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Comparison of the Belgrad Skin Suit to a Conventional Race Suit in the Swimming Speed of Females

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COMPARISON OF THE BELGRAD SKIN SUIT TO A CONVENTIONAL RACE SUIT IN THE SWIMMING SPEED OF FEMALES

by

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ABSTRACT

COMPARISON OF THE BELGRAD SKIN SUIT TO A CONVENTIONAL RACE SUIT IN THE SWIMMING SPEED OF FEMALES

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The purpose of this study was to compare the effect of the Belgrad skin suit with a conventional racing suit upon swimming speed in the 25 yard front crawl stroke. Testing involved 30 female subjects, fifteen each of competitive and non-competitive swimmers. The experiment involved both groups being tested twice under four conditions, for a total of eight trials: (1) a conventional suit alone; (2) a conventional suit with an orange juice placebo, suggested to be a supplement energy producer; (3) a Belgrad skin suit alone; and (4) the Belgrad skin suit with the orange juice placebo. A two-factor mixed design with repeated measures on one factor and a three-factor analysis with repeated measures were computed to study the interactions between suits, placebo conditions, and groups involved. Based on the statistical analysis, no significant difference at the .05 level of significance was found between the Belgrad skin suit and the conventional racing suit. Therefore, it was concluded that the Belgrad skin suit would not enhance swimming speed in the 25 yard front crawl.

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Chapter 1

INTRODUCTION

The length of time that it takes to accomplish an objective is a factor in many areas of interest to mankind. Athletics is one general area of interest where the time factor may indeed be an objective in itself. Examples of this are athletic events in swimming and track, where the time not only decides the winner of a race, but may be the basis of a state, national, or international ranking. Consequently, elements sought to reduce the elapsed time by increasing the speed of the participant have been subject to the most exhaustive research and analysis.

To achieve in athletic skills, Singer[1] reports that at least four variables must be developed to a sufficient degree if the performer is to be considered skillful. He presented these variables in the following formula:

Skill = Speed x Accuracy x Form x Adaptability

According to Singer then, speed is an important acquisition if success is to be attained. Exactly what speed is and how it can be improved are questions that command the closest review. deVries[2] defines speed as simply the result of applying force to mass. He hypothesizes from his own studies and from those of others that improvement may be possible by

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[1]Robert N. Singer, Motor Learning and Human Performance (New York, New York: The MacMillan Company, 1968), p. 6.

[2]Herbert A. deVries, Physiology of Exercise for Physical Education and Athletics (Dubuque, Iowa: William C. Brown, 1966), pp. 350-357.

increasing the applied force through stronger muscular contractions or by improved body neuromuscular coordination and flexibility. Both of these ingredients are obtained through specially designed training programs.

While deVries concluded that the strength training aspect appeared to be the most promising area for improvement of speed, most coaches and athletes also look for more immediate results from other extraneous factors. Athletes over the years have searched for methods to elicit instantaneous improvement in performance, such as a special high carbohydrate diet to increase body energy,[3] protein supplementation to enhance muscle building processes,[4] anabolic steroids to promote increased muscular strength,[5] and even warm showers or alcohol rubs to relax the muscles of the body just prior to performance.[6]

The search for immediate improvement in athletic results was not confined solely to physiological or psychological processes. Changes in the design, material and weight of athletic equipment was also a fruitful avenue to increased performance capacity. In sports such as scuba-diving, snow skiing and football, among others, clothing plays a significant role. Modern scuba divers found the wet suit to be tougher, warmer and more

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[3]Per-Olof Astrand and Kaare Rodahl, Textbook of Work Physiology (New York, New York: McGraw-Hill Book Co., 1970), pp. 480-482.

[4]Michio Ikai and Arthur H. Steinhaus, "Some Factors Modifying the Expression of Human Strength," Journal of Applied Physiology, 16:157, 1961.

[5]S. W. Casner, "Anabolic Steroid Effects on Body Composition in Normal Young Men," Journal of Sports Medicine and Physical Fitness, 11:98-103, 1971

[6]Erling Asmussen and Ove Boje, "Body Temperature and Capacity for Work," Acta Physiologica Scandinavica, 10:21-22, 1945.

flexible than the dry suit.[7] Snow skiers found that tight fitting stretch pants and quilted parkas, by reducing wind resistance to a minimum, were superior to the earlier conventional baggy, heavy clothing.[8] Football players went to a light weight mesh jersey from the traditional heavyweight close weave material during the hot weather of late summer and early fall in order to increase evaporative heat losses.[9]

In swimming events, with the advent of the highly discriminating capability of the electronic timer, which can distinguish between finish line touches on the order of one thousandth of a second, the swim suit seems to have become a factor of increasing significance in recent years. From the time of the 1956 Olympics when the great Dawn Fraser broke the world's record for the 100 meter freestyle event, interest has focused on women's swimming apparel. In that race Miss Fraser wore a nylon, four ounce, tricot Speedo swim suit.[10] The fact that this suit was lighter in weight than the synthetic nylon quarter panel skirt swim suit, approved by the Amateur Athletic Union for American women swimmers, made people conscious of the weight factor in women's swimming suits.

In 1972, an even more revolutionary suit, the Belgrad Skin Suit had been developed. Named after the meet in Belgrade, Yugoslavia, in which

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[7]Larry Bortstein and Henry Berkowitz, Scuba Spear and Snorkle (New York, New York: Cowles Book Co., 1971), pp. 29-31.

[8]Morten Lund, The Skier's World (New York, New York: Ridge Press, Inc., 1973), pp. 221-229.

[9]Mike Rathet, Pro Football!!! The World of the NFL (Chicago, Illinois: Henry Regnery Co., 1972), pp. 84-88.

[10]Jule Campbell, "Light, Tight and Right for Racing," Sports Illustrated, 41:46-49, August 14, 1974.

it first appeared, the Belgrad is an elastic, high-necked, tight form-fitting suit which has been acclaimed to be a major factor in breaking long established world records and magic time barriers in swimming. Manufactured by the Buesing Company of West Germany, it was specially designed for the German Democratic Republic at the First World Aquatic Championships in Belgrade, Yugoslavia, in 1973.[11] Also in 1973, the Women's German Democratic Republic team won the world championships, dominating almost every event, establishing a dozen world records, and all while wearing the revolutionary Belgrad suit.[12] It was not until the 1974 Indoor Nationals in the United States that the Belgrad was first worn by American swimmers in AAU competition due to the ruling that required a skirt at the front of the suit. But with the unprecedented vote to change the regulation, virtually every event winner wore the new suit and every women's record was broken.[13] Although not based on any actual scientific tests to support its claims of superiority, this suit has excited a new interest in the design of apparel to increase swimming speed.

What is there about the Belgrad suit that would gain world acceptance as being superior? More specifically, is the effect of the suit psychological or are there scientific principles involved that would render this suit more effective than the traditional racing swim suit? The question as to whether or not the effect, if any, of wearing the suit is psychological, physical or both is still to be answered. Jule Campbell,

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[11]"The Skin Suit Revolution," Aquatic World Magazine, September, 1975, pp. 12-15.

[12]Ibid.

[13]Ibid.

of Sports Illustrated, in interviewing some of the great coaches and swimmers of our day has placed some merit in the concept that the skin suit could elicit a psychological rather than a bodily lift.[14] Sherm Chavoor, author and coach of swimming at the Arden Hills Swim Club in California, said that he would not allow practice in the Belgrad because he said, "They go too fast." While Chavoor's statement implies that the skin suit provides a physical advantage there is as yet no concrete evidence to substantiate it. Mark Schubert, coach of the very strong Mission Viejo Natadores Swim Club feels that a swimmer going into a big swim meet after months of heavy training is mentally prepared for the event but the skin suit tops it off and when he puts it on at the meet, he is "psyched up" to produce.[15] Heather Greenwood, champion freestyle swimmer admitted, "I don't know how much my Belgrad suit contributed to my time, but it's worth something. This may be more psychological than physical but I always think that I am going to win when I wear it."[16]

Although some authorities have contended that psychological factors are the main benefit of the new suit, many swimming analysts and coaches interviewed by Joan Ryan of Women's Sports felt that it was the mechanical properties of the suit itself that were responsible for the success of the swimmers who wore it.[17] In an advertisement by Rothhammer International

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[14]Jule Campbell, "Light, Tight and Right for Racing," Sports Illustrated, 41:46-49, August 14, 1974.

[15]Ibid.

[16]Ibid.

[17]Joan Ryan, "The Great Swim Controversy," Women's Sports, 1:45-47, 62, August, 1974.

Incorporated in Swimming World magazine, who have exclusive United States importing rights to the Belgrad Swim Costume, time reductions of two seconds and more in 100 meter sprints have been attributed to the suit. This, is said, is due to minimized water flow into the suit and the special elastic fabric which sticks to the body causing a streamlining that the old suit lacked. Furthermore, the union of the shoulder straps together in the back permits full body freedom and allows the suit to move as a part of the swimmer.*

Considering the broad and enthusiastic acceptance of the Belgrad skin suit almost overnight, without discrete objective data it would appear that experimental evidence is necessary to support or disclaim its purported effectiveness.

THE PROBLEM

Statement of the Problem

The problem was to evaluate whether or not the new Belgrad skin suit influenced the swimming speed of females.

Purpose of the Study

The purpose of this study was to compare the effect of the Belgrad skin suit with a conventional racing suit upon swimming speed in the 25 yard front crawl stroke.

Hypothesis

The null hypothesis was used: There would be no significant difference in the results comparing the Belgrad skin suit to the conventional

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*Statement by Rothhammer International, Inc., Advertisement, Swimming World, 47:10, August, 1974.

racing suit in time recorded for the 25 yard front crawl stroke.

Significance of the Problem

In spite of the broad usage and acceptance of the Belgrad skin suit now worn in national competition, there has been no scientific research conducted over various distances to establish quantitatively its superiority over conventional swim suits. Hence, it is pertinent that such a study be made to establish the fact whether the advantage, if any, is physical, psychological or both.

Delimitations

This study was delimited by the following factors:

1. A total number of 30 subjects was used. Fifteen were grouped together and consisted of experienced competitive swimmers ranging in age from 8 to 18, with a mean of 13.07 and standard deviation of 2.69. The other group of fifteen was non-trained, recreational swimmers, ranging in age from 18 to 21 years of age with a mean of 19.00 and standard deviation of .926. The competitive swimmers were members of the Bounty Otter Swim Club, an age group swimming team in Virginia. The recreational swimmers were not members of a competitive swimming team but were selected as a control group who were not familiar in any way with the Belgrad suit.

2. The experiment involved both the above groups being tested twice under four conditions for a total of eight trials: (1) a conventional suit alone; (2) a conventional suit with an orange juice placebo, suggested to be a supplement energy producer; (3) a Belgrad skin suit alone; (4) the Belgrad skin suit with the orange juice placebo. The purpose of the orange juice placebo drink was to camouflage the true intent of the study. The subjects were led to believe that the importance of

the testing was to find out if there was any difference in speed after having received an energy supplemented orange juice which was to have immediate results. The false explanation was found necessary in order to control any psychological effects that wearing the Belgrad might induce.

3. The conventional suit utilized in this study was the White-Stag "Speedo" racing suit which, until recently, was considered by many to be the lightest weight and best designed of all brands.

4. Each subject was tested by sprinting the front crawl stroke for 25 yards; a push off from the wall was executed in a prescribed manner. Each trial was timed by an electric timing device.

5. Each subject was tested individually in order to control psychological effects encountered when racing another individual.

6. All tests began in the water in a manner prescribed by the investigator, the purpose of which was to limit the test to solely a swimming race and not to bring into consideration the dive used, a factor that could change the time significantly from one test to the next.

7. Each swimmer had approximately 15 minutes rest between swims. This was considered to be an adequate rest for the subjects to swim at maximum speed for each repeat.

8. All testing was accomplished in the morning on two consecutive days. The competitive group was tested on different days from the recreational swimmer group.

9. The water and air temperatures remained approximately 78^{0} and 75^{0} respectively. A constant water level in the pool was also maintained to avoid any extraneous variables that might affect the outcome of the testing.

Limitations

This study was limited by the following factors:

1. All attempts were made to prevent the groups from realizing the benefits of wearing the skin suit for the test, but the possible psychological effect could not be totally controlled.

2. This study was designed to examine only the swimming speed for one length of the pool. Hence it did not show what effect either suit had relative to the dive or repeated wall turns.

3. Since this test was one of speed alone over an established short distance, endurance was not a factor.

4. Random order of testing of the four different conditions was not possible for the experimental design used in this study. It would not have been compatible with the explanations given to the subjects as to the purpose of the study.

5. Each swimmer began the test by the shot of the electric gun which would automatically start the clock by the pressure on the trigger. However, due to malfunctioning of the pistol's cylinder, the non-competitive group started all 8 tests to the click of the gun's trigger, unloaded. However, this proved adequate for prompt reaction by the swimmer to start the race.

Chapter 2

REVIEW OF THE LITERATURE

INTRODUCTION

It was the purpose of this experiment to offer some factual data to the public as to any significant superiority of the Belgrad Skin Suit to the conventional racing suit in swimming speed for 25 yards. There have been statements made on behalf of the Belgrad that claim the skin suit to be superior in both material and design to the point of decreasing a swimmers time two seconds for each 100 meters swum.* However, since there has been no scientific research published to support these claims,[18] this chapter was primarily designed to analyze the differences of the two style suits relative to decreased water resistance, based on biomechanical principles. However a small discussion of psychological aspects was also of importance, and is covered below.

PSYCHOLOGICAL ASPECTS

Although this study was conducted with the purpose of comparing the mechanical considerations of both suits, special efforts were made to rule out any extraneous benefits relative to the knowledge the swimmer might have of the theoretical value of the Belgrad suit. To accomplish

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*Statement by Rothhammer International, Inc., Advertisement, Swimming World, 47:10, August, 1974.

[18]Based on personal correspondence between Mrs. Diane Rothhammer, President of Rothhammer International, Inc., and the writer.

this, an alias explanation of the study was given to the subjects in order for them to believe an energy supplement was the purpose of the investigation, and not the bathing suit. It has been found, through numerous research studies, that psychology and motivation play a very important role in the performance of an athlete.[19,20,21] Singer reported psychological staleness, i.e. a loss of interest in training and competition, can be as detrimental to the performance of the swimmer as would the loss of a physiological asset.[22] Counsilman noted that when a swimmer believes something will hurt or enhance his performance, the chances are that it will, even if there is no psychological basis for his belief.[23] Groscost feels that far more experimentation and consideration should be given to any item which might improve human performance physiologically, and which has the psychological effect of making an athlete feel that he is 'ready' and consequently perform accordingly.[24] In reviewing the psychological benefits of the skin suit, certain basic motivational effects are involved. Coach Mark Schubert of the Mission Viejo Natadores Swim Club allows his swimmers to wear the suit only in big meets. By limiting the use of the suit, the swimmers believe that everything is ideal for their ultimate

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[19]Donald Schollander, Inside Swimming (Chicago, Illinois: Henry Regnery Co., 1974), pp. 70-71.

[20]Robert N. Singer, Motor Learning and Human Performance, (New York, New York: The MacMillan Co., 1968), pp. 174-175.

[21]James Counsilman, The Science of Swimming,(Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1968), p. 364.

[22]Singer, loc. cit.

[23]Counsilman, loc. cit.

[24]Joseph Croscost, "Suckers Under the Pillow," Swimming Technique, 11:88, Fall, 1974.

performance when the suit is finally worn.[25] Sherm Chavoor, coach of the Arden Hills Swim Club, also disallows the suit for any but the big meet, again helping to build a climax for an outstanding time improvement.[26]

According to these swimming authorities, there appears to be a psychological benefit from wearing the Belgrad suit. Considering the fact that emotional motivation is extremely important to performance, it could be a factor to improved times. For this reason this study attempted to exclude the psychological factor when comparing the mechanical aspects of the Belgrad skin suit to the conventional Speedo racing suit.

MECHANICAL ASPECTS

Although psychological aspects, as illustrated above, might play the important part in the improved swimming performance while wearing a Belgrad skin suit, it is after all the superior design of the suit and its ability to decrease resistance, which led to its popularity. For this reason, before analyzing the design of the skin suit itself, an investigation of water resistance is discussed first.

Water resistance is a particular problem in swimming. Bunn stated that when a force of a given value is applied to a body to move it through a liquid, the velocity of the body will gradually increase until it reaches a certain limiting value equalizing the friction resistance to the applied force.[27] When that value is reached, the velocity will

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[25]Jule Campbell, "Light, Tight and Right for Racing," Sports Illustrated, 41:46, August 14, 1974.

[26]Ibid.

[27]John W. Bunn, Scientific Principles of Coaching (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964), p. 81.

remain constant as long as that force is applied. Any change in either the resistance or the force will result in acceleration or deceleration. Water resistance and force increase approximately with the square of the velocity.[28] Consequently, energy expenditure is linearly related to propelling force and curvilinearly related to velocity.[29] So important is water resistance to speed, that Bunn noted speed will come as much from eliminating resistance as from increasing the force.[30] Counsilman[31] also stated that probably the greatest amount of improvement in swimming in the last decade has been accomplished by reducing the resistance through improved stroke technique. Bunn,[32] Counsilman,[33] and Hay[34] all agree that there are three types of water resistance that are involved in varying amounts with a swimmers forward progress:

1. Frontal Resistance: This type of resistance is caused by the water immediately in front of the swimmer or any part of his body. The magnitude of such a resistance is controlled by the speed at which the swimmer is traveling forward through the water and the swimmer's cross-sectional area which he presents to the oncoming flow. As this is

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[28]James Counsilman, The Science of Swimming (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1968), p. 16-17.

[29]Ibid.

[30]John W. Bunn, Scientific Principles of Coaching (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964), pp. 357-359.

[31]Counsilman, op. cit., p. 2.

[32]Bunn, op. cit., pp. 81-84.

[33]Counsilman, op. cit., pp. 3-5.

[34]James Hay, The Biomechanics of Sports Techniques (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1973), pp. 357-359.

probably the most important resistive force to be overcome in swimming, much research has been done in this area.

In order to investigate the detriments of increased cross-sectional area in the crawl stroke, Counsilman[35] did a variety of tests involving horizontal body position and body roll to its frontal resistance. He found that when a swimmer is towed in a prone position, less resistance is encountered when the head is held at a normal or water-at-hairline level, than when the head is held high so that the water comes only to his eyebrows. The result is attributed to the increase in cross-sectional area occurring as the legs drop when the head is raised. Increased resistance also was found when Counsilman tested the effects of decreasing and increasing body roll in the crawl stroke.[36] Results showed that although body roll is a natural function of the stroke, exaggerated motions tend to increase resistance greatly to the point where it more than offsets any advantage to be gained in terms of propulsion.[37]

Alley,[38] in researching the drag effect of the flutter kick in the crawl stroke came to the conclusion that the vertical motions of the kick caused the legs to be raised higher in the water than they would otherwise be. This reduced cross-sectional area that resulted in a corresponding decrease in frontal resistance encountered by the swimmer.

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[35]Councilman, op. cit., pp. 20-21.

[36]Ibid.

[37]Ibid.

[38]Louis E. Alley, "An Analysis of Water Resistance and Propulsion in Swimming the Crawl Stroke," Research Quarterly, 23:261-269, 1952.

Frontal resistance then can be decreased by proportionately decreasing the amount of cross-sectional area involved.

2. Wave Resistance: Wave resistance is dependent upon the swimmer's speed, his body shape, and the movements he makes in proximity to the water surface.[39] Wave making is largely eliminated by avoiding up and down movements or rolling during the stroke. Alley[40] and Counsilman[41] have both found that the swimmers speed has an effect on the magnitude of wave resistance. They found that there was a formation of a pronounced bow wave as the speed at which they towed their respective subjects was increased, and that there was a corresponding increase in the rate at which the drag increased relative to the speed. Wave resistance then can most suitably be decreased by avoiding the large up-and-down movements of the swimmer's body.

3. Skin Friction: Skin friction is defined as that resistance caused by the water immediately next to the body. Counsilman,[42] Bunn,[43] and Hay,[44] all have found this type of drag to be of little practical significance to the swimming speed and resistance. Karpovich in his study

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[39]James Hay, The Biomechanics of Sports Techniques (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1973), p. 359.

[40]Alley, loc. cit.

[41]James Counsilman, "Forces in Swimming Two Types of Crawl Stroke," Research Quarterly, 26:133-134, 1955.

[42]James Counsilman, The Science of Swimming (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1968), p. 3.

[43]John Bunn, Scientific Principles of Coaching (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964), p. 83.

[44]Hay, Ibid.

of resistive forces, found that skin friction was the most important factor for moderate speeds, and that it varies in proportion to the skin area, and as the 1.7 to 1.92 power of the speed.[45] Swimmers in attempts to cut down on this type of resistance, shave all the hair on their bodies to make the surface smoother and/or apply oils of various kinds to the body. Counsilman,[46] although not finding any valid evidence to substantiate that shaving the hair off the body would lessen resistance, did contend that it could possibly make the swimmer more sensitive to the 'feel' or pressure of the water and consequently improve his coordination. Gambril,[47] and Torney and Clayton,[48] although sanctioning this concept of shaving prior to performance, do not offer any additional explanation as to its validity. Townes and Manley,[49] in a study comparing swimming speeds of five male swimmers before and then after having a hair cut found that a significant difference was evident in the longer tests of 100 yards, in favor of the time swum after the haircut, but not in the 50 yard sprint.

From the above discussion then, it can be seen that fluid dynamics play an important part in the forward progress of a swimmer. Performance

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[45]Peter Karpovich, "Water Resistance in Swimming," Research Quarterly, 4:21-28, 1933.

[46]James Counsilman, The Science of Swimming (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1968), p. 364.

[47]Donald Gambril, Swimming (Pacific Palisades, California: Goodyear Publishing Co., Inc., 1969), p. 76.

[48]John Torney and Robert Clayton, Aquatic Instruction (Minneapolis Minnesota: Burgess Publishing Co., 1970), p. 275.

[49]Ross Townes and T. Manley, "The Length of Hair and the Speed in Swimming," Athletic Journal, 55:12,83, April, 1975.

ability depends not only on the force exerted by the swimmer but also on his horizontal and lateral body position in the water and to some extent on skin friction.

Through an investigation of research literature, there was found a compatibility of the skin suit to those biomechanical principles utilized in effective swimming speed. In attempting to understand how this costume might produce such immediate improvements in swimming time, one must be aware of the design of the suit and realize its compatibility with the laws of fluid dynamics.

BASIC DIFFERENCES BETWEEN THE BELGRAD AND THE CONVENTIONAL SUIT

Weight and Material

The differences between the Belgrad and conventional suits are not so apparent when comparing their weight and type of material used. The Belgrad is composed of 84% nylon and 16% Lycra (the DuPont Company trademark name for a knit fabric with rubber injected between the fiber and weave), while the conventional suit is 100% nylon. For the Belgrad, two inches of fabric will stretch 4 1/4 inches lengthwise, 3 3/4 inches widthwise, and 4 inches when stretched diagonally.[50] The conventional suit will stretch 2 1/4 inches in length, 3 1/4 inches in width, and 2 1/2 inches in diagonal.[51] Also, the Belgrad was found to weigh 4 ounces when dry, and to absorb 2.3 ounces upon submersion, while the conventional suit weighs only 3 ounces when dry but would absorb 3.18 extra ounces of water when submerged.[52]

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[50]"The Skin Suit Revolution," Aquatic World Magazine, pp. 12-15, September, 1975.

[51]Ibid.

[52]Ibid.

Shoulder Straps

Another difference found between the two suits is the manner in which the suit fits over the shoulders of the body. The Belgrad back is slashed out in half-moons over the shoulder blades, allowing for larger armholes and freedom of movement, while the conventional suit was designed in a traditional shoulder strap style.[53]

Neckline

The neckline of the Belgrad is cut high in the front to eliminate water-trapping pockets that would occur normally in the conventional suit due to its low scoop neckline.[54] Swimmers would complain that after a dive or turn off the wall, they would get an air and/or water bubble in back that would leave only after swimming a couple lengths of the pool.[55] With the Belgrad's high neckline and lattice work center in the back seam, this entrapped air/water was expelled out.

Front Skirt Paneling

The Belgrad features a 'skirtless' novelty at the crotch level of the suit, which until 1974 was considered illegal by AAU standards.[56] In the conventional suit a panel of material, called the skirt, was placed across the crotch of the suit to coincide with the AAU regulations.

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[53]Joan Ryan, "The Great Swim Suit Controversy," Women's Sports, 1:42,62, August, 1974.

[54]Jule Campbell, "Light, Tight and Right for Racing," Sports Illustrated, 41:49, August 14, 1974.

[55]Ibid.

[56]Ibid.

ANALYSIS OF THE DIFFERENCES BETWEEN THE BELGRAD AND CONVENTIONAL SUIT

Weight, Material, and Shoulder Straps

An advantage can be seen in favor of the Belgrad over the conventional suit in the material's greater ability to stretch and relieve itself of excess water absorption. With the potential to stretch and return back to its normal length, the Belgrad offers both unrestricting body movements as well as a streamlining of the body due to its tighter fit.[57] The advantage of the shoulder backing of the Belgrad over the old conventional suit is apparent, since the racer back and larger armholes give plenty of shoulder freedom and eliminate the straps that often were tied together in back by shoestrings to prevent them from slipping off. This advantage can be seen when one considers that the individual swimmer is free to practice an arm reach stroke comfortable to their own style without being hampered by shoulder straps limiting their range.[58]

The fabric itself as well as the resultant fit causes a prevention of water absorption and air-pockets which could slow down speed. This of course is understandable in that if the suit is quite tight and form-fitting to the body it would decrease added water absorbed, which would decrease the total weight the body would normally have to propel through the water. Karpovich[59] found that the type of bathing suit is

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[57]"The Skin Suit Revolution," Aquatic World Magazine, pp. 12-15, September, 1975.

[58]Joan Ryan, "The Great Swim Suit Controversy," Women's Sports 1:41, 62, August, 1974.

[59]Peter Karpovich, "Water Resistance in Swimming," Research Quarterly, 4:21-28, 1933.

more important than the quality of the material in the suit. A suit which is loose about the back and tight about the legs, holding air and/or water may considerably increase the resistance. His testing however, compared a woolen suit to one that was made of nylon. Since speed is a factor of strength to weight, then it should increase the speed. Skin friction,[60] which is caused by the resistance of the water immediately next to the body, is possibly decreased with a potential increase in speed. Karpovich however, in measuring the effects of different water resistances on swimming, found that the shape of an object is more important than the nature of the surface area.[61] This type of resistance has been found to be of more importance in airplanes, boats, and high-speed objects, and is of less consequence in swimming.[62]

In behalf of the conventional suit, however, if one bought such a suit that fit her properly, it too is quite form-fitting and probably does not require any support in the back to hold the straps up. When wet the suit would tend to stretch, not imposing too much problem for arm freedom in movement. As it is, most coaches demand that their swimmers wear the old suit at practice sessions,[63] and the stroke they utilize at practice wearing that suit is certainly going to be the same they portray in races while in the Belgrad suit.

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[60]Herbert A. deVries, Physiology of Exercise for Physical Education and Athletics, (Dubuque, Iowa: William C. Brown Company, 1966), p. 359.

[61]Karpovich, loc. cit.

[62]James G. Hay, The Biomechanics of Sports Techniques, (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1973), p. 355.

[63]Jule Campbell, "Light, Tight and Right for Racing," Sports Illustrated, 41:49, August 14, 1974.

Neckline and Skirt Panel

As stated earlier, the advantage of the Belgrad's high neckline and skirtless panel to the conventional suit's low scooped one with quarter panel across the front is the elimination of air pockets which form in the back of the suit.[64] When air gets inside a suit and forms a bulge, this increases a type of resistive force called frontal resistance which is the resistance to forward progress that is created by the water immediately in front of the swimmer or any part of her body.[65] Frontal resistance is governed by the speed at which the swimmer is traveling forward through the water and by the cross-sectional area which she presents to the "oncoming flow."[66] Since slowing down to decrease frontal resistance clearly defeats the purpose of the exercise, a more practical means of decreasing the resistance would be to decrease the cross-sectional area.[67] Karpovich[68] also reported that the shape of the object has a pronounced effect on the resistance offered by the oncoming water. As an illustration of the importance of a decreased cross-sectional area to speed, Karpovich took an eighteen foot canoe with two people sitting in it and towed it a speed of seven feet per

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[64]Jule Campbell, loc. cit.

[65]James Counsilman, The Science of Swimming, (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1968), p. 364.

[66]Ibid.

[67]Ibid.

[68]Peter Karpovich, "Water Resistance in Swimming," Research Quarterly, 4:21-28, 1933.

second. Its resistance was twelve pounds, whereas the average man at the same speed would show a resistance of about thirty pounds. In relating the above to the Belgrad, the decrease in cross-sectional area has been attempted by designing the high neckline and elimination of the skirt panel, both of which would cancel out the trapped air-pockets and bulges reportedly found in the conventional suit.[69]

Although it has appeared that great improvements in swimming speed have been made while wearing the skin suit in competition, it is difficult to isolate one variable under the many influences that affect performances during athletic competition and state that it was the factor that increased the speed. Most coaches have the swimmers wear the skin suit for only a big meet, one in which they are finely tuned and tapered, and should probably improve regardless. Quoted in Sports Illustrated, Mark Schubert, coach of the Mission Viejo Natadores Swim Club stated that after heavy training his swimmers taper to almost one-fifth their normal amount and that is then that they get their explosive energy and the biggest time drops.[70] Though their minds may believe in the suit, their bodies were ready for improvement anyway.

Another question of merit concerning the eminent Belgrad, although not studied here, is the immense improvement of the male swimmer whose swim suit is still basically the same. Although there are Belgrad suits for males the only difference is the material rather than the style, and can certainly not be given credit for such time improvements. For

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[69]Campbell, loc. cit.

[70]Campbell, loc. cit.

men it would seem that improved skills and training were the factors responsible for the lowered times, a factor that should also be responsible for the improved times of the women swimmers.

To summarize, it would appear that the Belgrad suit does have a superiority over the conventional style as far as the design of the suit is concerned and based on principles of fluid dynamics. However, to what extent these advantages play in actual swimming speed has not yet been indicated in any scientifically controlled study.

Chapter 3

PROCEDURE AND EXPERIMENTAL METHODOLOGY

It was the purpose of this study to compare the relative effectiveness of the Belgrad skin suit, as contrasted to the conventional racing swim suit, upon swimming speed of female competitive and non-competitive swimmers. At the present time no factual data have offered for public review relative to the validity of claims made by the manufacturers of the Belgrad suit, although the usage and acceptance of the skin suit since its production in 1973 has been overwhelming. In this chapter, the discussion is centered upon the characteristics of the subjects, the equipment utilized, the procedure and the experimental design.

METHODOLOGY

Subjects

A total of 30 female swimmers were subjects for this study. Fifteen were highly trained competitive swimmers, from the Bounty-Otters Swim Club in Norfolk, Virginia. They ranged in age from 8-18, with $\bar{X}$ = 13.07 and SD = 2.69. A second group included fifteen members of an accredited Senior Life Saving Course offered by Old Dominion University in Norfolk, Virginia, Fall term 1975. These women were considered untrained, recreational type swimmers, but with good stroke mechanics. For this group, the age range was 18-21 with $\bar{X}$ = 19.00 and SD = .926;

they are referred to as the non-competitive group. All subjects were tested during August,1975.

Equipment

All testing was done in the 25 yard, 8 lane swimming pool of the Health and Physical Education Building at Old Dominion University, Norfolk, Virginia. A constant water and air temperature of 78^{0} and 75^{0}, respectively, was maintained, as well as a constant water level to gutter height so that no environmental factors could play a part in the resulting times. In order to record accurately the speed of each swimmer, the Kyroscope Electric Timer registering to 1/1000 second was used. This timer was connected by wire with both an electric gun which would automatically start the clock with the pull of the trigger, and an electronic pad located at the far end of the pool. This electronic pad was placed in the water and would instantly stop the clock when touched by the swimmer completing her sprint. For the non-competitive group however, due to a malfunction of the gun's carbine, each test was started by the sound of the click of the gun's trigger, which was loud enough to be heard by the swimmers, and would start the clock.

Parameters Tested

The criterion measure was the time to swim 25 yards using a free style stroke. Each subject was tested twice under four different conditions: (1) a conventional suit alone; (2) a conventional suit with an orange juice placebo, suggested to be a supplement energy producer; (3) a Belgrad skin suit alone; and (4) the Belgrad skin suit with the orange juice placebo. The placebo was used in order to camouflage the true purpose of the experiment, i.e. the comparison of the Belgrad suit

with the conventional speedo suit. The subjects were informed that the purpose of the study was to investigate the effect of a special energy supplement, which was in fact, the orange juice placebo.

Due to the use of non-competitive swimmers in this study, it was found necessary to set the distance swum at 25 yards, rather than a longer race. For instance, although, the competitive swimmers were conditioned physically and were capable of completing workloads with consistency, the recreational or non-competitive swimmers could not.

Other variables involved in utilizing a longer testing would be the advantage of the training effects, i.e. an acquiring of endurance, strength, and/or experience, developed between the first swim test and the last. Also, as they fatiqued, the non-competitive swimmers strokes would probably regress to the extent that their body positions and their effective pulling force would decrease.[71] Consequently a greater amount of water resistance would result that would eliminate any advantage the Belgrad might have. Karpovich,[72] in his experiment involving propelling force and resistance in the crawl stroke with competitive swimmers, recommended a shorter distance of 20 yards as the swimming distance to be covered. His recommendation was not explained except that he found it to be the most reliable for his testing purposes. Therefore, where four trails of 25 yard sprints each day could be done without tight control over all the factors involved in a swimming time, they would need to be

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[71]John Bunn, Scientific Principles of Coaching (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964), pp. 83-84.

[72]Peter Karpovich, "Analysis of the Propelling Force in the Crawl Stroke," Research Quarterly, 6:49-58, 1935.

controlled in a longer race for the non-competitive group and, in some cases, for the competitors.

The competitive swimmers were tested on two consecutive days at the same time each morning during their normal practice sessions from 9-11 a.m. The non-competitive swimmers, although tested on different days from the first group, were also timed in two consecutive days from 10-11:30 a.m.

General Procedure

Testing for this study was completed over a period of two days for both groups. On the first day, four swimming bouts were given with the conventional suit, and on the second day all tests were done while wearing the Belgrad skin suit.

For the first day of testing, no prior knowledge of the study was given to the subjects. The competitive swimmers were expected to wear the conventional suit at all practice sessions, consequently all swimmers wore one. However, for the non-competitive group, conventional suits were supplied to those not already owning one. Prior to the testing for the first day, a complete introduction and demonstration was made to explain the supposed purpose of the study. The swimmers were informed that the orange juice placebo, supposedly containing an energy supplement, was designed to produce immediate increases in speed. To their understanding, a comparison was going to be made between their maximum speed before and after having consumed a five ounce cup of the placebo energy supplement. This false explanation was utilized in an attempt to discount any psychological lift the knowledge of wearing the skin suit might have on their performance.

At the start of both days, standard instructions were read to each group so that they fully understood how they were to start from the wall, what stroke to swim, and how they were to touch the electronic timing pad on the opposite end of the pool. The instructions given the subjects were as follows:

> You are going to be tested today by swimming four times a 25 yard freestyle sprint. You will go one by one, with one minute apart, and will have all completed one sprint before starting the second round. After each of you has swum the distance twice, you will be given a five ounce cup of energy supplement diluted in orange juice before completing your last two trials for the day. In doing the race, please attempt to go as fast as you can each time. Follow the black line at the bottom of the pool to help you go straight. The pad on the shallow end stops the electric timer, so please touch it firmly. Each sprint will start in the water. In starting off, face to your left, and with your left hand holding the wall, place both legs up against the wall. Both the push off and the finish will be demonstrated for you. Remember not to glide into the wall at the finish, or take a long glide after pushing off. For this study to be accurate, you must please give a 100% effort each time.

For the competitive swimmer group, all were well acquainted with the push off and pad touch. After one demonstration, no further explanation was needed. For the non-competitive group, a demonstration was made by a volunteer competitive swimmer of both the push off and pad touch. Then each testee was given a practice trial, without actually swimming down the pool of both the correct start and finish. For the first day then, each group was tested four times in swimming the 25 yard crawl sprint. The first two times without the orange juice supplement placebo, and then again two times after having a five ounce cup of the placebo.

On the second day of the testing, the standard instructions were given again. The competitive swimmers were advised to wear their skin suit, and for those who did not own one, one was supplied by the investi-

gator. For all non-competitive swimmers, a Belgrad suit was supplied in their correct size. Because there are more brands of skin suits then just the Belgrad on the market, and to avoid any questions as to why only the Belgrad could be used, it was found necessary to give an alternate explanation as to its use. It was for this reason that all swimmers were told that the investigator planned to become a local agent in selling the suit, and hence eliminate the waiting period involved in ordering through the mail. All swimmers were asked to do their final four tests with the suit on and to give an opinion of the fit as well as their body measurements in order to help the investigator chart the correct size suit for a particular body type. It was made clear that it had no bearing on the testing being done, but was for the benefit of the investigator only.

Statistical Procedures and Experimental Design

A null hypothesis was used in this study to investigate the effects of the Belgrad skin suit to the conventional racing suit in time for a 25 yard crawl stroke sprint. The means and standard deviation were determined for all subjects in both the competitive and non-competitive groups, and tested under the conditions listed below: A conventional suit alone; a conventional suit with the orange placebo; a skin suit alone; and the skin suit with the placebo. The statistical analysis used was the two factor mixed design with repeated measures on one factor. A second statistical design was computed and placed in the appendix section of the thesis. This was a three-factor analysis with repeated measures designed to determine the effects of all factors used in the study, i.e. the placebo condition and group differences.

Chapter 4

PRESENTATION AND ANALYSIS OF DATA

The objective of this study was to determine the difference between swimming speeds of a female wearing a Belgrad to that female wearing a conventional racing suit. A two-factor mixed design with repeated measures of one factor was utilized to analyze the differences between these two suits. A .05 level of significance was established in order to measure any significant results.

STATISTICAL ANALYSIS

To determine the difference in speed between the Belgrad and the conventional suit, a two-factor mixed design with repeated measures on one factor was utilized. The comparison was made between groups and suits, the placebo effect being disregarded. Results can be seen in Tables I and II. As well as the above analysis, a three factor analysis with repeated measures was computed to further analyze the interactions between suit, placebo conditions, and groups; results are tabled in the Appendix. The statistical analysis of each aspect measured is as follows.

Statistical Results Using the Two-Factor Mixed Design

The data weresubjected to analysis for the differences between the Belgrad and conventional swim suits, differences between competitive verses non-competitive groups and interaction between the suit and groups.

Differences between the Belgrad and conventional swim suits. The $\bar{X}$ and SD for the Speedo, regardless of group involved was 18.213 and 3.197; for the Belgrad, 18.052 and 2.970 respectively. An insignificant F-ratio of .182 was found at the .05 level of confidence.

Differences between competitive verses non-competitive groups. Neglecting the suit worn, the competitive group had a $\bar{X}$ and SD of 16.279 and 2.313, to the non-competitives 19.985, 2.567. This difference was found to be highly significant at the .05 level of confidence, with an F-ratio of 16.971.

Interaction between the suit and groups. While wearing the Speedo, the competitive group had a $\bar{X}$ and SD of 16.347 and 2.368 to the non-competitive's 20.078 and 2.850. In the Belgrad, the competitive group had a $\bar{X}$ and SD of 16.211 and 2.339 to the non-competitives 19.892 and 2.354. An insignificant F-ratio of .037 was found in comparing the interaction of suit to group.

TABLE I

SWIMMING TIMES FOR 25 YARD FREESTYLE FOR COMPETITIVE AND NON-COMPETITIVE GROUPS IN THE SPEEDO AND BELGRAD SUITS

	Speedo		Belgrad	
	$\bar{X}$	SD	$\bar{X}$	SD
Competitive Group	16.35	2.37	16.21	2.34
Non-Competitive Group	20.08	2.85	19.89	2.35

*Entries represent mean and standard deviation of time in seconds.

TABLE II

SUMMARY FOR ANALYSIS OF VARIANCE USING A TWO-FACTOR MIXED DESIGN WITH REPEATED MEASURES

Source	SS	df	ms	F	p
Total	552.379	59			
Between Subj.	545.996	29			
Groups	206.047	1	206.047	16.971	.01
Error b	339.949	28	12.141		
Within Subj.	6.383	30			
Suits	.389	1	.389	.182	n.s.
Suits X Groups	.008	1	.008	.037	n.s.
Error w	5.986	28	.214		

DISCUSSION OF RESULTS

The main purpose of this study was to compare the Belgrad skin suit to a conventional racing suit in swimming speed for 25 yards. To accomplish this, a two factor mixed design with repeated measures was utilized to evaluate the effect of the two suits, and the results indicated no statistically significant difference. A difference was evident, however, in contrasting the two groups of competitors to non-competitors, the three factor analysis supported these findings and also revealed an apparent effect of the placebo. In the following sections, the discussion is centered upon possible reasons for these results.

Differences Between the Belgrad and Conventional Suit

As was stated earlier in the statistical analysis, there was found to be no significant improvement in swimming speed while wearing the Belgrad skin suit. This was found true regardless of the group or placebo conditions. Possible explanations could be given as to why the results showed no significant difference.

This study was designed to test the swimming speed of the subjects for 25 yards, perhaps a distance too short to substantially ascertain which suit was of surpassing quality. In comparing the mean values of both groups combined while wearing the Belgrad to that time while wearing the Speedo, it was found that the Belgrad had a faster mean average of 18.051 to the Speedo's 18.212. This however was considered an insignificant difference (F-ratio of .182). Perhaps with a longer distance, such as a 50 or 100 yard race, a more significant difference would have evolved. For example, if the conventional suit did indeed cause a greater resistance than the Belgrad, a longer race might have

imposed more strain on the swimmer.

In a study done by Townes and Manly[73] concerning skin friction and resistance caused by the length of the hair, there was found a significant difference in favor of shorter hair when the distance swum was set at 100 yards. However, when the distance was dropped to 50 yards, no difference was found in time before and after cutting the hair. In their study, however, only five subjects were used, with only one trial for each condition. The design of this study also did not employ the use of turns and dives, two factors which would have played a part in the outcome of the study. Ryan[74] and Campbell[75] both report that the high neckline of the Belgrad and the absence of the quarter-panel skirt have positive effects upon swimming time for a designated distance, due to the decrease in air pockets and retention of water at the dive and turn. Champion swimmer Heather Greenwell, quoted by Campbell, stated that as much as a gallon of water could be picked up during the turn, and air pockets would form in the old suit at the dive that would not go away for at least a length of the pool.[76] All this was theoretically

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[73]Ross E. Townes and Theodore Manly, "The length of Hair and the Speed in Swimming," The Physical Educator, 29:200-201, December, 1972.

[74]Joan Ryan, "The Great Swim Suit Controversy," Women's Sports, 1:41, 62, August, 1974.

[75]Jule Campbell, "Light, Tight and Right for Racing," Sports Illustrated, 41:49, August 14, 1974.

[76]Ibid., p. 46.

eliminated with the use of the Belgrad skin suit. Rothhammer international claims that a two second reduction in time for each 100 meters swum would be possible while wearing the Belgrad, especially in the turns.[77] Whether or not this two second reduction is evenly distributed over the turn, dive, and swimming portion, or is related only to the actual turning part, is not known. No dive or turn was used in the present study, however, the push off executed at the start of each race was similar to the push off normally used in turning. What is not known however, is at what point of the turn would the old suit pick up water, the push off or the actual turning. Again for this study, the inclusion of a dive and turn would have brought in added factors to be controlled that would not be deemed plausible with the use of non-competitive swimmers. As mentioned in Chapter 1, the use of non-competitive swimmers was necessary as a control group for the psychological effects that could occur while wearing the Belgrad.

Another possiblility for the lack of significant improvement in time with regards to the Belgrad could again be the lack of motivation for trials on the second day. With the long waiting periods between each sprint and the repetition of the trials, a lack of interest for the trials on the second day might have resulted. Both groups swam the first day's trials wearing the Speedo, and the second day while wearing the Belgrad. Hence, the order of administration of the trials was not counterbalanced.

Another aspect of this study which would explain the insignificant

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[77]Statement by Rothhammer International, Inc., Advertisement, Swimming World, 16:10, October, 1975.

difference between suits, could be that the Belgrad is not, in reality, a significantly superior suit, either in quality of material or design. The Belgrad is composed of 84% nylon and 16% Lycra to the Speedo's 100% nylon, while the Lycra content has been credited with a greater stretching ability and decreased water absorption.[78] Whether or not this difference was significant was not evident by the information offered, but Bunn[79] and Karpovich[80] both found that the quality of the material in a nylon swim suit was not as important as the type of suit used. A suit which is loose about the back and tight about the legs would considerably increase the resistance.[81] In regards to the design of the suit, it has been shown that the Belgrad included a high-neckline, to the Speedo's low-scooped one. This particular difference has been acknowledged by manufacturer, coach, and swimmer alike as a main factor in decreasing the amount of water or air that normally enters the front of the suit which may be entrapped, causing bulges in the suit and a decreased streamlining of the body.[82] Although streamlining of a body does decrease water resistance, the neckline effect of the suit has not been scientifically tested to measure its actual effectiveness and worth in decreasing water drag.

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[78]"The Skin Suit Revolution," Aquatic World Magazine, September, 1975, pp. 12-15.

[79]John Bunn, Scientific Principles of Coaching (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964), p. 175.

[80]Peter Karpovich, "Water Resistance in Swimming," Research Quarterly, 4:21-28, 1933.

[81]Ibid.

[82]Jule Campbell, "Light, Tight and Right for Racing," Sports Illustrated, 41:49, August 14, 1974.

The omission of a quarter-panel skirt across the front of the suit at crotch level in the Belgrad has also been credited with decreasing water resistance. Like the high neckline, this new design, different from the Speedo which has the skirt, eliminates the water and/or air that enters the suit from below and remains, again causing pockets and water resistance.[83] However, neither has this theory been substantiated relative to its effectiveness with regard to swimming speed and improved time.

Swimmers all agree that while wearing the Belgrad, they have a better 'feel' of the water, and the sensation that they are travelling faster. Perhaps this feel of the water can be likened to how a runner feels after training in heavy shoes or boots and then racing in light weight track shoes. The runner is given a false sense that he is running faster after removing the boots, than he was before wearing them.[84] Conversely, a skin diver gets two totally different sensations in power when kicking before and then after having worn swimming fins. His kicking power might seem adequately efficient before utilizing the fins, but due to the far greater force that can be exerted while wearing them, he seems almost non-moving when again kicking without them. The actual before and after kicking speeds, however, are the same.

Another theory along this line is that perhaps psychological considerations play a more important part in the success of the Belgrad than previously thought. When the East Germany women swimmers defeated the American women in 1973, wearing the Belgrad suit, most swimmers and

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[83]Ibid.

[84]Dean W. Cromwell, Championship Technique in Track and Field (New York, New York: McGraw-Hill Co., 1949), pp. 22-24.

coaches believed it was the suit that insured the victory.[85] From this point, and with the AAU dropping a regulation concerning quarter-panel skirt requirements, the swimmers started wearing the skin suit faithfully at all big meets. Some merit is placed in the thought that this superiority could be based on a psychological benefit rather than physical though, since many great coaches of our day believe the Belgrad should be used in only the big meets to prepare the swimmer mentally for an improved time drop. Swimmers too, like the feel of the suit and the confidence it gives them that improvement is inevitable while wearing the skin suit.[86]

Another factor that should be considered here though, is the recent outcome of the World Aquatics Championships held in Cali, Columbia in July, 1975. Out of 14 women's events, 10 were won by the German Democratic Republic team (GDR),[87] all of whom wore Belgrads.[88] The American women, winning four, wore the new Speedo "Racerback," comparable to the Belgrad design, and containing all of its advantages. In this instance the suits were equal yet the German women were still superior. Possibly this was the same reason for the GDR win two years earlier in their dual meet with the Americans, and did not involve the

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[85]"The Swim Suit Revolution," Aquatic World Magazine, September, 1975, pp. 12-15.

[86]Jule Campbell, "Light, Tight and Right for Racing," Sports Illustrated, 41:49, August 14, 1974.

[87]Jerry Kirshenbaum, "Polishing off their Rivals," Sports Illustrated, 43:8-11, August 4, 1975.

[88]Statement by Rothhammer, International, Inc., Advertisement, Swimming World, 16:10, October, 1975.

use of a superior suit after all.

A final consideration as to the improvement in time while wearing the Belgrad is that, like the male swimmers, improvement in ability was forth-coming with or without the skin suit. With hard training and advanced swimming technique,[89] an improvement was inevitable. Perhaps not enough credit is given to this aspect of progress, since not many swimmers would dare to wear an old styled Speedo in any important national competition.

Orange Juice Placebo

The results of the statistical analysis found in the Appendix, revealed a definite drop in speed for both groups, wearing either suit, after having taken the orange juice placebo.

The reason for this was not readily apparent. A 15 minute interim between each trial was taken by all subjects tested, and considering the short duration of the test itself, it would seem adequate resting time to sufficiently regain any loss of energy or power. Although this is especially true for the competitive group who were in peak condition at the time of testing, the non-competitive group were also capable of completing the work load easily.

However, fatigue must be considered a factor here, since a speed drop was apparent for both days of testing after having taken the orange juice placebo.

Another possible explanation for this increase in time could be due to the long waiting period between trials and the repetitious

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[89]James Counsilman, The Science of Swimming (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1968), p. 364.

nature of the testing. The subjects might have become sufficiently bored with the task after having watched the first two trials, that the motivation to excel had decreased upon the last two. This could especially be true with the competitive group's routine of sprint work as a daily function, which might have rendered the additional sprinting as a tedious task rather than an experiemental study.

Singer and his colleagues[90] in a study concerning placebos and their effects in motor learning situations, found little evidence to verify related research data demonstrating the positive effects of a placebo. On the basis of their own findings, they concluded that the beneficial psychological effects of a placebo are varied and dependent upon the situations. They suggested that negative placebo effects might be due to an upsetting experience for a number of subjects, who were not sure of possible side effects from the placebo. Orne[91] suggested that other negative placebo results could be due to such variables as subject's attitude toward the experiment or subject's responsiveness to demand characteristics of the situation. In Singer's study, however, the placebo effect was not found significant from one group to the next.

A third explanation might possibly lie in the air temperature.

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[90]R. N. Singer, Jack Llewellyn, Ellington Darden, "Placebo and Competitive Placebo Effects on Motor Skill," Research Quarterly, 44:51-57, 1973.

[91]M. T. Orne, "On the Social Psychology of the Psychological Experiment with Particular Reference to Demand Characteristics and Their Implications." American Psychologist, 17:776-83, 1962.

Although 78° is considered warm enough for the environment of indoor pools,[92] a chilling factor might have resulted in sitting along the pool deck while awaiting the next trial. Ihm found in his experiment that the use of a cold pack prior to performance on a bicycle ergometer showed no significant difference either positively or negatively.[93] Muido, on the other hand, found that on swimming performance, cold baths were detrimental,[94] as did Glidewell in his study of various warm-up procedures in relation to physical performance.[95]

Differences Between Groups

It was not surprising to find a significant superiority of the competitive group over the non-competitive group in mean time for the 25 yard sprint (F-ratio of 16.969). This was true regardless of which suit was worn and whether or not the orange juice placebo had been administered. Since the competitive group was highly trained, talented group of swimmers, they would be expected to show the superior speed.

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[92]Don Watson, Hinsdale Swimming Program (Hinsdale, Illinois, 1973), pp. 1-8.

[93]Joseph A. Ihm, "A Comparison of the Effectiveness of 3 Methods of Warming-Up," (Unpublished Doctor's Dissertation, University of Iowa, 1966), p. 23.

[94]Leonid Muido, "The Influence of Body Temperature on Performance in Swimming," Acto Physiologica Scandinavica, 12:108-109, 1947.

[95]William Foster Glidewell, "An Investigation of Various Warm-Up Procedures in Relation to Physical Performance," (Unpublished Doctor's Dissertation, University of Texas, 1964), p. 20.

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this study was to compare the effect of the Belgrad skin suit with a conventional racing suit, the speedo model, upon swimming speed in the 25 yard front crawl stroke. Testing involved 30 female subjects, fifteen each of competitive and non-competitive swimmers. The experiment involved both groups being tested twice under four conditions, for a total of eight trials: (1) a conventional suit alone; (2) a conventional suit with an orange juice placebo suggested to be a supplement energy producer; (3) a Belgrad skin suit alone; and (4) the Belgrad skin suit with the orange juice placebo. A two-factor mixed design with repeated measures on one factor was utilized in tabulating any significant results, and entered in Table I and II of Chapter 4. As well as the above analysis, a three factor analysis with repeated measures was computed to further study the interactions between suits, placebo conditions, and groups involved. Results for this analysis can be found in the appendix.

Based on the limitations and delimitations of this study, the following conclusions were made.

CONCLUSIONS

1. No significant difference resulted in the mean swimming time swum while wearing either the Belgrad (18.05) or the conventional suit (18.21). An insignificant F-ratio of .182 was found, suggesting that the advertised qualities of the Belgrad suit are not effective in

increasing speed in a short sprint involving no turns or dive. As related to the prime purpose of this study, and based on the statistical analysis, no significant difference was apparent between the Belgrad skin suit and the conventional racing suit. The hypothesis set at the beginning of this study could not be rejected at the .05 level of confidence.

2. A significant F-ratio of 12.677 was found in comparing the means of the times before and after distributing the orange juice placebo. This was true regardless of which suit was worn or the group involved, and was significant at .05 level of confidence. The times after the placebo, however, were slower than tests without the placebo.

3. A significant F-ratio of 16.969, in favor of the competitive group, was found in comparing the mean speed of the competitive group to the non-competitive group. This was found to be significant at the .05 level of confidence.

In conclusion then, and based on the statistical analysis brought forth in this study, it was found that no significant difference was apparent between the Belgrad skin suit and the conventional racing suit. The hypothesis set at the beginning of this study could then not be rejected at the .05 level of confidence.

RECOMMENDATIONS

As mentioned earlier in this study, an experiment to compare the mechanical aspects of the skin suit to the conventional racing style suit could be done in other ways to measure different aspects of the suit. Recommended studies for further research are to set up an experiment involving a longer distance with dives and turns. Also, a study

examining the psychological aspects of the suit and how it affects the swimmer who fully realizes the importance of the Belgrad. A third recommendation would be to analyze not only the Belgrad, but also all the other new skin suits, by different companies, now on the market (Speedo Racerback, Jantzen Swim Skins, Arena Skinfit, Dolfin Streaker, and the Culbenkian Skimp).

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Statistical Results using the Three Factor Analysis with Repeated Measures

A. Three factor analysis of variance was utilized to analyze the effect of the orange juice placebo, and the differences between the competitive and non-competitive groups although some of this information is incorporated in the two factor analysis. It was deemed appropriate to conduct a three-factor analysis in order to present the results of the effect of the orange juice placebo. However, this data was not of major importance to the main purpose of the study.

1. Differences Between the Belgrad and Conventional Swim Suits.

   a. The $\bar{X}$ and SD for the Speedo, regardless of the group or placebo condition was 18.213 and 3.197. For the Belgrad the $\bar{X}$ and SD was 18.052 and 2.970 respectively. No significant difference resulted in the mean time swim while wearing either of the suits. An insignificant F-ratio of 1.925 was found at the .05 level of confidence. A 4.20 F-ratio was needed for a significant difference between the two suits.

   b. While wearing the Speedo suit, and regardless of the placebo, the competitive group had an $\bar{X}$ and SD of 16.347 and 2.339. The Belgrad had an $\bar{X}$ and SD of 16.201 and 2.298. For the non-competitive group, the $\bar{X}$ and SD while wearing the Speedo was 20.078 and 2.818, and 19.893 and 2.366 while wearing the Belgrad. There was an insignificant F-ratio of .026 within the interaction of the group and the suit worn.

   c. Before having taken the placebo, regardless of the group, the $\bar{X}$ and SD while wearing the speedo was 18.165 and 3.301, and was 18.260 and 3.115 after having taken the orange juice.

While wearing the Belgrad, the $\bar{X}$ and SD was 17.897 and 2.864 before the placebo, and 18.197, 3.111 after taking it. There was an insignificant F-ratio of 1.926 between the placebo condition and the suit worn.

2. Orange Juice Placebo

   a. Before having taken the placebo, regardless of group or which suit was worn the $\bar{X}$ and SD was 18.031 and 3.068. After having taken the placebo, the $\bar{X}$ and SD was 18.228 and 3.087. This was a significant difference with an F-ratio of 6.370.

   b. The competitive group for both suits, had an $\bar{X}$ and SD of 16.204 and 2.328 before the placebo and a 16.343 and 2.309 after taking it. For the non-competitive group, the $\bar{X}$ and SD was 19.857 and 2.612 before the placebo, and 20.114 and 2.588 afterwards. There was no significance between the two conditions, with an F-ratio of .565.

   c. The $\bar{X}$ and SD before taking the placebo while wearing the Speedo was 18.165 and 3.301. After taking the placebo the $\bar{X}$ and SD was 18.260 and 3.115. In the Belgrad, the $\bar{X}$ and SD before the placebo, was 17.897 and 2.864 and 18.197 and 3.111 after the placebo. With an F-ratio of 1.926, there was no significant difference.

3. Competitive verses Non-Competitive Group

   A. Neglecting both suit worn and placebo condition, the competitive group had a $\bar{X}$ and SD of 16.279 and 2.313 to the

non-competitive's average of 19.985 and 2.567 respectively. This difference was found to be highly significant at the .05 level of confidence, with an F-ratio of 17.031.

b. For the competitive group, while wearing the Speedo, disregarding the placebo condition, the $\bar{X}$ and SD was 16.347 and 2.339, to a $\bar{X}$ and SD of 16.201 and 2.298 while in the Belgrad. For the non-competitive group the $\bar{X}$ and SD was 20.078 and 2.818 in the Speedo, and 19.893 and 2.366 while in the Belgrad. An insignificant F-ratio of .026 was found in comparing the group to the suit worn.

c. For the competitive group, neglecting suit worn, the $\bar{X}$ and SD before taking the placebo was 16.204 and 2.328. After the placebo, the $\bar{X}$ and SD was 16.343 and 2.309. For the non-competitive group the $\bar{X}$ and SD was 19.857 and 2.612 before, and 20.114, 2.588 after. A nonsignificant F-ratio of .565 was found in comparing the group to the placebo condition involved.

TABLE III

MEAN TIMES AND STANDARD DEVIATIONS FOR THE INTERACTION BETWEEN SUITS, PLACEBO, AND GROUPS

	Speedo		Belgrad		Competitive		Non-Competitive		No O.J.		O. J.	
	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
Speedo	18.21	3.20			16.35	2.34	20.08	2.82	18.17	3.30	18.26	3.12
Belgrad			18.06	2.97	16.20	2.30	19.89	2.37	17.90	2.85	18.20	3.11
Comp.	16.36	2.34	16.20	2.30	16.28	2.31			16.20	2.34	16.34	2.31
Non-Comp.	20.08	2.82	19.89	2.37			19.99	2.58	19.86	2.61	20.11	2.59
No O.J.	18.17	3.30	17.90	2.86	16.20	2.33	19.86	2.61	18.03	3.07		
O. J.	18.26	3.12	18.20	3.11	16.34	2.31	20.11	2.59			18.23	3.09

TABLE IV

SUMMARY FOR ANALYSIS OF VARIANCE FOR THREE-FACTOR DESIGN WITH REPEATED MEASURES

Source	SS	df	ms	F-ratio	
Total	1118.156	119			
Between Subjs.	1092.631	29			
Groups	413.250	1	413.250	17.031	under 0.001
Error b	679.381	28	24.264		
Within Subjs.	25.525	90			
Suits	.826	1	.826	1.925	n.s.
O.J.	1.172	1	1.172	6.370	0.002
Group X Suit	.011	1	.011	0.026	n.s.
Group X O.J.	.104	1	.104	0.565	n.s.
Suit X O.J.	.312	1	.312	1.926	n.s.
Gr. X Suit X O.J.	1.404		1.404	8.667	.01
Error 1	12.023	28	.429		
Error 2	5.150	28	.184		
Error 3	4.523	28	.162		

TABLE V

SWIMMING TIMES FOR THE 25 YARD FREESTYLE INTERACTING GROUPS, PLACEBO, AND SUITS

	SPEEDO		BELGRAD	
	Competitive	Non-Competitive	Competitive	Non-Competitive
Control	16.220 2.313	20.109 3.022	16.188 2.425	19.605 2.202
Placebo	16.472 2.437	20.047 2.706	16.312 2.249	20.180 2.561

Entries represent mean and standard deviation of time in seconds.

Date Due