

$^{15}$Johnson, op. cit.
$^{16}$Winer, op. cit.
variance. The results of the test for homogeneity of variance are presented in Table 10.

<table>
<thead>
<tr>
<th>Treatment groups</th>
<th>d.f</th>
<th>Sums of squares</th>
<th>Mean squares (variance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>9</td>
<td>20.556</td>
<td>2.284</td>
</tr>
<tr>
<td>Competitive (speed)</td>
<td>9</td>
<td>18.775</td>
<td>2.086</td>
</tr>
<tr>
<td>Synchronized</td>
<td>9</td>
<td>27.725</td>
<td>3.081</td>
</tr>
<tr>
<td>( F_{\text{max}} ) computed</td>
<td></td>
<td></td>
<td>1.477</td>
</tr>
<tr>
<td>( F_{\text{max}} ) required</td>
<td></td>
<td></td>
<td>5.34</td>
</tr>
</tbody>
</table>

The null hypothesis that the group variances were equal was tested. With nine degrees of freedom involving the comparison of three variances, an \( F_{\text{max}} \) of 5.34 was required for significance at the five percent level of confidence. An \( F_{\text{max}} \) of 5.34 or greater would occur by chance alone only five percent of the time. Since the computed \( F_{\text{max}} \) was 1.47, no evidence for rejecting the null hypothesis was provided.

No evidence was found that indicated the basic assumption for the analysis of variance had not been met.

The null hypothesis that the group means were from a common population was tested. The results of that analysis are presented in Table 11.
TABLE 11. Analysis of Variance of the Hip and Trunk Flexion Score of Beginning, Competitive (speed), and Synchronized Female Swimmers

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sums of squares</th>
<th>d.f.</th>
<th>Mean squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>51.5375</td>
<td>2</td>
<td>25.77</td>
<td>10.38*</td>
</tr>
<tr>
<td>Within</td>
<td>67.0562</td>
<td>27</td>
<td>2.484</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>118.5938</td>
<td>29</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the .05 level of confidence.

With 2 and 27 degrees of freedom, an F of 3.35 or larger was required for significance at the five percent level of confidence. Since the computed F was 10.38, the hypothesis that the means were from a common population was rejected at the five percent level of confidence.

Since the group means were not from a common population of means, the Newman-Keuls test\(^\text{17}\) was applied to all groups means to determine which means were significantly different from the other group means. The results of the multiple range test on the group means for hip and trunk flexion are presented in Table 12.

\(^{17}\)Dotson, op. cit.
TABLE 12. Newman-Keuls Test for Comparing the Means of Beginning, Competitive (speed), and Synchronized Female Swimmers

<table>
<thead>
<tr>
<th>Means</th>
<th>Beginning</th>
<th>Synchronized</th>
<th>Competitive (speed)</th>
<th>Shortest significant ranges*</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.775</td>
<td>6.700</td>
<td>8.900</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Beginning  .925       3.125*       R₂=1.7493
Synchronized  2.200*     R₂=1.4478

*Ranges for the .05 level of confidence.

In terms of hip and trunk flexion measured by the Well's Modified Sit and Reach test, the mean performances of the competitive (speed) swimming group were significantly different from both the beginning and the synchronized groups. However, the synchronized swimmers proved not to be significantly different from the beginning swimmers.

The Analysis of Hyperextension of the Back Bridge-up Test

The beginning, competitive (speed), and synchronized swimmers were tested for back hyperextension using Johnson and Nelson's Bridge-up test. Table 13 presents the groups, sample sizes, means, standard deviations, and variances utilized to evaluate back hyperextension.

---

18 Johnson, loc. cit., p. 73.
TABLE 13. Summary of the Performance of Beginning, Competitive (speed), and Synchronized Swimmers in Back Hyperextension

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>X</th>
<th>S.D.</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>10</td>
<td>25.83</td>
<td>4.067</td>
<td>16.542</td>
</tr>
<tr>
<td>Competitive</td>
<td>10</td>
<td>18.88</td>
<td>6.596</td>
<td>44.837</td>
</tr>
<tr>
<td>(speed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Synchronized</td>
<td>10</td>
<td>18.15</td>
<td>4.919</td>
<td>24.197</td>
</tr>
</tbody>
</table>

As was previously stated, it is necessary to determine whether the data meet the assumption underlying the analysis of variance technique. Hartley's $F_{max}^{*}$ statistic, suggested by Winer, was used to test for homogeneity of variance. The results of the test for homogeneity of variance are presented in Table 14.

TABLE 14. Summary of Hartley's Test for Homogeneity of Variance for the Back Hyperextension Measures

<table>
<thead>
<tr>
<th>Treatment groups</th>
<th>d.f.</th>
<th>Sums of squares</th>
<th>Mean squares (variance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>9</td>
<td>148.881</td>
<td>16.542</td>
</tr>
<tr>
<td>Competitive</td>
<td>9</td>
<td>403.531</td>
<td>44.837</td>
</tr>
<tr>
<td>(speed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Synchronized</td>
<td>9</td>
<td>217.775</td>
<td>24.197</td>
</tr>
</tbody>
</table>

$F_{max}$ computed $= 2.710$

$F_{max}$ required $= 5.340$

---

19 Winer, op. cit.

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The null hypothesis that the group variances were equal was tested. With nine degrees of freedom involving the comparison of three variances, an \( F_{\text{max}} \) of 5.34 was required for significance at the five percent level of confidence. An \( F_{\text{max}} \) of 5.34 or greater would occur by chance alone only five percent of the time. Since the computed \( F_{\text{max}} \) was 2.710, no evidence for rejecting the null hypothesis was provided.

No evidence was found that indicated the basic assumptions for the analysis of variance had not been met.

The null hypothesis that the group means were from a common population was tested. The results of that analysis are presented in Table 15.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sums of squares</th>
<th>d.f.</th>
<th>Mean squares</th>
<th>( F )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>359.112</td>
<td>2</td>
<td>179.5</td>
<td>6.295*</td>
</tr>
<tr>
<td>Within</td>
<td>770.187</td>
<td>27</td>
<td>28.53</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1129.300</td>
<td>29</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the .05 level of confidence.

With 2 and 27 degrees of freedom, an \( F \) of 3.35 or larger was required for significance at the five percent level of confidence. Since the computed \( F \) was 6.295, the
hypothesis that the means were from a common population was rejected at the five percent level of confidence.

Since the group means were not from a common population of means, the Newman-Keuls test\textsuperscript{20} was applied to all group means to determine which means were significantly different from the other group means. The results of the multiple range test on the group means for back hyper-extension are presented in Table 16.

\begin{table}[h]
\centering
\caption{Newman-Keuls Test for Comparing the Means of Beginning, Competitive (speed), and Synchronized Female Swimmers}
\begin{tabular}{lccc}
\hline
Means & Synchronized & Competitive & Beginning (speed) \\
\hline
18.15 & 18.88 & 25.83 & \\
Synchronized & .73 & 7.68* & R\textsuperscript{2}=5.9286 \\
Competitive (speed) & 6.95* & & R\textsuperscript{3}=4.9065 \\
\hline
\end{tabular}
\end{table}

*Ranges for the .05 level of confidence.

In terms of back hyperextension measured by the Bridge-up test, the mean performances of the beginning swimming group was significantly different from both synchronized and competitive (speed) groups. However, the synchronized swimmers proved not to be significantly different from the competitive (speed) swimmers.

\textsuperscript{20}Dotson, op. cit.
The Analysis of Kinesthesis
Arm Positioning Test

The beginning, competitive (speed), and synchronized swimmers were tested for kinesthesis using Toler's Arm Positioning test. Table 17 presents the groups, sample sizes, means, standard deviations, and variances utilized to evaluate kinesthesis arm positioning performance.

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>( \bar{X} )</th>
<th>S.D.</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>10</td>
<td>49.00</td>
<td>7.379</td>
<td>54.444</td>
</tr>
<tr>
<td>Competitive (speed)</td>
<td>10</td>
<td>54.50</td>
<td>4.378</td>
<td>19.167</td>
</tr>
<tr>
<td>Synchronized</td>
<td>10</td>
<td>54.00</td>
<td>8.756</td>
<td>76.667</td>
</tr>
</tbody>
</table>

As was previously stated, it is necessary to determine whether the data meet the assumption underlying the analysis of variance technique. Hartley's \( F_{\text{max}} \) statistic, suggested by Winer, was used to test for homogeneity of variance. The results of the test for homogeneity of variance are presented in Table 18.

\[21\] Toler, op. cit.

\[22\] Winer, op. cit.
The null hypothesis that the group variances were equal was tested. With nine degrees of freedom involving the comparison of three variances, an $F_{\text{max}}$ of 5.34 was required for significance at the five percent level of confidence. An $F_{\text{max}}$ of 5.34 or greater would occur by chance alone only five percent of the time. Since the computed $F_{\text{max}}$ was 4.0, no evidence for rejecting the null hypothesis was provided.

No evidence was found that indicated the basic assumptions for the analysis of variance had not been met.

The null hypothesis that the group means were from a common population was tested. The results of that analysis are presented in Table 19.
TABLE 19. Analysis of Variance of Kinesthesis Arm Positioning Score of Beginning, Competitive (speed), and Synchronized Female Swimmers

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sums of squares</th>
<th>d.f.</th>
<th>Mean squares</th>
<th>F*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>185.000</td>
<td>2</td>
<td>92.50</td>
<td>1.847</td>
</tr>
<tr>
<td>Within</td>
<td>1352.500</td>
<td>27</td>
<td>50.09</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1537.500</td>
<td>29</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F required at 5% level equals 3.35.

With 2 and 27 degrees of freedom, an F of 3.35 or larger was required for significance at the five percent level of confidence. Since the computed F was 1.847, no evidence was provided to reject the null hypothesis. Thus the data provided no evidence that the mean kinesthesis in arm positioning of the three groups differed significantly.

The Analysis of Kinesthesis
Leg Positioning Test

The beginning, competitive (speed), and synchronized swimmers were tested for kinesthesis using Toler's Leg Positioning test.\(^{23}\) Table 20 presents the groups, sample sizes, means, standard deviations, and variances utilized to evaluate kinesthesis leg positioning performance.

---

\(^{23}\)Toler, op. cit.
As was previously stated, it is necessary to determine whether the data meet the assumption underlying the analysis of variance technique. Hartley's $F_{\text{max}}$ statistic, suggested by Winer, was used to test for homogeneity of variance. The results of the test for homogeneity of variance are presented in Table 21.

TABLE 21. Summary of Hartley's Test for Homogeneity of Variance for the Kinesthesis Leg Positioning Measures

<table>
<thead>
<tr>
<th>Treatment groups</th>
<th>d.f.</th>
<th>Sums of squares</th>
<th>Mean squares (variance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>9</td>
<td>590.000</td>
<td>65.556</td>
</tr>
<tr>
<td>Competitive (speed)</td>
<td>9</td>
<td>272.500</td>
<td>30.28</td>
</tr>
<tr>
<td>Synchronized</td>
<td>9</td>
<td>412.500</td>
<td>45.833</td>
</tr>
</tbody>
</table>

$F_{\text{max}}$ computed

$F_{\text{max}}$ required

24 Winer, op. cit.
The null hypothesis that the group variances were equal was tested. With nine degrees of freedom involving the comparison of three variances, an $F_{\text{max}}$ of 5.34 was required for significance at the five percent level of confidence. An $F_{\text{max}}$ of 5.34 or greater would occur by chance alone only five percent of the time. Since the computed $F_{\text{max}}$ was 2.165, no evidence for rejecting the null hypothesis was provided.

No evidence was found that indicated the basic assumptions for the analysis of variance had not been met.

The null hypothesis that the group means were from a common population was tested. The results of that analysis are presented in Table 22.

TABLE 22. Analysis of the Kinesthesia Leg Positioning Score of Beginning, Competitive (speed), and Synchronized Female Swimmers

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sums of squares</th>
<th>d.f.</th>
<th>Mean squares</th>
<th>$F^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>61.667</td>
<td>2</td>
<td>30.83</td>
<td>0.653</td>
</tr>
<tr>
<td>Within</td>
<td>1275.000</td>
<td>27</td>
<td>47.22</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1336.667</td>
<td>29</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$F^*$ required at 5% level equals 3.35.

With 2 and 27 degrees of freedom, an $F$ of 3.35 or larger was required for significance at the five percent level of confidence. Since the computed $F$ was 0.653, no
evidence was provided to reject the null hypothesis. Thus the data provided no evidence that the kinesthesis in leg positioning differed significantly between the three groups.

The Analysis of Right Ankle Flexibility Average Ankle Flexibility Test

The beginning, competitive (speed), and synchronized swimmers were tested for right ankle flexibility using Johnson and Nelsons' Average Ankle Flexibility test. Table 23 presents the groups, sample sizes, means, standard deviations, and variances utilized to evaluate ankle flexibility.

TABLE 23. Summary of the Performances of Beginning, Competitive (speed), and Synchronized Swimmers in Right Ankle Flexibility

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>X</th>
<th>S.D.</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>10</td>
<td>99.98</td>
<td>13.916</td>
<td>193.656</td>
</tr>
<tr>
<td>Competitive (speed)</td>
<td>10</td>
<td>110.80</td>
<td>14.266</td>
<td>203.511</td>
</tr>
<tr>
<td>Synchronized</td>
<td>10</td>
<td>106.60</td>
<td>10.752</td>
<td>115.599</td>
</tr>
</tbody>
</table>

As was previously stated, it is necessary to determine whether the data meet the assumption underlying the analysis of variance technique. Hartley's $F_{\text{max}}$ statistic,  

---

25Johnson, loc. cit., p. 76.
suggested by Winer, was used to test for homogeneity of variance. The results of the test for homogeneity of variance are presented in Table 24.

TABLE 24. Summary of Hartley's Test for Homogeneity of Variance for Right Ankle Flexibility Measures

<table>
<thead>
<tr>
<th>Treatment groups</th>
<th>d.f.</th>
<th>Sums of squares</th>
<th>Mean squares (variance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>9</td>
<td>1742.900</td>
<td>193.656</td>
</tr>
<tr>
<td>Competitive (speed)</td>
<td>9</td>
<td>1831.599</td>
<td>203.511</td>
</tr>
<tr>
<td>Synchronized</td>
<td>9</td>
<td>1040.399</td>
<td>115.600</td>
</tr>
<tr>
<td>$F_{\text{max}}$ computed</td>
<td></td>
<td></td>
<td>1.760</td>
</tr>
<tr>
<td>$F_{\text{max}}$ required</td>
<td></td>
<td></td>
<td>5.340</td>
</tr>
</tbody>
</table>

The null hypothesis that the group variances were equal was tested. With nine degrees of freedom involving the comparison of three variances, an $F_{\text{max}}$ of 5.34 was required for significance at the five percent level of confidence. An $F_{\text{max}}$ of 5.34 or greater would occur by chance alone only five percent of the time. Since the computed $F_{\text{max}}$ was 1.760, no evidence for rejecting the null hypothesis was provided.

No evidence was found that indicated the basic assumptions for the analysis of variances had not been met.

The null hypothesis that the group means were from a

\[26\] Winer, op. cit.
common population was tested. The results of that analysis are presented in Table 25.

TABLE 25. Analysis of the Right Ankle Flexibility Scores of Beginning, Competitive (speed), and Synchronized Female Swimmers

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sums of squares</th>
<th>d.f.</th>
<th>Mean squares</th>
<th>F*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>604.469</td>
<td>2</td>
<td>302.2</td>
<td>1.768</td>
</tr>
<tr>
<td>Within</td>
<td>4614.898</td>
<td>27</td>
<td>170.9</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5219.367</td>
<td>29</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ F \text{ required at 5\% level equals 3.35.} \]

With 2 and 27 degrees of freedom, an F of 3.35 or larger was required for significance at the five percent level of confidence. Since the computed F was 1.768, no evidence was provided to reject the null hypothesis. Thus the data provided no evidence that the mean right ankle flexibility of the three groups differed significantly.

The Analysis of Left Ankle Flexibility Average Ankle Flexibility Test

The beginning, competitive (speed), and synchronized swimmers were tested for left ankle flexibility using Johnson and Nelson's Average Ankle Flexibility test.\(^{27}\) Table 26 presents the groups, sample sizes, means,

\(^{27}\)Johnson, loc. cit., p. 76.
standard deviations, and variances utilized to evaluate left ankle flexibility.

TABLE 26. Summary of the Performances of Beginning, Competitive (speed), and Synchronized Swimmers in Left Ankle Flexibility

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>X</th>
<th>S.D.</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>10</td>
<td>91.40</td>
<td>15.042</td>
<td>226.267</td>
</tr>
<tr>
<td>Competitive (speed)</td>
<td>10</td>
<td>109.10</td>
<td>8.373</td>
<td>70.100</td>
</tr>
<tr>
<td>Synchronized</td>
<td>10</td>
<td>107.20</td>
<td>16.410</td>
<td>269.289</td>
</tr>
</tbody>
</table>

As was previously stated, it is necessary to determine whether the data meet the assumption underlying the analysis of variance technique. Hartley's $F_{max}$ statistic, suggested by Winer, was used to test for homogeneity of variance. The results of the test for homogeneity of variance are presented in Table 27.

TABLE 27. Summary of Hartley's Test for Homogeneity of Variance for Left Ankle Flexibility Measures

<table>
<thead>
<tr>
<th>Treatment groups</th>
<th>d.f.</th>
<th>Sums of squares</th>
<th>Mean square (variance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>9</td>
<td>2036.389</td>
<td>226.267</td>
</tr>
<tr>
<td>Competitive (speed)</td>
<td>9</td>
<td>630.899</td>
<td>70.100</td>
</tr>
<tr>
<td>Synchronized</td>
<td>9</td>
<td>2423.599</td>
<td>269.2886</td>
</tr>
</tbody>
</table>

$F_{max}$ computed 5.842
$F_{max}$ required 5.340

28 Winer, op. cit.
The null hypothesis that the group variances were equal was tested. With nine degrees of freedom involving the comparison of three variances, an $F_{\text{max}}$ of 5.34 was required for significance at the five percent level of confidence. An $F_{\text{max}}$ of 5.34 or greater would occur by chance alone only five percent of the time. Since the computed $F_{\text{max}}$ was 3.842, no evidence for rejecting the null hypothesis was provided.

No evidence was found that indicated the basic assumptions for the analysis of variance had not been met.

The null hypothesis that the group means were from a common population was tested. The results of that analysis are presented in Table 28.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sums of squares</th>
<th>d.f.</th>
<th>Mean squares</th>
<th>$F$</th>
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<tr>
<td>Between</td>
<td>1888.469</td>
<td>2</td>
<td>944.2</td>
<td>5.008*</td>
</tr>
<tr>
<td>Within</td>
<td>5090.898</td>
<td>27</td>
<td>188.6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6979.367</td>
<td>29</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* $F$ required at 5% level equals 3.35

With 2 and 27 degrees of freedom, an $F$ of 3.35 or larger was required for significance at the five percent level of confidence. Since the computed $F$ was 5.008, the
hypothesis that the means were from a common population was rejected at the five percent level of confidence.

Since the group means were not from a common population of means, the Newman-Keuls test\textsuperscript{29} was applied to all group means to determine which means were significantly different from the other group means. The results of the multiple range test on the group means for left ankle flexibility are presented in Table 29.

\textbf{TABLE 29. Newman-Keuls Test for Comparing the Means of Beginning, Competitive (speed), and Synchronized Female Swimmers}

\begin{tabular}{|c|c|c|c|}
\hline
Means & Beginning & Synchronized & Competitive \ (speed) \\
\hline
91.40 & 107.2 & 109.1 & \\
\hline
Beginning & 15.8 & 17.70* & R\textsubscript{2}=15.243 \\
Synchronized & & 1.9* & R\textsubscript{3}=12.615 \\
\hline
\end{tabular}

*Ranges for the .05 level of confidence

In terms of left ankle flexibility measured by the Average Ankle Flexibility test, the mean performance of the beginning swimmers was significantly different from both the synchronized and competitive (speed) swimming groups. However, the synchronized swimmers proved not to be significantly different from the competitive swimmers.

\textsuperscript{29}Dotson, op. cit.
SUMMARY

A summary of the means, standard deviations, and variances are presented in Table 30. There were no significant differences observed in the following test items: arm strength, right ankle flexibility, kinesthesia arm positioning, kinesthesia leg positioning, and percent of total body fat. However, significant differences did exist in the measures of hip and trunk flexion, back hypertension, and left ankle flexibility.
<table>
<thead>
<tr>
<th>Test Item</th>
<th>Group</th>
<th>X</th>
<th>S.D.</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Percent Body Fat</td>
<td>Beginning</td>
<td>28.33</td>
<td>7.572</td>
<td>57.342</td>
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<tr>
<td></td>
<td>Competitive</td>
<td>21.75</td>
<td>4.535</td>
<td>20.564</td>
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<td></td>
<td>Synchronized</td>
<td>25.58</td>
<td>6.667</td>
<td>44.576</td>
</tr>
<tr>
<td>Arm Strength</td>
<td>Beginning</td>
<td>30.10</td>
<td>4.982</td>
<td>24.822</td>
</tr>
<tr>
<td></td>
<td>Competitive</td>
<td>33.15</td>
<td>5.207</td>
<td>27.114</td>
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<td></td>
<td>Synchronized</td>
<td>29.30</td>
<td>4.436</td>
<td>19.677</td>
</tr>
<tr>
<td>Hip/Trunk Flexion</td>
<td>Beginning</td>
<td>5.775</td>
<td>1.511</td>
<td>2.284</td>
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<tr>
<td></td>
<td>Competitive</td>
<td>8.900</td>
<td>1.444</td>
<td>2.086</td>
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<td>6.700</td>
<td>1.756</td>
<td>3.081</td>
</tr>
<tr>
<td>Hyperextension of the Back</td>
<td>Beginning</td>
<td>25.83</td>
<td>4.067</td>
<td>16.542</td>
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<tr>
<td></td>
<td>Competitive</td>
<td>18.88</td>
<td>6.966</td>
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<td></td>
<td>Synchronized</td>
<td>18.15</td>
<td>4.919</td>
<td>24.197</td>
</tr>
<tr>
<td>Kinesthesia Arm Positioning</td>
<td>Beginning</td>
<td>49.00</td>
<td>7.379</td>
<td>54.444</td>
</tr>
<tr>
<td></td>
<td>Competitive</td>
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<td>4.378</td>
<td>19.167</td>
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<td>Synchronized</td>
<td>54.00</td>
<td>8.756</td>
<td>76.667</td>
</tr>
<tr>
<td>Kinesthesia Leg Positioning</td>
<td>Beginning</td>
<td>44.00</td>
<td>8.097</td>
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<td>40.50</td>
<td>5.503</td>
<td>30.278</td>
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<td></td>
<td>Synchronized</td>
<td>42.50</td>
<td>6.770</td>
<td>45.833</td>
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<td>Right Ankle Flexibility</td>
<td>Beginning</td>
<td>99.98</td>
<td>13.916</td>
<td>193.656</td>
</tr>
<tr>
<td></td>
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<td>110.80</td>
<td>14.266</td>
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<td>Synchronized</td>
<td>106.60</td>
<td>10.752</td>
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<td>15.042</td>
<td>226.267</td>
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<tr>
<td></td>
<td>Competitive</td>
<td>109.10</td>
<td>8.373</td>
<td>70.100</td>
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<td>Synchronized</td>
<td>107.20</td>
<td>16.410</td>
<td>269.289</td>
</tr>
</tbody>
</table>
CHAPTER V

DISCUSSION OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER RESEARCH

In this chapter, the study is discussed in three sections: (1) findings, (2) conclusions, and (3) recommendations for further research.

Discussion of Findings

The results of this study showed that the variable of flexibility was the only characteristic that in some instances proved significant among the three groups of female swimmers; beginning, competitive (speed), and synchronized.

In the Wells Sit and Reach test, measuring hip and trunk flexion, competitive (speed) swimmers were found to be significantly more flexible than synchronized and beginning swimmers. There was no significant difference found between synchronized and beginning swimmers in hip and trunk flexion.

The Bridge-up test, measuring hyperextension of the back, showed that beginning swimmers differed signifi-

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1Johnson, loc. cit., p. 70.
2loc. cit., p. 73.
icantly from synchronized and competitive swimmers. The beginning group had less back flexibility than the other two groups. No significant differences existed between synchronized and competitive (speed) swimmers.

A significant difference also was found in the flexibility variable of the left ankle. Synchronized swimmers and competitive swimmers were significantly different than beginning swimmers as they had greater mean flexibility measures in left ankle flexibility.

There were no significant differences observed in all of the other test items: arm strength, right ankle flexibility, kinesthesis arm positioning, kinesthesis leg positioning, and percent of total body fat.

Therefore, the idea that advanced swimmers have a higher degree of kinesthesis, arm strength, and right ankle flexibility cannot be supported by this study. Although a difference did exist between the means of the three groups in the percent of total body fat measure, a statistically significant difference did not occur.

Advanced swimmers (competitive and synchronized) do, however, indicate a higher degree of flexibility in the area of hip and trunk flexion, back hyperextension, and left ankle flexion and extension.

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3Johnson, loc. cit., p. 76.
CONCLUSIONS

The conclusions reached were based on findings of this study, and are stated below:

1. In measures of arm strength, there were no significant differences between the three groups of female swimmers; beginning, competitive (speed) and synchronized.

2. In right ankle flexibility measures there were no significant differences between the three groups of female swimmers.

3. In measures of kinesthesia (both the arm positioning and leg positioning tests) there were no significant differences between the three groups of female swimmers.

4. In percent of total body fat measures, no significant differences existed between the three groups of female swimmers.

5. Significant differences did exist in hip and trunk flexion between beginning, competitive (speed), and synchronized swimmers. Competitive (speed) swimmers showed greater hip and trunk flexibility than synchronized and beginning swimmers. There was no significant difference, however, between synchronized and beginning swimmers.

6. In back flexibility measures, beginning swimmers had significantly less back flexibility than competitive (speed) swimmers and synchronized swimmers. No difference existed between competitive (speed) swimmers and synchronized swimmers in back flexibility.

7. In left ankle flexibility measures, synchronized and competitive (speed) swimmers had greater flexibility than beginning swimmers. No difference existed between synchronized and competitive (speed) swimmers, however.
RECOMMENDATIONS FOR FURTHER RESEARCH

There are relatively few studies related to women involved in the area of aquatics. There is a need, therefore, to have further research in this field.

In this study, the pools of available subjects were limited. The investigator, therefore, recommends that larger groups of participants in the areas of beginning, competitive (speed), and synchronized swimming be used in further research.

Future studies in this area could include taking measurements prior to and following participation in an aquatic program (test-retest method). Tests measuring more joints of flexibility, skinfold measures, reaction time, reflex time, cardio-vascular endurance, resting pulse, and demographic data could also be included in future studies.
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Cotten, Doyice J. and Bonnell, Lorraine, "Investigation of the T-5 Cable Tensiometer Grip Attachment for Measuring Strength of College Women." Research Quarterly, XL (December 1969), 848.

Cureton, Thomas K., "Flexibility as an Aspect of Physical Fitness." Research Quarterly, XII (May 1941), 381.


McCue, Betty, "Flexibility in Relation to Weight Jumping and Performance on an Obstacle Course." Research Quarterly, XXIV (October 1953), 316.


Montoye, Henry J. and Lamphiear, Donald E., "Grip and Arm Strength in Males and Females, Age 10 to 69." Research Quarterly, XLVIII (March 1977), 109.


Pipes, Thomas V., "Body Composition Characteristics of Male and Female Track and Field Athletes." Research Quarterly, XLVIII (March 1977), 244.


Chatillion scales: John Chatillion & Sons
83-30 Kew Gardens Road
Kew Gardens, New York 11415
(max. 9 kilos x 10 grams)

Physician's scales: Health-o-meter by Continental
Grand Rapids Scale Company
4217 Stafford S.W.
Grand Rapids, Michigan 49508

Propper Spirometer: Dry spirometer PC 5155
J. A. Preston Corporation
71 Fifth Ave.
New York, New York 10003

Hand Grip Dynamometer: Model #76502
Lafayette Instrument Co.
Lafayette, Indiana

Shoulder Breadth Caliper: PC 5026
J. A. Preston Corporation
71 Fifth Ave.
New York, New York 10003

Protractor: Design adapted from Toler
Equipment construction is described below:

A protractor with a range of 180 degrees was designed
on a 4 foot by 8 foot sheet of heavy duty plastic. This
was supported by a frame built of 1 x 2 yellow pine wood.
The angles were marked every 5 degrees, alternating red
and black lines for ease in reading. Waterproof felt

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marking pens were used for drawing these lines. This apparatus was suspended 6 inches above the surface of the water by the use of two inner tubes and the edge of the pool.

Two stick figures were drawn on separate pieces of 9" by 6" cardboard that were laminated for use near the water. One figure was shown lying on its back with a left arm extended 55 degrees outward from his side. The other figure was shown on its side with his right leg extended 35 degrees forward while the left leg remained straight.
APPENDIX B

FORMULAS FOR COMPUTATION OF
PERCENT OF TOTAL BODY FAT
In underwater weighing, selected equations must be used to estimate body density and percent of total body fat is assessed. The following computational procedures provide the needed information.

1. Find the body density in grams/cc.

\[ \text{\(D_b = \frac{M_a}{M_a - M_w} \times \left( \frac{D_w}{D_w - RV} \right)\)} \]

- \(M_a\): Weight of subject in air in grams.
- \(M_w\): Weight of subject in water in grams.
- \(D_w\): Density of water at temperature taken during underwater weighing (conversion factors are listed below).
- \(RV\): Residual volume in cc as estimated from vital capacity.

2. Compute the relative fat, (i.e., the percent of the body weight that is stored in fat) according to the equation:

\[ \text{\(\text{Percent of Fat} = \left[ \frac{4.570 - 4.142}{D_b} \right] \times 100\)} \]

3. Compute the absolute Fat (i.e., the total weight of the stored body fat) according to the equation:

\[ \text{Fat} = \text{Weight} \times \frac{\text{Percent Fat}}{100} \]

Fat and Weight: Expressed in kilograms.

4. Find the LBW:

\[ \text{LBW} = \text{Weight} - \text{Fat} \]

Fat and Weight: Expressed in kilograms.

---

### BTPS* conversion factors

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<th>Temperature (°C)</th>
<th>BTPS Factor</th>
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<tr>
<td>21</td>
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<tr>
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<td>1.039</td>
</tr>
</tbody>
</table>

*Body temperature, ambient pressure, saturated with water vapor.

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<tr>
<th>Temperature (°C)</th>
<th>D$_w$ (grams/ml)</th>
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<td>21</td>
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APPENDIX C

TEST ITEM RAW SCORES
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<tr>
<th>N</th>
<th>Group</th>
<th>Arm strength</th>
<th>Wells</th>
<th>Hip/trunk</th>
<th>Bridge-up</th>
<th>Percent body fat</th>
<th>Kinaesthesia arm</th>
<th>Kinaesthesia leg</th>
<th>Right ankle</th>
<th>Left ankle</th>
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APPENDIX D

TEST ITEM SCORE SHEET
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<th>HT:</th>
<th>SYNCH:</th>
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<th>SPEED:</th>
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| *If you are interested in receiving a copy of the findings in this test, please fill your home address in on the bottom.* THANK YOU FOR TAKING PART! Mary Jo

### Grip Test - Arm Strength

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<tr>
<th>Right Hand</th>
<th>Left Hand</th>
<th>BEST EFFORT</th>
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### Well's Sit & Reach Test

1. 
2. 
3. 

### Bridge-Up

1. 
2. 
3. 

### Ankle Flexibility

Recorded on card number: _____

### Underwater Weighing

1. _____
2. _____
3. _____
4. _____
5. _____

### Kinesthetic Sense

1. _____ ARM ANGLE
2. _____
3. _____
4. _____ LEG DEVIATION
5. _____

Average Weight

- **Air Temp:** _____
- **H₂O Temp:** _____
- **Vital Capacity:** _____

Home Address:

Signature of subject: