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Women athletes participating on the women's varsity crew team were assessed for skeletal, skinfold, and circumference measurements to provide a descriptive analysis of the physique of female competitive rowers. The rowers were divided into the group of crew team members who successfully completed the crew season and the group of crew team members who did not complete the season. A reference group consisted of women employees of an insurance company. A single classification analysis of variance design suggested that the only significant difference found among the three groups for the skeletal measurements were the left arm length, right knee width, and right and left elbow widths. Otherwise, no significant difference among the groups for the skeletal assessments was observed. No significant difference among group means as found between groups in terms of skinfold assessments or body fat percentage. A significant difference

existed between rowers and the reference groups for right and left upper arm circumferences, arm diameter, and arm-muscle-bone diameter. The rowers did not differ significantly in any of the girth measurements. Between the first and second measurements of the successful oarswomen, a significant difference was found for age, right knee width, right and left subscapular skinfold, right and left suprailiac skinfold, and the percentage of body fat.

Physiques of Female Competitive Rowers

by

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Typed by Louise Padley for Donalyn Louise Hammer.

DEDICATION

To the loving memory of my father
and
to the living strength of my mother

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CHAPTER I

INTRODUCTION

In recent years, women's sports has experienced a voluminous growth in athletic participation and spectator interest. This increased interest provides an incentive to investigate the female athlete in a variety of areas - anatomical, physiological, psychological, and sociological. Rowing is one of the sports increasing in popularity and, due to its vigorous demands, provides a potential opportunity for the improvement of the physical condition of the woman athlete. As performance improves, there will be a basis for a comparison of changes in the female athlete.

Studies of various sports and sport participants have shown that certain physical characteristics are required for successful performance. Investigations of the physical characteristics of female rowers are extremely limited. The ability to use the physique or body type as a predictor in selecting successful performers may provide a positive feature for both the team and the individual. The purpose of this study is to provide a descriptive investigation of the physical characteristics of women crew members. This investigation will provide a basis of comparison for further studies with women rowers and other women athletes. The study may also yield a certain criteria for guiding women athletes of varying physical characteristics into an appropriate sport or provide a selection process in predicting abilities of highly competitive athletes.

PURPOSE

The intent of this research was to note a) if the women who tried out for a varsity crew team differed significantly from non-athletes or general population, b) if the physiques of rowers who successfully completed the crew season differed significantly from the rowers who did not complete the crew season, and c) if the anthropometric measurements of the successful women rowers taken in the Fall differed significantly from the same anthropometric measurements taken in the Spring.

METHODOLOGY

Three groups were involved in this study: a) a group of women athletes who participated as members of the crew team: b) a group of women athletes who did not complete the rowing season: and c) a reference group of women employees of an insurance company who had not participated in crew.

A single classification analysis of variance was utilized to test differences among the three groups. A *t*-test was used for the analysis of pre- and post-test scores of the successful rowers.

HYPOTHESES

The following null hypotheses were employed to statistically achieve the purposes of the study:

1. No significant difference in body type existed between the athlete and the non-athlete.

2. No significant relationship existed in physiques of the rowers who successfully completed the season and those who did not successfully complete the rowing season.

3. No significant difference in physical characteristics existed between the first and second assessments of the successful women rowers.

DEFINITIONS

The following terms were utilized for the purpose of a proper understanding and interpretation of information and results presented in this study.

1. Anthropometric measurements: anthropometric measurements referred to the physical measurements of the human body and its parts.

2. Ectomorph: ectomorph referred to the third component of somatotyping characterized by linearity, fragility, small bones, and thin muscles.

3. Endomorph: endomorph referred to the first component of somatotyping characterized by roundness and softness of the body, relatively short, stubby and long bones.

4. Mesomorph: mesomorph referred to the second

component of somatotyping characterized by square body, large bones, and thick muscles.

5. Physique: physique referred to the physical structure of the body.

6. Skinfold measurements: skinfold measurements referred to the double-layer of skin and subcutaneous fat grasped between the thumb and index finger at various sites of the body.

DELIMITATIONS

Criterion instruments utilized in this study were GPM anthropometer, Lange skinfold caliper, standard balance weight scales, and a linen measuring tape. The anthropometric measurements analyzed included height, weight, sitting height, biacromial and bicristal width, femoral and humeral bicondylar widths, calf and upper arm girths, arm lengths, skinfold thicknesses (triceps, biceps, subscapular, and supra-iliac), and calculated measurements. The experimental groups were confined to the women students who were seeking membership on the Oregon State University crew team during the 1978-1979 shcool year. The reference group consisted of the women employees of the claims department of the Portland office of Employees Benefit Insurance Companies (EBI Companies). The subjects of the reference group were fellow employees of this investigator. To the best of knowledge, none of the women subjects experienced child-bearing.

LIMITATIONS

The study was limited to one sport and one team. Subject selection was dependent on the willingness of the athletes and reference group to participate. The women subjects of this study consisted of competitive collegiate rowers. None of the individuals were involved in international competition. In terms of the reference group, the study was limited to women subjects from one insurance company. The anthropometric measurements were limited to the tester's ability and the accuracy of the criterion instruments.

CHAPTER II

REVIEW OF THE LITERATURE

INTRODUCTION

Studies conducted with rowing have mostly appertained to the physiological aspects of the sport (2,5,13,15,16,17, 19,20,21,24,26,40,49,52,53,58). Several of the studies included a brief description of the physiques of these athletes and the relation to the physiological characterisitics (2,5,10,15,16,20,26,48). Until recently, studies on body types of athletes had considered both sexes, but much of the literature focused on the Olympic male (9,22,33,49). Although some authors have investigated the physiques of female athletes to specific sports, the majority of the studies were conducted in the decade of the 1970's. (1,9,11, 14,22,23,32,33,35,36,38,41,43,56).

ASSESSMENT OF PHYSIQUES RELATED TO SPORTS

Malina, et al. (31) reported that each individual shows a general fitness but each is specific to the particular activity of the individual. Certain body shapes are consistent with a particular activity. The ectomorph possessed long legs and the light body was suited to long distance running. The endomorph with a stocky and short body performed well in weight lifting. The well-proportioned body with a medium height enabled a mesomorph to perform successfully in various activities, particularly team sports (31).

Medved (34) reported on the height and weight of 596 female athletes. Little difference was found between the mean body height of female athletes and the general female population. The female athletes included tennis and hockey players, skiers, alpinists, hand-ball players, basketball and volleyball players, figure skaters, swimmers, and bowlers. However, the female athlete competing in rowing and track and field were taller at the 0.10 significance level. The female table tennis players were taller at the 0.05 level. The height of the female gymnasts was less than the general population. Hirata (22) studied the height, weight, and age of 722 female Olympic athletes during the Tokyo Olympics. The average age for the best performance was between seventeen and twenty-three years compared to twenty and thirty years for the male athlete. The female Olympic champion had a similar muscular structure to the male because she would be unable to perform as efficiently if she possessed the subcutaneous fat of the general female population. Conger and MacNab (11) studied forty female participants of intercollegiate sports and forty female non-participants in comparison to strength, body composition, and work capacity of each group. Conger and MacNab measured height, weight, and skinfold thicknesses (triceps, scapula, chest, lower ribs, waist, supra-iliac, knee, umbilicus, thigh and pubic sites). The participants in swimming, volleyball, basketball, and gymnastics were taller and heavier than the non-participants, but possessed greater lean body mass. The participants scored higher in strength measurements than the non-participants. The strength variance may, in part, be due to the weight difference.

Carter (9), in somatotyping the female athlete, found that the gymnasts were the shortest, lightest, and most mesomorphic which compared to the results of Hirata (22), Falls and Humphrey (14), and Sinning (43). Carter also revealed female golfers were endomesomorphic while female swimmers were taller than average and the majority were mesomorphic. Plowman (38), in a review of studies, found, in addition to the above, that female field hockey and softball players were endomesomorphs; female skiers were ectomorphs; and women track and field athletes varied according to events.

Malina, et al. (32) reported on sixty-six female track and field athletes. Anthropometric measurements employed in the study included height, weight, skeletal assessments (shoulder, pelvis, femur, and humerus width, and arm length), calf and upper-arm girths, and skinfolds (triceps, biceps, subscapular, supra-iliac). They found the sprinters were short-legged and muscular; long distance runners were small, lean with narrow hips and shoulders; throwers were large, muscular, and tall; and jumpers and hurdlers were muscular, long-legged, and linear. In a study of 180 women volleyball players by Hasler, et al. (23), the subjects were taller (169.2 cm) and heavier (65.06 kg) than the 166.0 cm and 59.9 kg of the volleyball players assessed by Conger and MacNab. These female athletes also possessed broad shoulders and narrower hips. The measurements employed in this study were weight, height, skinfolds, (triceps, suprailiac, and thigh) bicristal and biacromial widths.

A study by Carter (9) on female basketball players from the USSR revealed that these athletes were fairly tall (68 inches) and heavy (156.6 lbs.). Carter noted a close relationship between mesomorphy and endomorphy, but few ectomorphs. Alexander (1) disagreed with the above stereotype characteristics of the female basketball player. In a study of fifty-three participants in a national championship basketball tournament, Alexander measured height, weight, biacromial and bicristal breadths, bicep and calf girths, triceps, subscapular and suprailiac skinfolds, and calculated somatotype componets (endomorphy, ectomorphy and mesomorphy). The top ten players were not significantly taller than the other players to support the idea that female basketball players were extremely tall and unusally ectomorphic. Alexander found that the top ten players were larger, more muscular, and heavier than the other players. Height was a factor in general play, rebounding, and scoring.

Eleven males and five females of the United States Nordic Ski Team were measured by Sinning, et al. (42). In comparison to the non-athletic population, both groups were very lean and equivalent to the leanest endurance athletes of both sexes. Anthropometric measurements consisted of height, weight, elbow and knee widths, arm and calf circumferences, and five skinfold thicknesses.

BODY DIMENSIONS AND PERFORMANCE OF SPORTS SKILLS

Leedy, et al. (29) found in relating performance and body composition that the performance item needed to move the whole body depended not on the amount of lean body mass, but on the percent of lean body mass. Malina (31) found the correlation of performance and skinfold thicknesses was manifested in activities which necessitated movement of the entire body. The relationship of the endomorph to performance indicated that an overabundance of fat had its detrimental effects on performance.

Since fat is inert, it limits physical performance because of the dead weight an individual must carry. Wear and Miller (57) reported that excess fat is possibly the result of lack of activity, thus, reducing muscle strength and power. Thin subjects were not the best performers, in general, due partly to factors which may lead to muscle weaknesses, such as malnutrition, metabolic disturbances, and chronic infections.

Several investigators reported a basic change of body composition through exercise. In a study with male and female members of a national gymnastics team training for the Olympic Games, Parizkova (36) reported that after intense training, the weight of the body was practically unaltered and the physical performance was enhanced along with the decrease of total body fat and subcutaneous fat. Parizkova noted in both sexes during the time of inactivity, a relative and sometimes absolute decrease of lean body mass and, at the same time, there resulted a deposition of adipose tissue. Behnke and Wilmore (4) noted that lean body weight increased as a possible result of muscle hypertrophy due to an increase in the HGH (Human-Growth-Hormone) level in the blood, which has been shown to rise during exercise. In another study, reported by Wilmore (4), results indicated a gain in weight in lean tissue only and a decrease in both absolute and relative fat. In actuality, a discriminating increase in the external subcutaneous and a decrease in internal fat was observed.

Fat is vitally needed for the structural and functional lipids of the nerves, brain, and other tissues. However, the more fat one has the lower one's metabolic rate becomes. Therefore, when the body adapts to intensive training or work, the result is the systemic metabolic changes, for there is an increase in the utilization of fatty acids in the muscle during intense muscular work. (8)

Morris (35) investigated twelve men and twelve women who were measured for the strength of muscle per square centimeter of cross section. The muscles involved the flexors and extensors of the forearms and lower legs. The unweighted average of muscle strength was slightly above 9.2 k/cm^2 for men and 7.1 k/cm^2 for women. Women possessed only seventy-eight percent of the muscle strength of men, provided there was equal leverage and muscle cross section. Men possessed 10 kilograms of $force/cm^2$ and women had 7.5 kilograms of $force/cm^2$.

In a study by Laubach and McConville (27), forty-five male subjects were measured for interrelationships between strength, flexibility, and body size. The correlation coefficient of skinfold measurements and strength measurements were found generally low and non-significant statistically. Therefore, lean body mass as measured by skinfold had no significant advantage over the use of body weight as a criterion for comparing strength of the four muscle groups: hip flexors and extensors and trunk flexors and extensors. Little correlation was found between flexibility and muscle strength and between flexibility and anthropometric measurements. The only somatotype to correlate significantly with muscle strength was the mesomorph, but the correlation was too low to use for prediction.

One hundred male subjects between the ages of eighteen and twenty years were assessed in regard to skeletal size, lean body mass, fat mass, water content, and total body mass. Royce (39) did not find the high relationship between strength and limb circumference that was reported by Tanner. Some of the best performers in the weight lifting class demonstrated poorly on the Clark cable tensiometer.

A ten-week weight training program was studied by Wilmore (56) to observe strength development in men and women. He reported that almost identical alterations in body composition were found in both men and women. Change in body weight, a definite increase in lean body weight, and a significant decrease in relative and total body fat were observed. In five of seven skinfold sites for the women, a significant decrease was noted. The decrease paralleled to the loss of total body fat. All of the skinfold sites of the men decreased, but only one site was statistically significant. The two areas exercised the most, the thigh and upper arm, did not change in subcutaneous fat thicknesses. Apparently, fat is mobilized in a general manner from various depots and not specific to the area used or exercised. Muscle hypertrophy did not always occur as a result of strength gain. Leg strength showed the greatest gain, but yet, for both men and women, the thigh circumference displayed slight decreases and skinfold sites showed no change in subcutaneous fat.

An investigation by Brown and Wilmore (6) studied the effects of weight training upon five female athletes who were champions in either javelin, shot put, or discus. An average of three days a week was spent on weight lifting for a duration of seven months. Three of the athletes increased their body weight but only two had an increase of fat weight. All subjects demonstrated greater changes in adipose tissue than in lean tissue gains, particularly two larger subjects. These two individuals reduced three to six kilograms of fat, mostly in the first three months. A slight reduction of adipose tissue was observed on the other subjects of normal values, and the two leanest had a gain of 1.8 kilograms and 2.1 kilograms of fat. The average lean body weight had an increase of less than one kilogram during the six months. On the contrary, males were observed to gain one to two kilograms in just a few weeks of training. One of the major factors for this discrepancy was the difference of hormones between males and females.

Smith and Royce (45) conducted a study of the relationship of leg strength to body weight, estimated body weight, leg volume and estimated "lean leg volume" in both females and males. The subjects consisted of thirty-two men and twenty-seven women from seventeen to twenty-nine years of age. The "lean leg volume" was assessed by water displacement while lean body weight was measured by hydrostatic weighing. No relationship was found between gross body size or lean body weight to leg strength. It was also concluded that the utilization of lean body weight, leg volume, and "lean leg volume: as a criterion to measure leg strength had no particular advantage over employing body weight.

In summary, studies on the effects of body composition and performance of both male and female athletes revealed that body weight was practically unaltered, but performance was enhanced due to the gain of lean body mass and the decrease of absolute and relative body fat. However, other investigations showed that little or no significance existed between strength and lean body mass. The decrease in fat was not specific of the particular area exercised. Fat reduction resulted in a general fashion from various depots. Increased muscle mass was not always a result of a gain in strength.

ROWING

Due to the demands of rowing, particularly the rugged pace required to row 2000 meters, the successful oarsman should possess high levels of cardiovascular fitness, endurance, and muscular strength. Hagerman, et al. (15) performed three different tests on twenty-six competitive oarsmen. These tests included static strength, rowing ergometer, and treadmill steady state run. Tests results were compared between Olympic level oarsmen and non-Olympic level oarsmen. The Olympic group's performance demonstrated greater ergometer work output, significantly lower energy costs, and greater respiratory adaptability to heavy exercise. No significant difference in strength variables was reported. A study by Ishiko (24) of Japanese candidates for the Tokyo Olympics revealed that muscular strength was more important because the fundamental concern of rowing is the employment of great force to the oars. Ishiko also discovered that aerobic capacity, motivation, anaerobic capacity, skill and coordination, and muscular endurance were also important factors in considering successful performance.

Hagerman, et al. (18) studied the metabolic responses of twelve women rowers of the 1973 United States National Team utilizing the electrostatic rowing ergometer. Heart rate, V_E, VO_2, and lactate analysis were performed. Results of the mean and range for the study included: VO_2 max, 3.38 (2.904.2) l/minute, V_E max, 130.3 (113.0-146.9) l/min; R max, (177-192) beats/min.; lactic acid max, 130.6 (114.7-153.1) mg% or 221 (194-259) cal/kg.; alactic max, 106.0 (72.5-129.2) cal/kg. Oxygen deficit was 4.4 liters. Aerobic metabolism yielded 70% of the total energy, the lactic acid system provided 20% and the alactic system contributed 10%. Therefore, Hagerman, et al. concluded that the anaerobic process, in addition to the aerobic process, was important in successful rowing performance and emphasized that training programs should employ approximately 70% aerobic and 30% anaerobic workouts.

Thirty-two male rowers were submitted to test on a bicycle ergometer for a maximum duration of six minutes (a specific duration of male rowing events). Maximum oxygen uptake, heart volume, and oxygen pulse were measured. The subjects were divided into three groups: preponderant aerobic rate; optimum aerobic rate; and deficient aerobic rate. Szogy et al. (49) found that it was possible to improve aerobic power in athletes who displayed a deficiency in this area. The work capacity tests proved beneficial in determining the degree of training for successful oarsmen. Rowing required a reasonably constant energy ratio between energy metabolic aerobic and anaerobic rates.

The determination of aerobic demands of rowing three different shells was studied by Jackson and Secher (25) on two Olympic oarsmen. Rowing speed and VO_2 were measured while rowing the single, double, and coxless pair shells. The study revealed that the required expenditure of successful international oarsmen is approximately 5.8 to 6.0 liters O_2/minute. Oxygen demands for successful oarsmen ranged from 1.2 to 6.45 liters O_2/minute. The oxygen cost of the arm and leg work during rowing was similar to the oxygen cost of work on the bicycle ergometer. Hagerman, et al. (19) tested five conditioned oarsmen and four unconditioned oarsmen for oxygen consumption and heart rate during maximum work on a rowing ergometer. All of the oarsmen were at one time of Olympic caliber. The mean VO_2 max. for the conditioned oarsmen was 5.8 liters/minute with the highest value at 6.2 liters/minute. The mean VO_2 max. value of the unconditioned rowers was 4.8 liters/minute with the highest VO_2 max. at 5.1 liters/minute. The mean maximum heart rate was slightly higher for the unconditioned oarsmen at 192 b/m to 184 b/m for the conditioned oarsmen. On an average, the unconditioned rowers maintained 82% of their former aerobic power. The investigators concluded that a continuous intensive and stable conditioning program cultivated a greater or lesser aerobic maintenance of former athletes or some performers adapted to physiological requirements of specific sports due to genetic capacity to succeed at sports.

Five high class rowers were tested under two different conditions: standing rowing in a basin; and actual rowing on a two-oared racing shell with coxswain. The parameters tested by diPrampero, et al. (13), were heart rate, oxygen uptake (VO_2), blood concentration of lactic acid, pulmonary ventilation (VE) and mechanical work performed. A linear correlation was found between the heart rate and oxygen uptake. In simulated rowing, pulmonary ventilation was a linear function of oxygen uptake. Mechanical efficiency rated lower in simulated rowing than in actual rowing conditions with low stroke frequency below twenty-five strokes/minute. A maximum performance was reached at a high frequency of thirty-five strokes/minute under both conditions (13).

Secher (40) examined the winning times of men's international rowing championships during a 79-year period between 1893-1971. A forty percent improvement in work output during this 79-year period was ascertained. The investigator also found a ten percent increase in height which resulted in maximum physical power. In addition, the review revealed a) fifteen percent better selection and training of oarsmen; b) fifteen percent improved shells with less water resistance; c) fifteen percent better rigging of shells resulting in preponderant technique at greater mechancial efficiency.

In a study by Williams (53), thirty-three oarsmen trying out for the New Zealand Colt representative teams were tested by: a) six minute rowing bout on a rowing ergometer to test heart rate, work output, and stroke rate; b) thirteen anthropometric measurements; c) back and leg strength; d) Cattell;s Sixteen Personality Factor questionaire. The exercise bout with the ergometer produced the most potent physiological predictors. The stroke rate was not a significant predictor. Whereas successful New Zealand oarsmen appeared to possess body types that differentiated them from non-oarsmen, the differences were not significant predictors. Strength demonstrated a prediction. The variables of personality were denoted to predict successful oarsmen. The conclusion of the study revealed the particular methods of evaluation, when employed as a combination of physiological, physical, and psychological variables, were important in the prediction of champion rowers. Arnot (2) discussed the methods employed by the German Democratic Republic (DDR) in the selection of competitive oarsmen. A rower was selected at the age of fifteen, with a fit and trim body physique, with height of 186 cm., and with three years' of growth left determined by x-ray for bone and plate closure. The selection entailed verification of normal lordosis, no history of serious injury, spondylosis, meningitis, or epilepsy. In addition, other anthropometric measurements, maximum oxygen uptake, heart volume, and fibre typing were observed. Arnot further suggested that knowledge of exercise physiology was necessary for an elite class of endurance athletes. The following physiology gauges were employed in the selection and training of successful rowers: a) chest x-rays; b) echocardiograms; c) pulmonary gas exchange; and d) ergometry.

Williams (52) tested 181 oarsmen who contended for the New Zealand rowing team with a battery of physiological, anthropometric, and psychological tests. The subjects were divided into three groups of ages. Anthropometric measurements included height, weight, triceps skinfold, subscapular skinfold, suprailiac skinfold, elbow and knee widths, and biceps and calf girths. Three body type components (endomorphy, mesomorphy, ectomorphy) were calculated from the above measurements. The difference of anthropometric measurements among the three groups was slight. A number of variables reflected age differences. Body weight, biceps and calf girths, and mesomorphism were greatest for the older group, least for the youngest group. Williams reported that the heavier and older oarsmen yielded more work. Compared with non-oarsmen, the three groups were taller, heavier, and mesomorphic. Despite the existence of ectomorphy in the younger group, mesomorphy dominated as a differentiator. In studying fifteen candidates for the National Lightweight Rowing team, Hagerman, et al. (20) observed that compared to the heavyweights (the group included in the majority of the studies), the lightweights were leaner and slightly shorter. In comparison to middle and long distance runners and cross country skiers, the lightweights were greater in percentage of body fat and taller. The maximum oxygen uptake was observed as an excellant indicator of aerobic capacity. Relative VO_2 max (oxygen consumption as related to body weight) was higher in the lightweights. Body mass differences demonstrated the differences in the power measurements between the heavy and light weight rowers.

Seventeen members of the Czechoslavak Olympic Games representatives for speed canoeing were assessed to determine which somatic and functional factors were characteristic of the sport. Assessments of the canoeists included: height, weight, length of segments of upper extremities, length of lower extremities, biacromial, bicristal and bitrochanteric breadths, and circumferences of upper arm and chest. The canoeing participants contrasted to non-participants, were taller, heavier, and leaner. They had longer upper extremities, greater breadth of shoulders and pelvis and circumferences of chest and upper arm, higher values of maximum strength, strength endurance, and cardiovascular efficiency. Strength was found as one of the most important characteristics to improve during training (10).

Sutorius (48) described the physique of championship male rowers. Measurements for height, weight, rowing experience, and Heath-Carter somatotyping were assessed on fifty subjects. The successful light oarsman was found to possess a ectomorphic-mesomorphic rating with a mean height of 186.3 cm. and a mean weight of 84.9 kg. A significant difference was found in age, rowing experience, and the somatotype of second and third place crews. The second place crew was more ectomorphic and less mesomorphic. The third place crew was older and more experienced.

Most studies on rowers have investigated the physiological aspects of male rowers. Literature of female rowers was extremely limited. Results of the one study of female rowers were similar to the results of studies on male rowers which reported possession of high levels of cardiovascular fitness,endurance, and strength. Some studies observed that the body types of the male rowers were differentiated from non-oarsmen. The rowers were taller, more muscular, and mesomorphic. A difference existed between the taller and heavier heavyweight oarsmen and the shorter and leaner lightweight oarsmen. The sturdy physiques slightly enhanced the efficiency of cardiovascular fitness, strength, and endurance required for a successful performance in rowing.

ASSESSMENT FOR BODY COMPOSITION

Body composition is thought of in terms of body fat, extracellular water, cell residue, and bone mineral, or in terms of "obesity-tissue" and "reference body". Chemical analysis was the most direct and accurate measurement; however, only a half dozen cadavers have been studied in this manner. The efforts were large and the data was questionable. The percentage of fat, water, protein, and ash have been estimated from studies on animals, but the comparison of data to human is unknown. As described by Behnke and Wilmore (4), the more common methods were indirect and included: body density - hydrostatic weighing, direct volume by water displacement, and helium dilution; biochemical analysis - potassium content, isotopic dilution, inert gas absorption; radiographic analysis; ultrasonics; skinfold measurements; and anthropometric measurements.

Body Density

The density of any object is determined through the relationship of weight to volume: Density = Weight/Volume or D = w/v. The body is divided into lean tissue and fat tissue, each of a different density. Rathbun and Pace, Brozek, et al. and Siri, all established basic equations, similar but differing in values, used to estimate density of fat and lean body tissue.

Rathbun and Pace (4) - %body fat = $\left(\frac{5.548}{S.\ G.} - 5.044\right) \times 100$

Brozek, et al. (4) - %body fat = $\left(\frac{density}{4.570} - 4.142\right) \times 100$

Siri (4) - %body fat = $\left(\frac{4.950}{density} - 4.500\right) \times 100$

The calculation of absolute fat is expressed by the following equations:

Absolute Fat = Body weight $\times \frac{\%FAT}{100}$

and lean body weight by the equation:

LBW = Weight - Fat Weight

The hydrostatic weighing technique embodied the Archimeadean principle. The volume of inanimate objects can be obtained by lowering the object into water of specially built pools or tanks, and measuring the volume of overflow. When an individual was weighed under water the total volume was equal to the loss of weight in water. Therefore, the volume was derived from the equation: $V = \frac{Wa-Ww}{Dw}$ or $SG = \frac{Wa}{Wa-Ww}$. To determine the percentage of fat, the more widely used formula of Rathbun and Pace, Siri, and Brozek, et al. is utilized in calculations: percentage of fat = $100(\frac{5.548}{S.\ G.} - 5.044)$.

However, underwater weighing of human subjects presented a problem with error due to residual air left in the lungs. Several techniques were used to measure this residual volume. The underwater weighing was one of the most widely used methods in assessing the percentage of body fat (4).

A body volumeter was used to assess body volume through water displacement. This differed from hydrostatic weighing in that the actual volume of water displaced was measured rather than the loss of weight in water. The residual volume (RV) should be measured to account for its influence in the final determination of body density. The equation for calculating body density was: $D = \frac{Wa}{\frac{V}{DW} - (RV + 100ml)}$

This technique of water displacement was less accurate for the same degree of discrimination. Its advantage was in assessing segmental volumes of the body (4).

The Helium Dilution technique involved a mixing of a constant and a known volume of helium to measure body volume. The volume being assessed was the volume of the difference between the chamber volume and the subject volume as shown in the equation $V = \Delta Vc - Vs$.

The Helium Dilution method had several advantages over hydrostatic weighing. These advantages were: 1) no need of RV measurements since the lungs are part of ΔV; 2) applicable to healthy or ambulatory, young or old individuals; 3) no requirement of subject's intelligence or cooperation. Validity appeared high with error of 0.5% in determination of volume.

Both the helium dilution and hydrostatic weighing methods were favorable for measuring. (4).

Biochemical Analysis

To determine fat and lean tissue of the body, several biochemical approaches may be employed. Each technique was unique, valuable, and varied in complexity and validity.

Potassium^{-40} count was a means of evaluating body composition by the natural emission of potassium^{-40} from the body. The subject was placed in a chamber and surrounded by a layer of Scintillator liquid solution. ^{40}K was proportional to total body potassium which makes ^{40}K counting a significant method to assess body composition, for lean body tissue had a rather constant content of potassium.

Inert Gas Absorption technique used inert gases, which are highly soluble in fat and were absorbed readily in body fat, to estimate the percentage of fat by the amount of absorption of the inert gases. The subject was placed in a breathing chamber until a near equilibrium was reached between the gases and the body tissues. Though this technique was fairly accurate, it was awkward and demanded strict cooperation between the examiner and subject (4).

Isotopic Dilution measured total body water in estimating lean body weight (LBW - total body water x $\frac{100}{73.2}$). Isotopic tracers were either injected venously or ingested orally until an equilibrium was attained. A sampling was then taken through blood and/or urine samples and total body water volume was calculated by either $C_1 x V_1 = C_2 x V_2$ or $V_2 = C \times V_1 / C_2$.

Most studies showed this method to be fairly accurate, though there are quite large differences due to the varying degrees of hydration in individuals.

The ^{40}K technique has been shown to be the most accurate measure (4).

Radiographic Analysis

Radiographic analysis assessed body composition by utilizing soft tissue X-ray to differentiate between bone, fat and muscle. This technique of measurement has been greatly improved since its start in the 1920's. A most notable facet of radiographic analysis of body composition was the endeavor to provide a tangible and a direct linkage between a highly reliable radiographic measurement and individual percentage values for body fat.

A problem of this technique of radiography was the conversion of the measured width to the individual estimation of body fat. Therefore, this analysis of data was restricted to statistical vagueness, logarithmic manipulation and with dubious results and leads to a roundabout estimation of body density. To counteract this failure, an implementation Matieka formulated in 1921, a principle with reference to skinfolds, especially the weights of body fat, can be computed as a product of surface area and skinfold thickness. Applied to radiogrammetry W(Fat) = Fat width x Surface area x K and % Fat = W(Fat)/Wt x 100. A close approximate of surface area was 3F (or) D x h x K or % Fat - $\frac{\text{Fat Widths}}{\text{3F or DxK}}$ (Radiogrammetric). (4)

Ultrasonography

The technique of ultrasonography can also assess the proportion of adipose tissue. The ultrasonic device is used frequently in diagnostic work. Ultrasound involves sound waves at a frequency of 20 kilocycles/second, which is beyond the range of human hearing, to differentiate various types of tissue. The ultrasonic scope houses two crystals. One crystal converts an electrical impulse into mechanical vibrations which are emitted at a very high frequency as an alternating voltage is applied. This energy is centered into a narrow beam which is then conveyed and reflected in a similar manner to that of a beam of light. As it travels through a medium, the vibrations are reflected in varying degrees by the far border and by the discontinuance of the medium in the path of the beam. This energy is either deflected or absorbed to produce heat. As the energy is reflected with a change of density, it is reconverted to an electrical impluse and transmitted to a cathode ray oscilloscope. The scope receives echoes which are porportional to the time the energy takes to be deflected back to the scope. The deflected distance of the trace is measured to the distance of the reflecting surface from the scope.

For purposes of adipose tissue assessment, the pulsed energy is transmitted to the skin for just a brief period of time. Whittinghar's (51) subjects reported no pain or discomfort nor any heating effect from the scope. Those who use ultrasonics in diagnostic work agree that this procedure was convenient, comfortable, and harmless. Whittingham also reported that measurements of subcutaneous fat produced more reliable results for a small population than do the skinfold calipers. However, he pointed out that there was no guarantee that ultrasonography is the most precise estimation of fat. Sloan (45) reported that the use of the ultrasound equipment produced no greater accuracy in estimating fat than did the skinfold caliper which is less expensive, less complex and less awkward.

Stouffer (47) found that ultrasound in the estimation of fat, was feasible and practical. Though it measured the same sites as the skinfold technique, ultrasonography could be of value in predicting fatness and alteration in body composition. Researchers (45,47,51) were in agreement as to the further use of ultrasonics in determining fat due to the vast improvements and novelty of this system. However, the use of ultrasonics in measuring adipose tissue will depend on correlation of results from other methods for assessing fat free body weight.

Skinfolds

The above methods, while relatively accurate and reliable, varying in degrees, are quite awkward and time consuming, non-portable, expensive and complex. They were directed toward smaller populations and laboratory uses. Most researchers used the indirect approach of skinfold measurements to assess body compositon.

It was possible to grasp loose tissue between the thumb and index finger at various sites of the body. This is called skinfold and involves a double layer of skin plus subcutaneous fat. The thickness represents the amount of fat and is measured in milimeters with a skinfold caliper. Several calipers are used in measuring skinfolds. The early models of skinfold calipers were scissor-like, requiring manual or spring pressure on the jaws of the calipers. The exerted pressure was not standardized, resulting in variable results and making it difficult to reproduce data. Therefore, the C-shaped caliper was developed. The pressure exerted by the jaws of this instrument could be maintained at ten grams per square millimeter. Modification of this instrument produced two types of calipers: the Lange and the Harpendon. The Lange calipers were cheaper, lighter, and easier to handle while the Harpendon calipers are more accurate for making readings. Both calipers exert ten grams per square millimeter, but require calibration prior to use and at frequent periods.

The arbitrary index of body fat may be based on the sum of a number of skinfold measurements or a regression equation may be derived to calculate body density (and body fat) from skinfold measurements which have the highest correlation with density.

Typical sites for assessing skinfold measurements were: cheek, chin, scapula, triceps, chest, waist, suprailiac, abdominal or juxta-umbilicus, thigh, knee, and calf.

Sloan (45) used six skinfold sites to measure the percentage of fat and found that a fairly accurate estimate may be made with two sites. One of the most frequently used techniques is Behnke's (3) technique of measuring lean body weight by the use of skinfolds, body circumferences and diameters. Correlated to hydrostatic weighing, skinfolds have been fairly accurate ($r = 0.74$ to $r = 0.87$)

and both body circumferences and diameters correlation range from r = 0.71 to r = 0.92. Consolazio (12) had a conservative feeling toward skinfold measurements and the reproducibility due to 1) the extreme differences of the same individual as measured by two different trained examiners; and 2) the difference of skin turgor caused by hydration.

Whittingham (51) reported skinfold measurements are good for a large number of subjects because the errors that do occur in reading were "made less important in the broad pattern of the survey."

Anthropometric Measurements

Behnke (3) described in depth his technique for quantitative evaluation of body composition, i.e. assessment of adipose tissue and lean tissue, in relation to skeltal size using anthropometric diameter. Eleven circumferences and eight diameters provided quantitative assessment of body build. The sites for diameters included: biacromial diameter, chest width, bi-iliac diameter, bitrochanteric diameter, wrists, ankles, knees, and elbows. The circumference measurements consisted of: shoulders, chest, abdomen-maximum, abdomen-waist, abdomen-umbilicus, buttocks, thighs, biceps (flexed), forearm and calf (at maximum circumference), ankle, wrist, and knee.

Lean Body Weight was calculated by these and skeletal measurements. The two equations are: 1) $LBW = D^2 \times ht$; and

2) LBW = D^2 x ht, dm^7 x 0.263.

The use of skinfold thicknesses and anthropometric assessment, though an indirect method to assess body composition have fairly accurate correlations of $r = 0.74$ to $r = 0.87$ for skinfold thicknesses and $r = 0.71$ to $r = 0.92$ for anthropometric measurements (54,55).

To obtain a closer estimate of LBW, Wilmore and Behnke (54,55) suggested the importance to employ k values specific to the group being tested. Body density and LBW were predicted by five anthropometric measurements with a multiple $R = 0.867$ and $R = 0.958$ respectively for men. For women the multiple $R = 0.76$ and $R = 0.93$ respectively. The results of the two studies recommended that the accuracy of the prediction equation was limited to the similarity of the original and independent populations.

Sloan (44,45) predicted body density by correlation of two skinfolds. The skinfold sites for men were the thigh and scapula ($r = 0.845$). The formula for prediction of body density is: $X_1 = 1.1043 - 0.001327x_2 - 0.001310x_3$ with x_1 = body density; x_2 = thigh skinfold; x_3 = scapula skinfold (44). The prediction equation ($r = 0.74$) for women was:

$$x_1 = 1.0764 - 0.00081x_2 - 0.00088x_3$$

with x_1 = body density; x_2 = suprailiac skinfold and, x_3 = triceps skinfold (43).

Jackson, et al. (25) employed three testers independently to assess anthropometric and skinfold measurements on three different days. The ability differed from extensive experience to minimal. The results showed the testers' variation was only a slight significant source of error. Therefore, the use of anthropometric measurements was upheld for field measures of body composition.

Investigations of body compositions utilized a variety of indirect methods which include: body density-hydrostatic weighing, water displacement, and helium dilution; biochemical analysis-potassium content, isotopic dilution and inert gas absorption; radiographic analysis; ultrasonography; skinfold measurements; and anthropometric measurements. Each technique was found unique, relatively accurate and reliable, and varied in complexity and expense. Skinfold measurements and anthropometric measurements were considered the least expensive, least time consuming, least complex, and most portable. The two measurements were reported to have reasonable reliability and validity when compared to hydrostatic weighing.

CHAPTER III

METHODS AND PROCEDURES

The purpose of this research was to observe a) if the women trying out for the varsity crew team differed significantly in physical characteristics from non-athletes or general population; and b) if the physique of rowers selected for the varsity crew team differed significantly from the rowers who were not selected. The research, statistical analysis, and interpretation of date were undertaken at Oregon State University. The testing of non-athletes was conducted at a Portland insurance company.

Subjects

Approval for the use of human subjects for the intent of this research was granted by the Oregon State University Committee for the Protection of Human Subjects. (Appendix A)

The subjects consisted of twenty-six female students trying out for the women's crew team at Oregon State University during Fall term of 1978 and Spring term of 1979. The coaches were contacted during fall term of 1978 and they agreed to permit assessment of those individuals who were willing to participate in the study. The team members were presented with a written description of the study and its requisites. The subjects were scheduled for a convenient time within a designated two day administration of assessment. Written consent was acquired from those volunteering as subjects per the "Willingness to Participate" form. (Appendix B)

The non-athlete group consisted of eighteen female employees of a Portland insurance company. The claims manager of the company was contacted during fall term of 1978 and agreed to permit company time to assess those women who were willing to partake in the study. A list of women employees in the same age range as the crew members was provided. The employees were selected due to the easy access and the least amount of cost. These employees were personally contacted in late February. After a brief explanation of the study and its requisites, those willing to participate were scheduled for a convenient time to be measured. Prior to the actual acquisition of measurements, written consent was acquired through the "Willingness to Participate" form.

Criterion Instruments

The criterion instruments used in this study included the GPM anthropometer, Lange skinfold caliper, linen measuring tape, standard weight scales, and calculated measurements.

The GPM anthropometer (Figure 1), produced in Switzerland, was made of a metal that will not warp when exposed to hot or cold temperatures. The anthropometer was divided into three parts. Assembly required careful attention in order to match each part properly. This procedure was to ensure accurate calibration of the instrument. The units of measurements consisted of centimeters and millimeters. The anthropometer was employed to measure the following measurements described by Tanner (50), Malina, et al. (32), and Bielz (5):

1. Height was measured with subject standing in an erect position. Height was recorded to the nearest .1 cm. (Figure 2)

2. Sitting Height was measured with the subject's back erect while sitting on a table with knees dangling. The subject was then measured from the tip of the head to the table. Sitting height was recorded to the nearest .1 cm. (Figure 3)

3. Biacromial diameter was taken from the front and measured the width of the outermost projection of the acromion, with the subject in the Fundamental Standing position. (Figure 4)

4. Bicristal diameter was measured from the front the distance between the outermost projections of the iliac crest. The subject was told to raise the arms at the sides while the anthropometer was placed, then lowered the arms during the process of measuring. The blades of the anthropometer were placed at a 45^{o} angle to the iliac crest. (Figure 5)

5. Bicondylar breadth of the femur was taken with the knee bent at right angles and the width between the lateral projections of the femoral condyles was measured. Measurements included right and left femurs. (Figure 6)

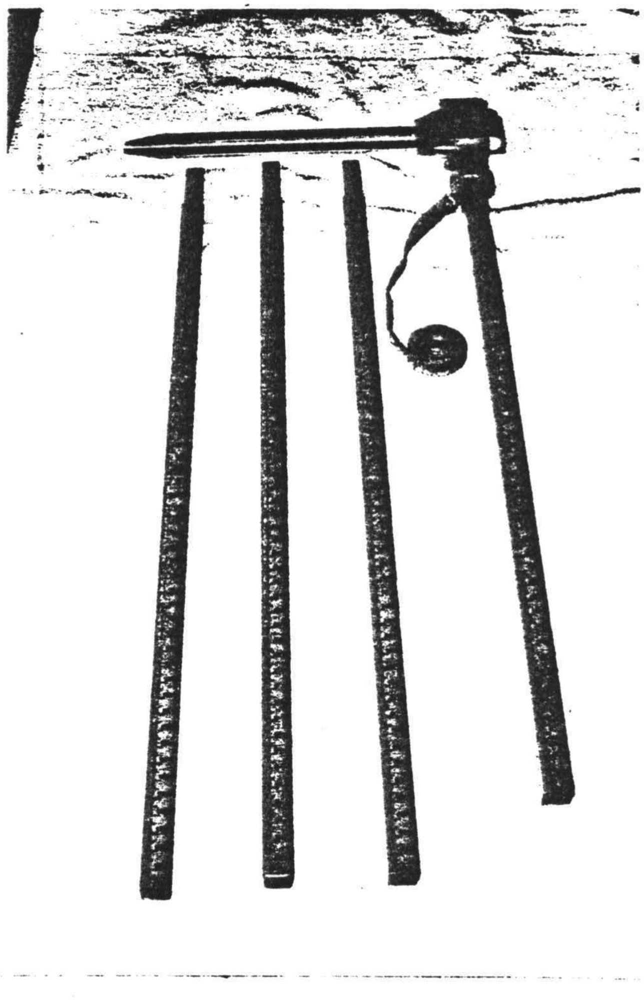

Figure 1: GPM Anthropometer

Figure 2: Height

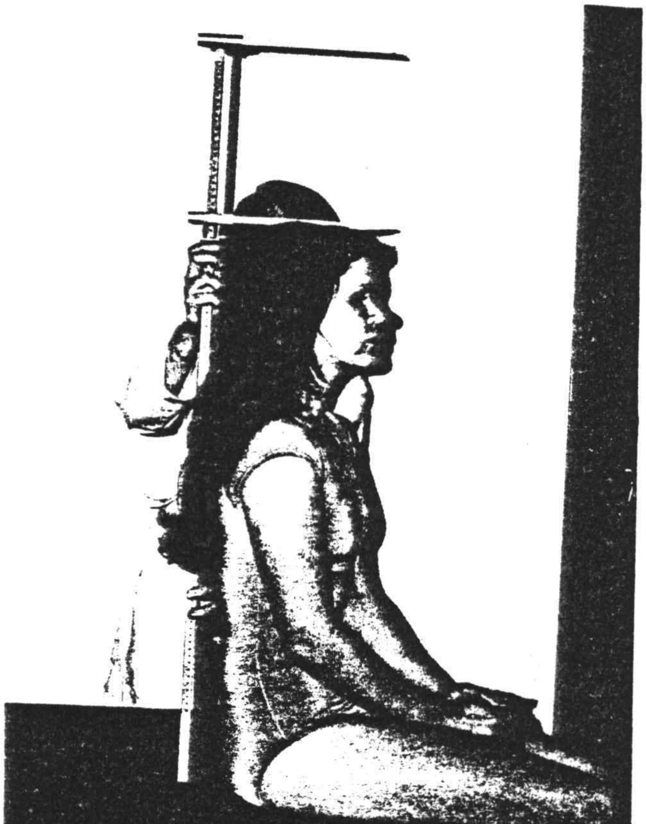

Figure 3: Sitting height

Figure 4: Biacromial diameter

Figure 5: Bicristal diameter

Figure 6: Bicondylar breadth of femur

6. Bicondylar breadth of the humerus was taken with the elbow bent at right angles and palms toward the head. The width between the outermost projections of the distal portion of the humerus was measured. The right and left elbows were assessed. (Figure 7)

The Lange skinfold calipers (Figure 8) were utilized to measure four skinfold measurements. The caliper exerted ten grams per square millimeter of pressure. Measurement unit was in millimeters. The Lange Caliper used in this study was produced by Cambridge Scientific Instruments. The sites for skinfold assessments were the following:

1. Triceps skinfold was pinched between the thumb and forefinger halfway between the acromion and the head of the radius (1 cm. superior to arm circumference) directly in line with the olecranon process. This measurement was read to the nearest 0.1 mm. Skinfold thicknesses were measured on the right and left portions of the body. (Figure 9)

2. Subscapular skinfold was measured just under the angle of the left scapula. The fold should be vertical or pointing slightly downwards and outwards. The subscapular skinfold was measured on the right and left portion of the body. (Figure 10)

3. Suprailiac skinfold was taken just superior and medial to the anterior superior iliac spine. The suprailiac skinfold was assessed on the right and left portion of the body. (Figure 11)

4. Biceps skinfold was measured over the biceps or anterior part of the relaxed arm at the same level as the triceps skinfold. The biceps skinfold was taken on the right and left portion of the body. (Figure 12)

Other measurements included the use of a linen measuring tape which was calibrated against the anthropometer for accuracy. The assessments measured by the linen measuring

Figure 7: Bicondylar breadth of humerus

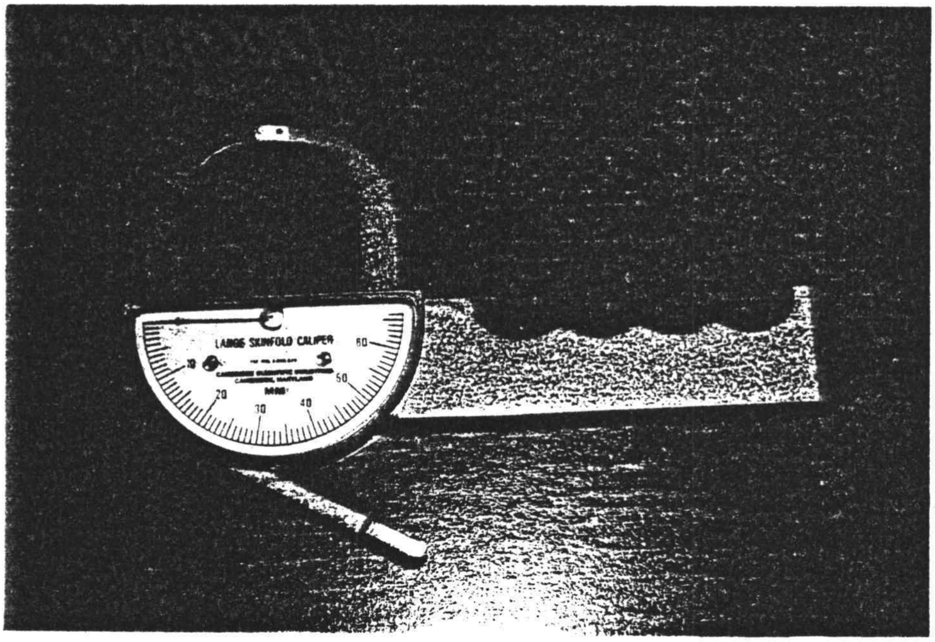

Figure 8: Lange skinfold caliper

Figure 9: Triceps skinfold

Figure 10: Subscapular skinfold

Figure 11: Suprailiac skinfold

Figure 12: Biceps skinfold

tape included the following:

1. Arm length was measured with a linen tape from the tip of the acromion process to the tip of the third digit. The right and left arms were taken for arm length assessments. (Figure 13)

2. Upper arm circumference was assessed with a linen measuring tape at a midway point between the acromion and the head of the radius. The subjects maintained the Fundamental Standing position. The right and left upper arms were used for the assessment of circumferences. (Figure 14)

3. Calf circumference was measured by a linen measuring tape at the maximum circumference of the calf. Right and left legs were measured. (Figure 15)

The standard balance scale was used for the weight assessments.

Calculated measurements were derived from the above procedures. These included leg-length (stature minus sitting height) and the ratio of sitting height/height. Total arm diameter and muscle-bone diameter were calculated by the use of the upper arm circumference. The arm diameter was achieved by the following formula:

$$\text{Arm Diameter} = \frac{\text{upper arm circumference}}{\pi}$$

From the arm diameter, the arm-muscle-bone diameter was derived by the following method:

$$\text{Arm-Muscle-Bone diameter} = \frac{\text{upper arm circumference}}{\pi} \text{ less triceps skinfold}$$

Body density was calculated by utilizing the regression equation of Sloan, et al. (44) which predicted body density from triceps and suprailiac skinfold measurements.

Figure 13: Arm length

Figure 14: Upper arm circumference

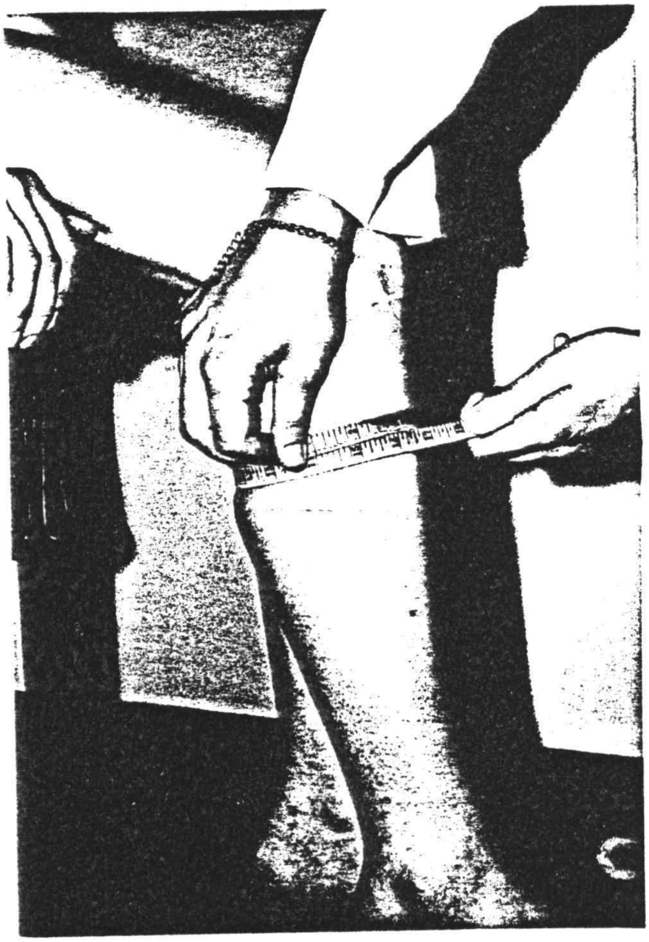

Figure 15: Calf circumference

$$D = 1.0764 - 0.00081x_1 - 0.00088x_2 \text{ in which}$$

D = density
x_1 = suprailiac skinfold (mm)
x_2 = triceps skinfold (mm)

The percentage of body fat was derived from the density values using the formula of Brozek, et al (7) as follows:

$$FAT = \frac{4.570}{\text{Density}} - 4.142$$

The values of the right portion of the body were used in the above equation.

Testing Procedure

Prior to the actual testing, the investigator practiced measuring repetitively on a number of individuals not associated with this study. This was done to insure proper assessments on the subjects and to establish administrative procedures and reliability.

The subjects, attired in apparel of snug fit such as a swimsuit or dance skins, were measured by the methods described by Tanner (50), Malina, et al. (32), and Bielz (5).

Two weeks prior to testing the female rowers, a brief description of the study (Appendix C) and a time schedule (Appendix D) were distributed to the athletes. The purpose of the time schedule was to allow the athlete to register for a convenient time for measuring. The time allotted for each subject was fifteen minutes with a fifteen minute break every four subjects. For the convenience of the subjects' academic schedule, testing was performed over a two-day period.

The testing site was the former training room for the Department of Women's Athletics, located in the Women's Building at Oregon State University. This room contained the necessary equipment except for the standard balance scale which was located in the nearby women's locker room.

The order of assessment followed the sequence of measurements on the data recording card (Appendix E). Age, weight, height and sitting height were obtained first, followed by skeletal assessments, skinfold measurements, girth measurements and arm length assessments. Age and length assessment were not originally part of the designed series of measurements, which resulted in omission from the data recording card. The values were recorded on the data recording card after each site was assessed.

Throughout the fifteen minutes of measurements, each subject's questions regarding the investigation were discussed. Most of the subjects expressed a desire to receive results from this investigation. At the end of each series of measurements, the subject was thanked for her cooperation.

Measurement procedures employed for the athletes were the same procedures employed for the reference group. The testing site for the reference group was located in the Assistant Claims Manager's office in the Persona Building of EBI Companies. A standard balance scale was placed in the office to complete the necessary equipment.

Time Schedule

The first test of the rowers was performed during the Fall term of 1978. This testing was administered during two days of the sixth week of the twelve-week term. The reference group was measured the eighth and ninth week of the eleven-week term. The second assessment of the rowers was during two days of the first week of the eleven-week Spring term of 1979.

Experimental Design

A single classification, Groups by Trial, analysis of variance was used to test the hypotheses that no difference existed among mean value (Figures 16 and 17). Groups included in this study were the following: a) an experimental group of women crew members who successfully completed the crew season; b) an experimental group of women crew members who did not finish the crew season; and c) a reference group of non-athletic women who worked for EBI Companies.

The athletic women were measured in the Fall. Members of the team were re-measured in the Spring with the same procedures to see if the measurements had changed. The reference group was measured in the Spring.

The null hypothesis was employed to ascertain the

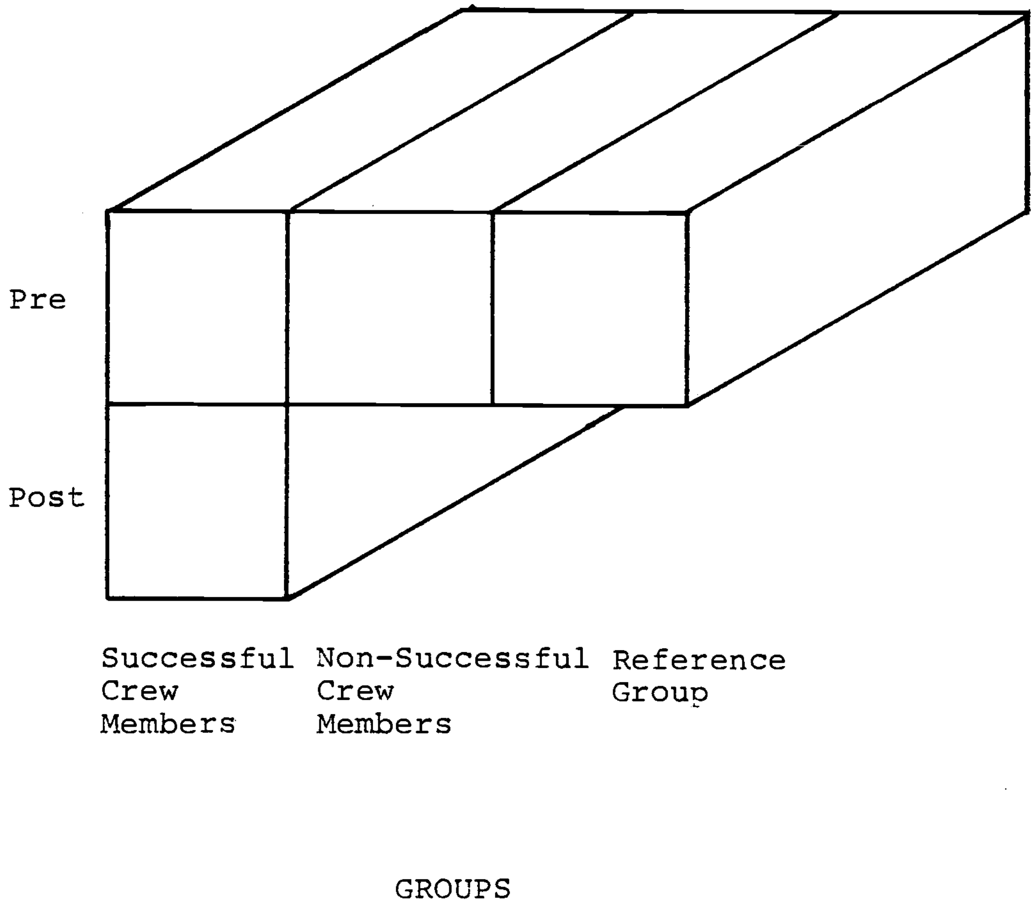

Figure 16: Experimental model

Source	df	MS	F Ratio
Between Groups	2		
Within Groups	41		
Total	43		

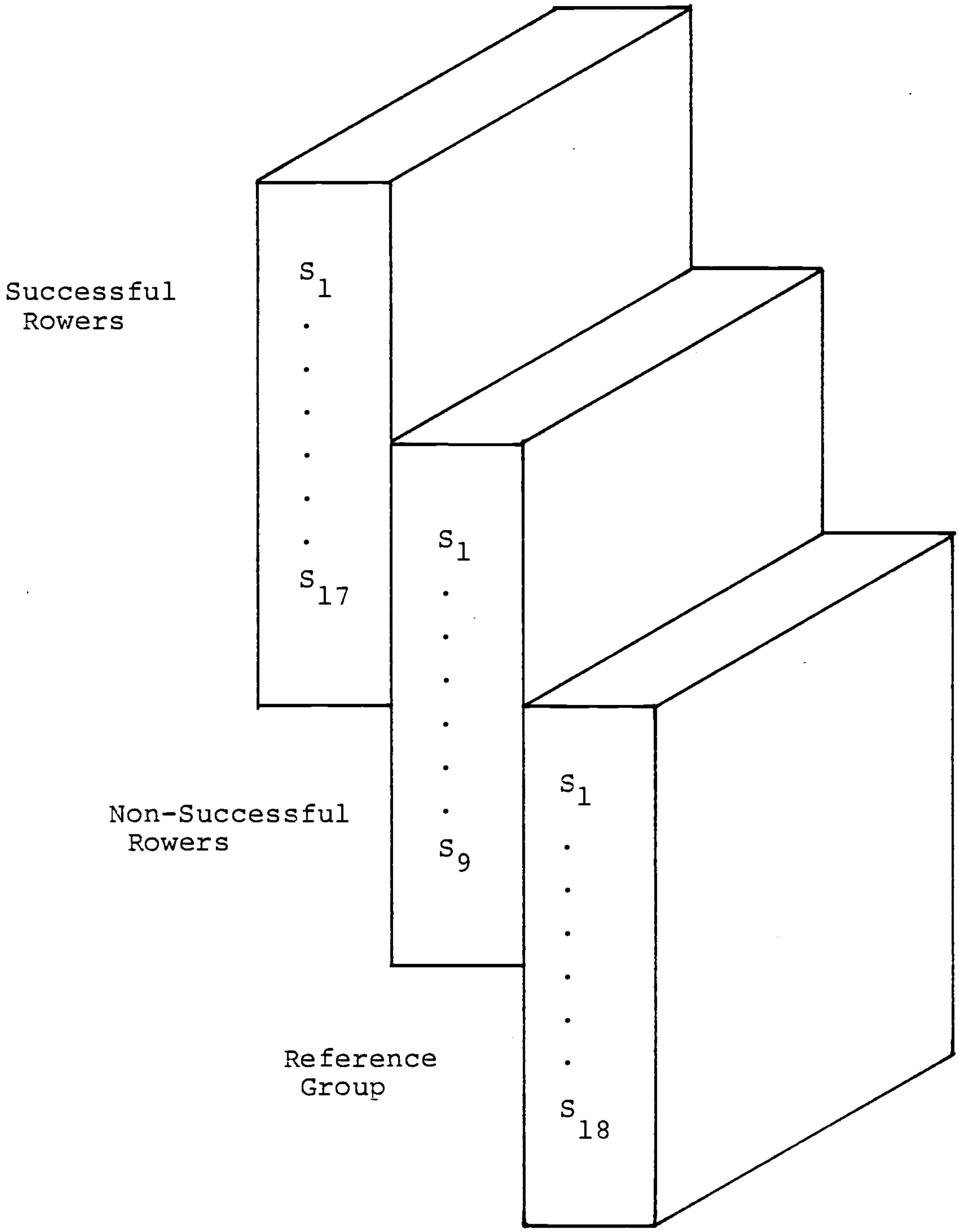

Figure 17: Single classification model

statistical significance of the hypothesis denoted in Chapter I. The hypothesis were rejected at the .05 significance level and assessed by a two-tailed test.

The statistical method utilized to test the significance of difference among the three groups was the single classification analysis of variance. A t-test was utilized to evaluate the pre- and post-test scores of the successful women rowers.

Analysis of Data

The data recording cards were reviewed after each day of test administration. The necessary calculations were completed and written on the data recording card. When all data for a particular group was collected, the data was transferred to a computer card.

The measurement values of the three groups were analyzed by ANOVA. This analysis was to denote any significant difference among the three groups.

A t-test was employed to analyze the pre- and post-test scores of the rowers.

All data was tabulated at the Oregon State University Computer Center through the CDC 3300.

CHAPTER IV

RESULTS AND DISCUSSION

The objective of this study was to observe and describe body type measurements of competitive female rowers. The analysis of data was based on the single classification analysis of variance. The data analysis and interpretation of the data results are discussed in this chapter.

RESULTS

Group Mean Measurements

The significance of difference of group means for body type assessments were processed statistically within the single classification analysis of variance design of this study. Results of each ANOVA contrast of group means are denoted in tables featured in the following pages. The *F* value required for significance at the .05 level is F = 3.18. The *F* values, mean squares, and degrees of freedom of each variable are presented in Tables IA to XXIXA. The group means, standard deviations, and ranges of each variable are depicted in Tables IB to XXIXB. The *t* values for contrast of variance of each variable are presented in Tables IC to XXIXC. The required *t* value for significance at .05 level is *t* = 2.02. Graphic illustrations of the mean values and ranges of each variable are represented in Figures 18 to 35.

The following graphs and tables are classified in groups of measurements - skeletal (plus age), girth, and skinfolds.

Skeletal Measurements:

Comparison of the mean score among the groups indicated a significant difference in age, right femoral bicondylar breadth, right and left elbow width, and left arm length. (Tables IA,C - XIVA,C)

The *F* value was significant between group mean ages (*F* = 4.44) The contrast variance of age was significant between the athletes and the reference group (*t* = 2.42).

The right knee width was not significant between groups (*F* = 2.18), but was significant between the successful versus non-successful group with a *t* value of 2.08. Similarly, the *F* value of the left elbow width was not significant, but the *t* value was significant between the athletes and the non-athletes (*t* = 2.42). A significant difference existed between groups for the right humeral bicondylar breadth and left arm length (*F* = 4.18 and *F* = 3.36 respectively). The same two variables were also significant (*t* = .01 and *t* = .02 respectively) when group means were contrasted between the athletes and the non-

TABLE I ANALYSIS OF AGE

A. Analysis of Variance

	SOURCE	DF	MEAN SQUARES	*F* RATIO
1.	Between Groups	2	15.33	4.44*
2.	Within Groups	41	3.45	
3.	Total	43		

* *F* = 3.18 with: 2 and 43 df required for significance at .05 level

B. Mean, SD and Range

	GROUP	MEAN	SD	RANGE
1.	Successful Rowers	19.29	1.45	18.0 - 23.0
2.	Non-Successful Rowers	20.22	1.86	18.0 - 23.0
3.	Reference Group	21.17	2.18	18.0 - 24.0

C. Contrast Variance

	GROUPS	*t* VALUE	DF	*t* PROBABILITY
1.	Rowers vs Reference	2.42	41.0	.02*
2.	Successful vs Non-Successful	1.21	41.0	.23

* *t* = 2.02 with: 41 df required for significance at .05 level

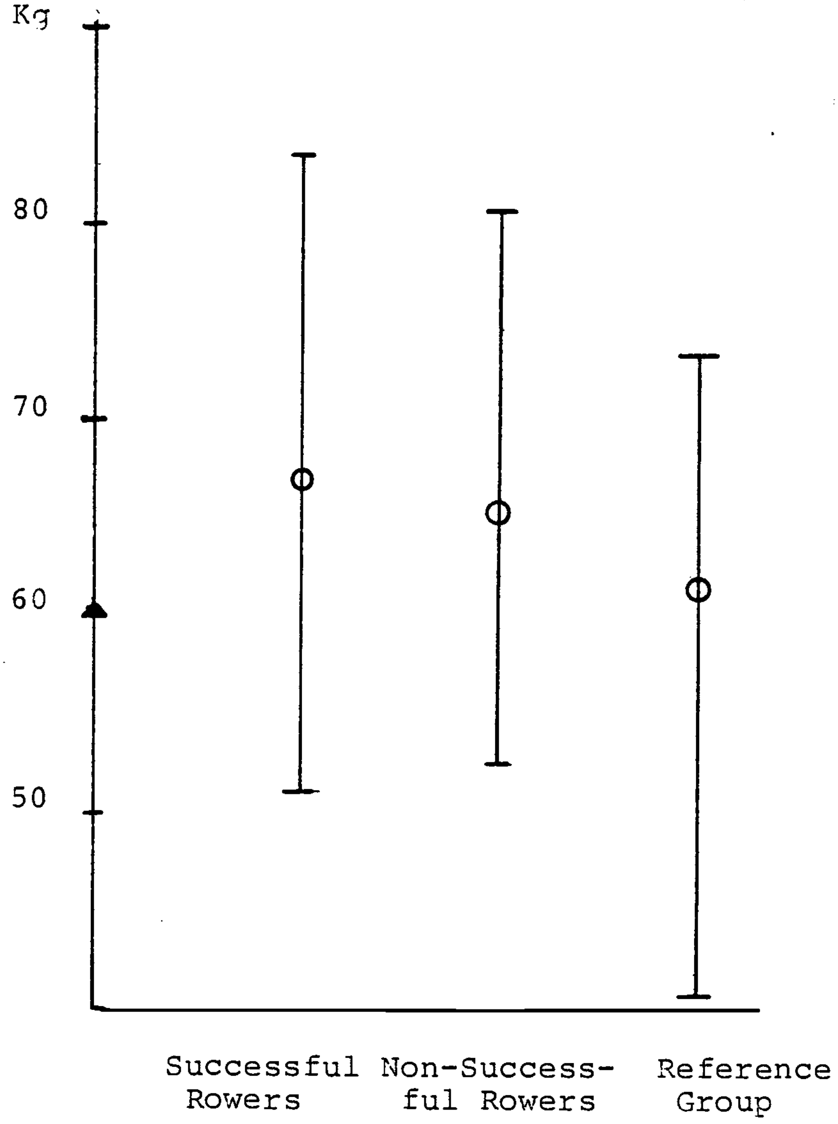

Figure 18: Mean scores and ranges of weight

TABLE II ANALYSIS OF WEIGHT

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	$\underline{F}$ RATIO
1. Between Groups	2	133.86	1.99
2. Within Groups	41	67.02	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	66.62	8.01	50.9 - 83.3
2. Non-Successful Rowers	64.94	8.98	52.7 - 80.4
3. Reference Group	61.18	7.96	40.5 - 73.4

C. Contrast Variance

GROUPS	$\underline{t}$ VALUE	DF	$\underline{t}$ PROBABILITY
1. Rowers vs Reference	1.79	41.0	.08
2. Successful vs Non-Successful	.498	41.0	.62

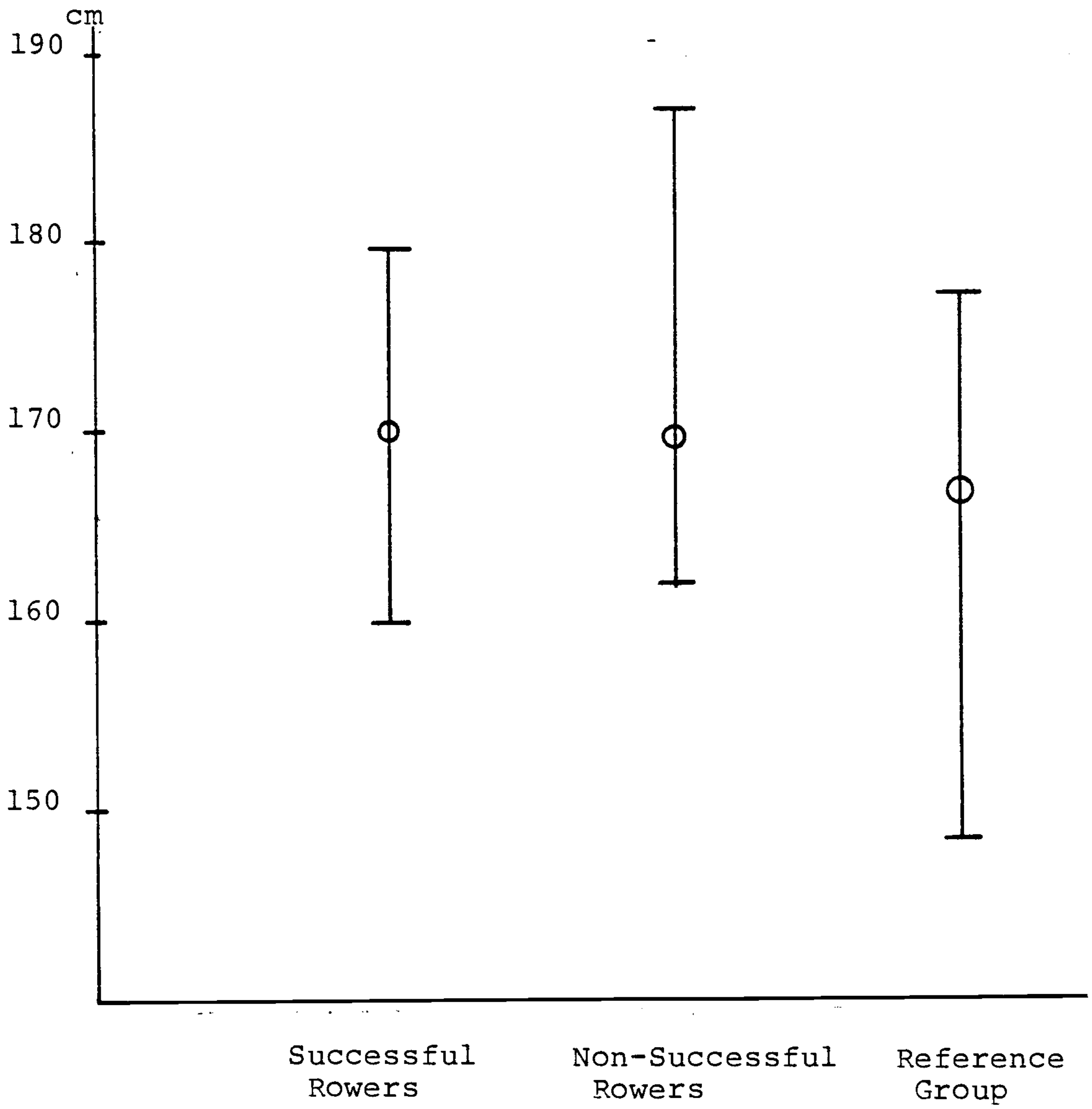

Figure 19: Mean scores and ranges of height

TABLE III ANALYSIS OF HEIGHT

A. Analysis of Variance

	SOURCE	DF	MEAN SQUARES	F RATIO
1.	Between Groups	2	61.62	1.48
2.	Within Groups	41	41.65	
3.	Total	43		

B. Mean, SD and Range

	GROUP	MEAN	SD	RANGE
1.	Successful Rowers	169.64	5.97	159.8 - 179.4
2.	Non-Successful Rowers	169.28	7.45	161.7 - 186.5
3.	Reference Group	166.12	6.39	148.3 - 176.8

C. Contrast Variance

	GROUPS	t VALUE	DF	t PROBABILITY
1.	Rowers vs Reference	1.65	41.0	.11
2.	Successful vs Non-Successful	.14	41.0	.89

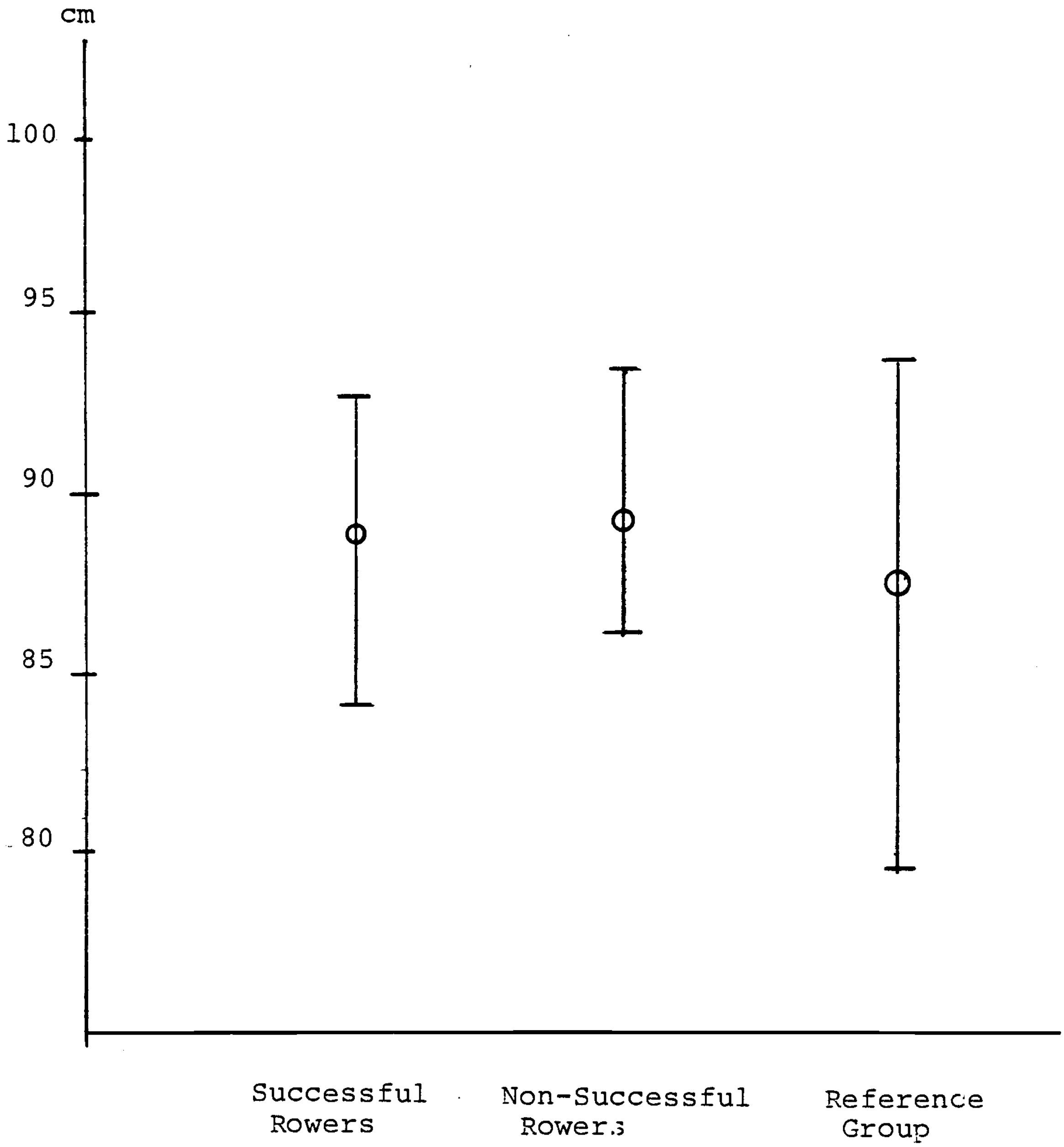

Figure 20: Mean scores and ranges of sitting height

TABLE IV ANALYSIS OF SITTING HEIGHT

A. Analysis of Variance

	SOURCE	DF	MEAN SQUARES	*F* RATIO
1.	Between Groups	2	13.49	1.33
2.	Within Groups	41	10.11	
3.	Total	43		

B. Mean, SD and Range

	GROUP	MEAN	SD	RANGE
1.	Successful Rowers	88.98	2.93	84.0 - 92.7
2.	Non-Successful Rowers	89.01	2.82	86.0 - 93.2
3.	Reference Group	87.40	3.55	79.3 - 93.5

C. Contrast Variance

	GROUPS	*t* VALUE	DF	*t* PROBABILITY
1.	Rowers vs Reference	1.60	41.0	.12
2.	Successful vs Non-Successful	.02	41.0	.98

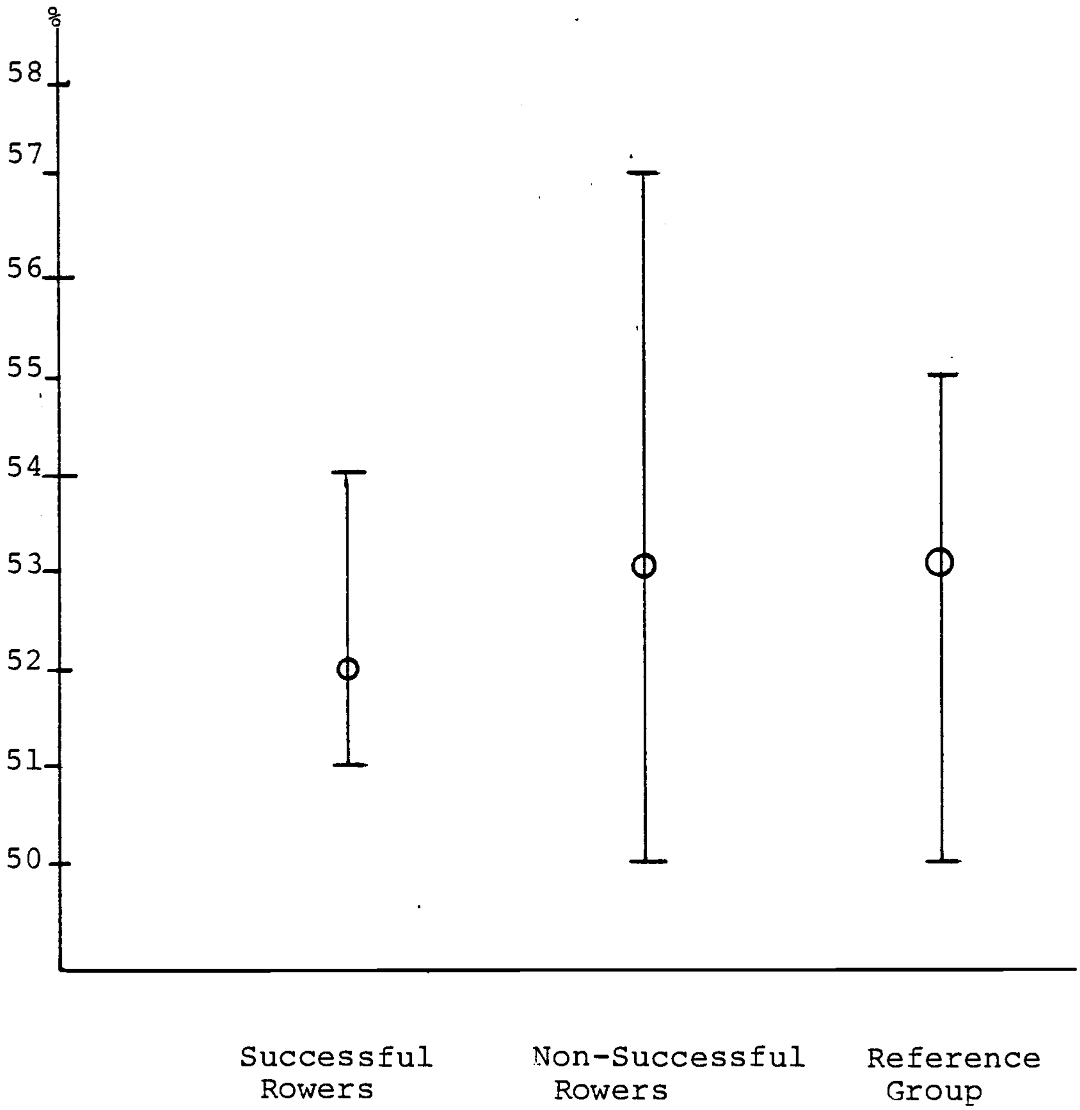

Figure 21: Mean scores and ranges of sitting height/height ratio

TABLE V ANALYSIS OF SITTING HEIGHT/HEIGHT

A. Analysis of Variance

	SOURCE	DF	MEAN SQUARES	F RATIO
1.	Between Groups	2	.00002	0.11
2.	Within Groups	41	.0001	
3.	Total	43		

B. Mean, SD and Range

	GROUP	MEAN	SD	RANGE
1.	Successful Rowers	.52	.01	.51 - .54
2.	Non-Successful Rowers	.53	.02	.50 - .57
3.	Reference Group	.53	.01	.50 - .55

C. Contrast Variance

	GROUPS	t VALUE	DF	t PROBABILITY
1.	Rowers vs Reference	.22	41.0	.83
2.	Successful vs Non-Successful	.35	41.0	.72

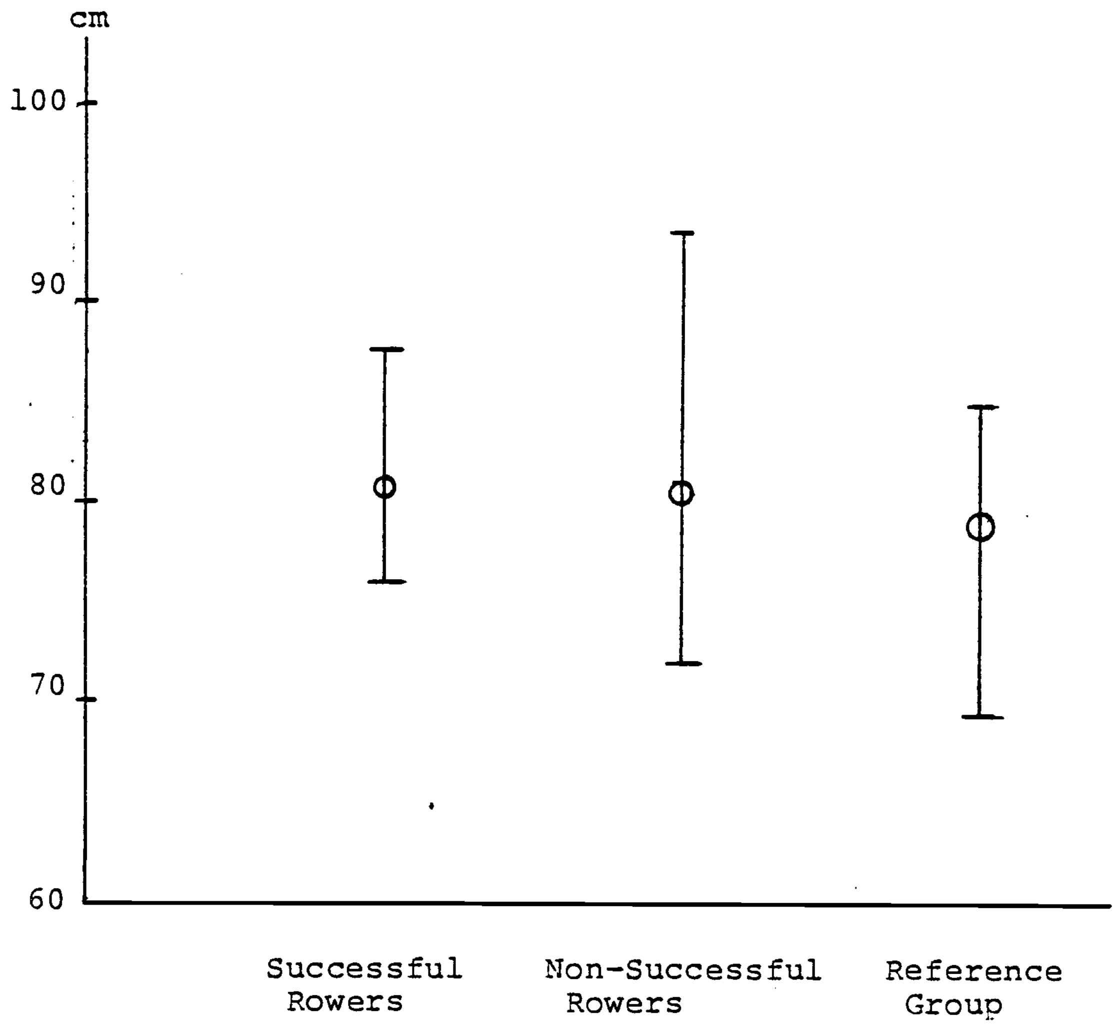

Figure 22: Mean scores and ranges of leg length

TABLE VI ANALYSIS OF LEG LENGTH

A. Analysis of Variance

	SOURCE	DF	MEAN SQUARES	*F* RATIO
1.	Between Groups	2	17.70	1.03
2.	Within Groups	41	17.18	
3.	Total	43		

B. Mean, SD and Range

	GROUP	MEAN	SD	RANGE
1.	Successful Rowers	80.66	3.58	75.8 - 87.5
2.	Non-Successful Rowers	80.27	5.74	71.8 - 93.3
3.	Reference Group	78.72	3.72	69.0 - 84.7

C. Contrast Variance

	GROUPS	*t* VALUE	DF	*t* PROBABILITY
1.	Rowers vs Reference	1.34	41.0	.19
2.	Successful vs Non-Successful	.23	41.0	.82

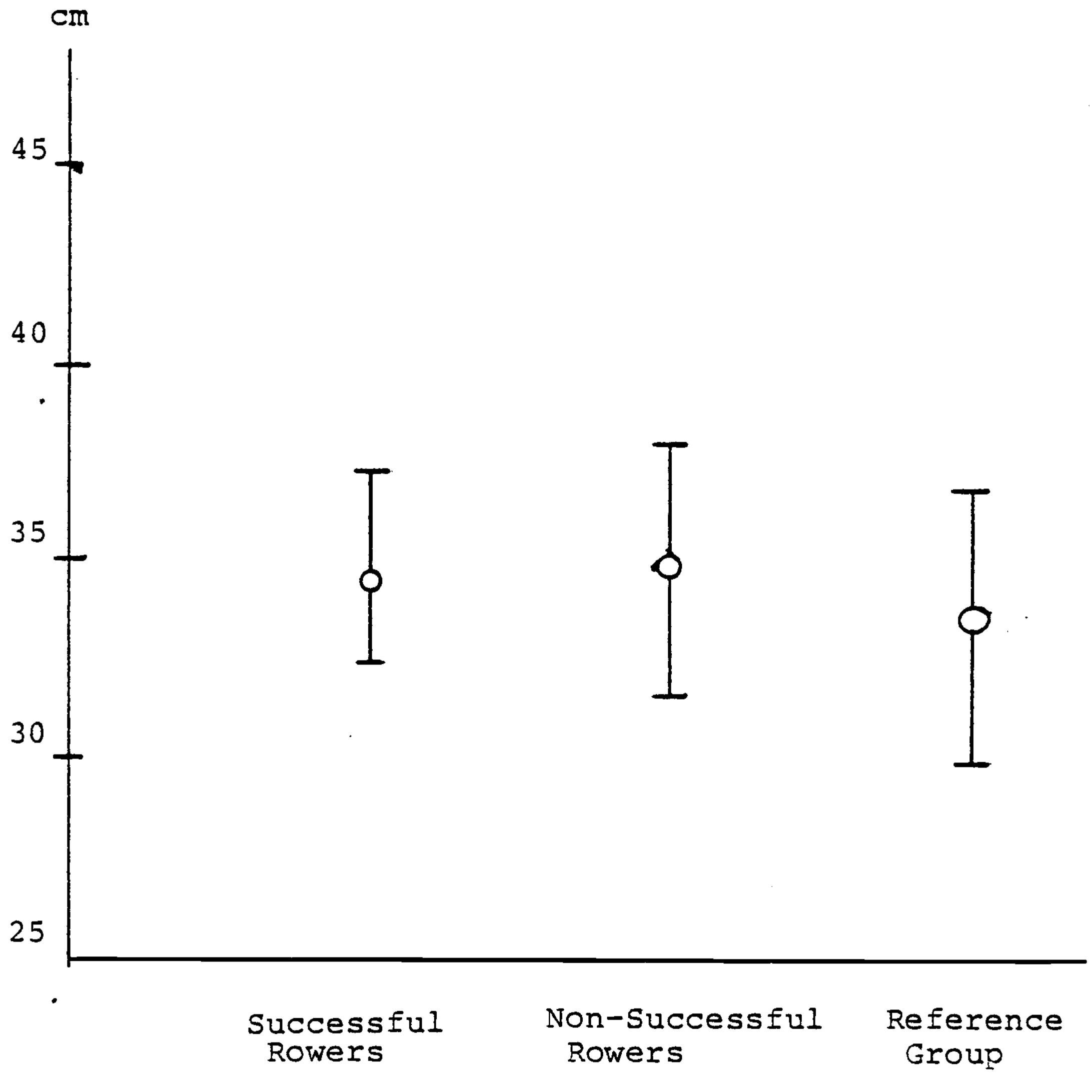

Figure 23: Mean scores and ranges of biacromial breadth

TABLE VII ANALYSIS OF BIACROMIAL BREADTH

A. Analysis of Variance

SOURCE	DF	MEAN SQUARE	*F* RATIO
1. Between Groups	2	5.99	1.75
2. Within Groups	41	3.41	
3. Total	43		

B. Meam, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	34.30	1.32	32.4 - 37.0
2. Non-Successful Rowers	34.57	2.04	31.5 - 37.6
3. Reference Group	33.35	2.15	29.9 - 36.6

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	1.87	41.0	.068
2. Successful vs Non-Successful	.35	41.0	.728

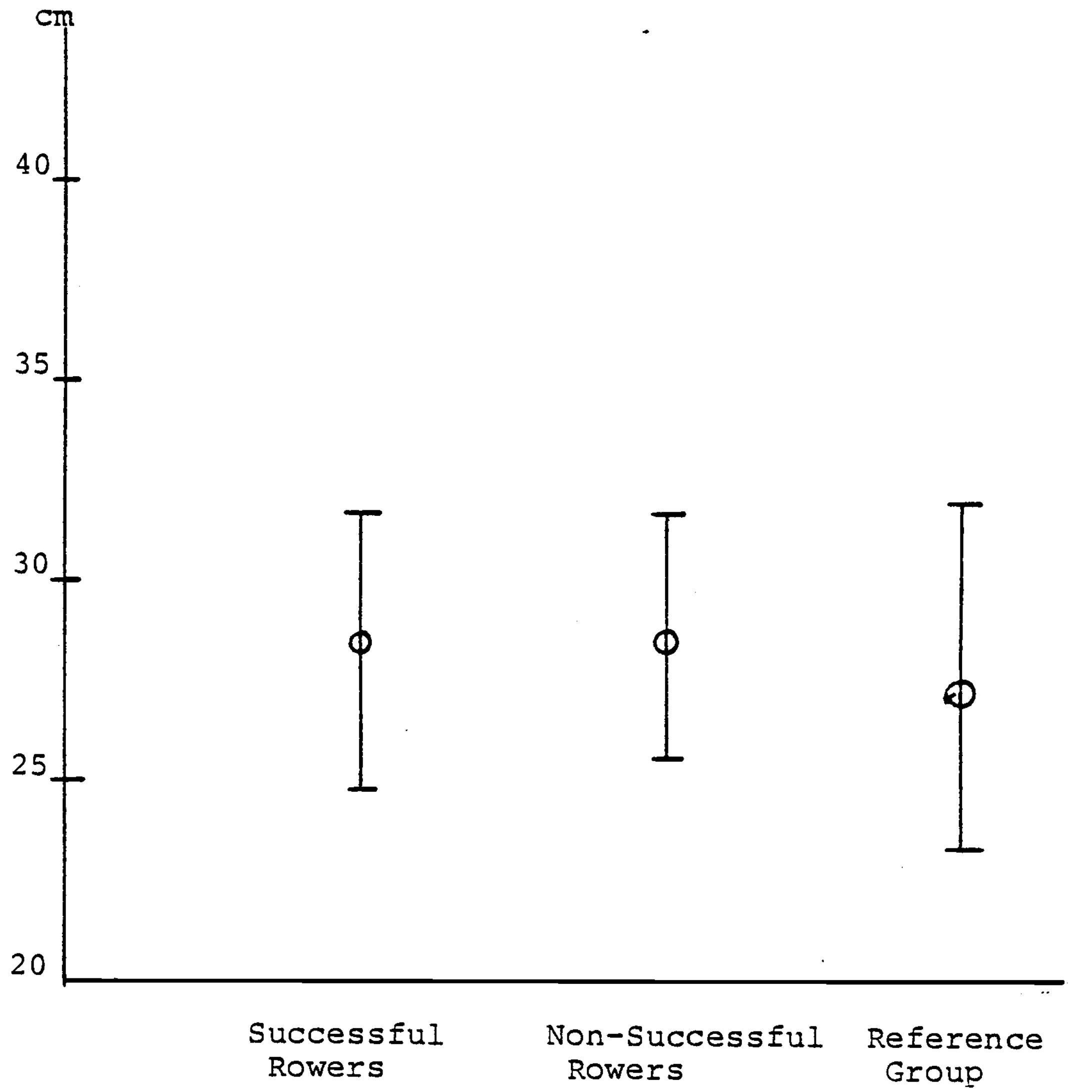

Figure 24: Mean scores and ranges of bicristal breadth

TABLE VIII ANALYSIS OF BICRISTAL BREADTH

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	7.72	1.93
2. Within Groups	41	4.01	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	28.33	1.70	24.8 - 31.5
2. Non-Successful Rowers	28.31	2.05	25.5 - 31.4
3. Reference Group	27.12	2.23	23.3 - 31.7

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	1.92	41.0	.06
2. Successful vs Non-Successful	.03	41.0	.98

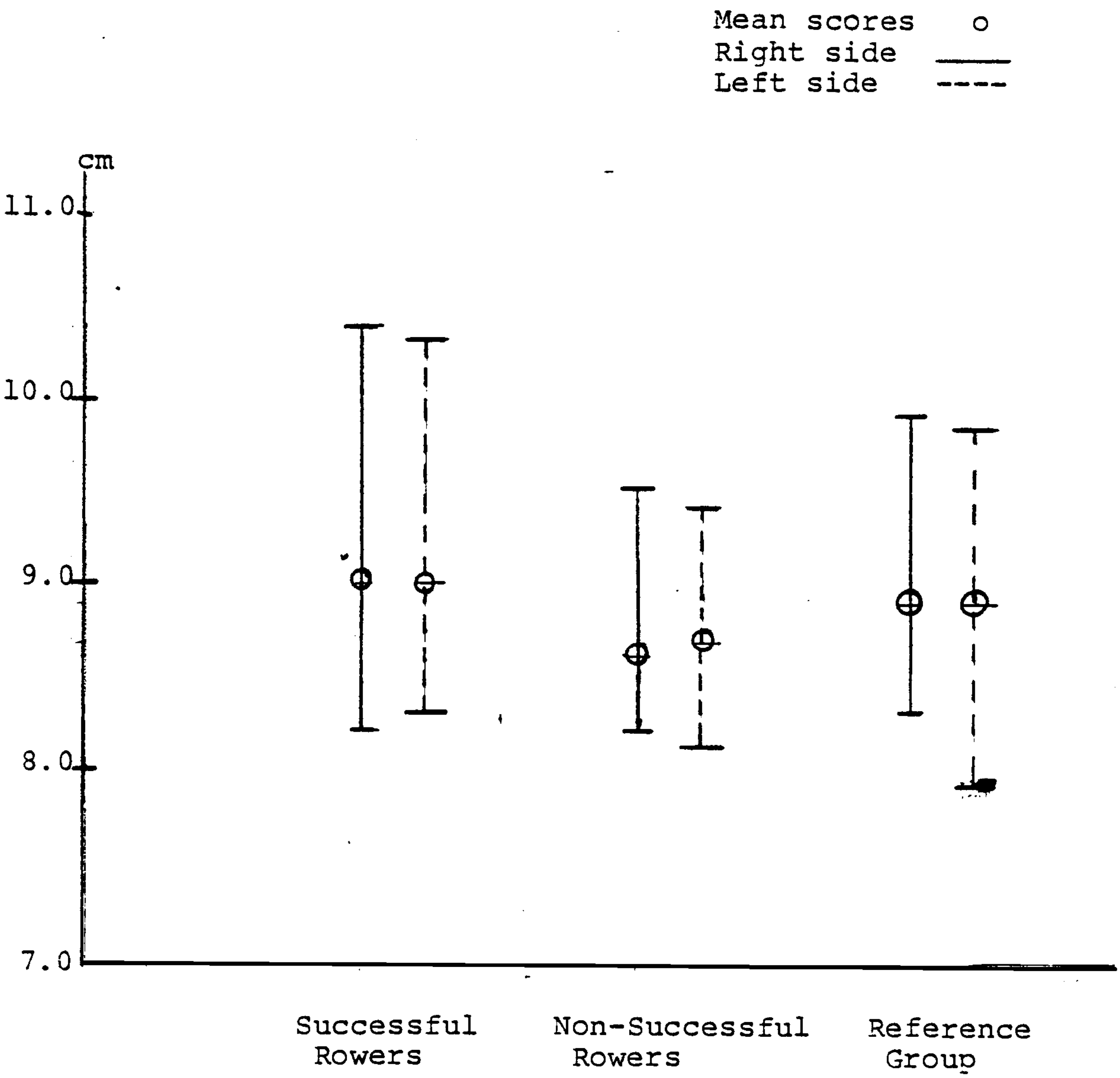

Figure 25: Mean scores and ranges of bicondylar breadth of femur

TABLE IX ANALYSIS OF RIGHT BICONDYLAR BREADTH (FEMUR)

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	F RATIO
1. Between Groups	2	.52	2.18
2. Within Groups	41	.24	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	9.02	.53	8.20 - 10.40
2. Non-Successful Rowers	8.60	.42	8.20 - 9.50
3. Reference Group	8.84	.47	8.30 - 9.90

C. Contrast Variance

GROUPS	t VALUE	DF	t PROBABILITY
1. Rowers vs Reference	.23	41.0	.82
2. Successful vs Non-Successful	2.08	41.0	.04*

* t = 2.02 with: 41 df required at .05 level

TABLE X ANALYSIS OF LEFT BICONDYLAR BREADTH (FEMUR)

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	.46	1.77
2. Within Groups	41	.26	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	9.04	.59	8.30 - 10.30
2. Non-Successful Rowers	8.68	.39	8.10 - 9.40
3. Reference Group	8.80	.48	7.90 - 9.80

C. Contrast Variance

GROUP	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	.37	41.0	.71
2. Successful vs Non-Successful	1.73	41.0	.09

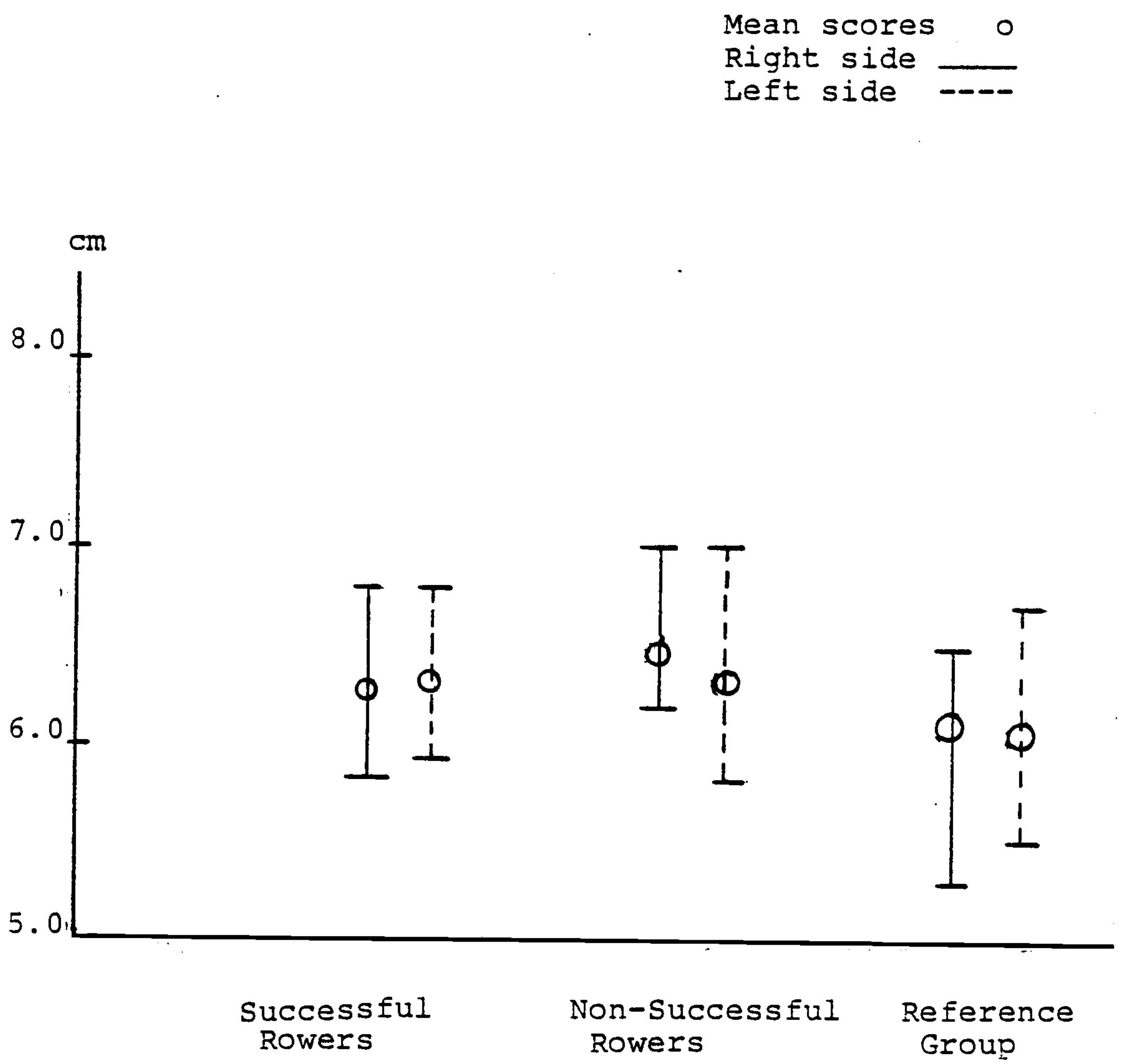

Figure 26: Mean scores and ranges of bicondylar width of humerus

TABLE XI ANALYSIS OF RIGHT BICONDYLAR BREADTH (HUMERUS)

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	F RATIO
1. Between Groups	2	.42	4.18*
2. Within Groups	41	.10	
3. Total	43		

* F 3.18 with: 2 and 43 df required at .05 level

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	6.28	.27	5.8 - 6.8
2. Non-Successful Rowers	6.47	.29	6.2 - 7.0
3. Reference Group	6.10	.38	5.3 - 6.5

C. Contrast Variance

GROUPS	t VALUE	DF	t PROBABILITY
1. Rowers vs Reference	2.75	41.0	.01*
2. Successful vs Non-Successful	1.41	41.0	.17

* t = 2.02 with: 41 df required at .05 level

TABLE XII ANALYSIS OF LEFT BICONDYLAR BREADTH (HUMERUS)

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	.31	3.10
2. Within Groups	41	.10	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	6.32	.25	5.9 - 6.8
2. Non-Successful Rowers	6.31	.39	5.8 - 7.0
3. Reference Group	6.08	.34	5.5 - 6.7

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	2.42	41.0	.02*
2. Successful ve Non-Successful	.09	41.0	.93

*t = 2.02 with: 41 df required at .05 level

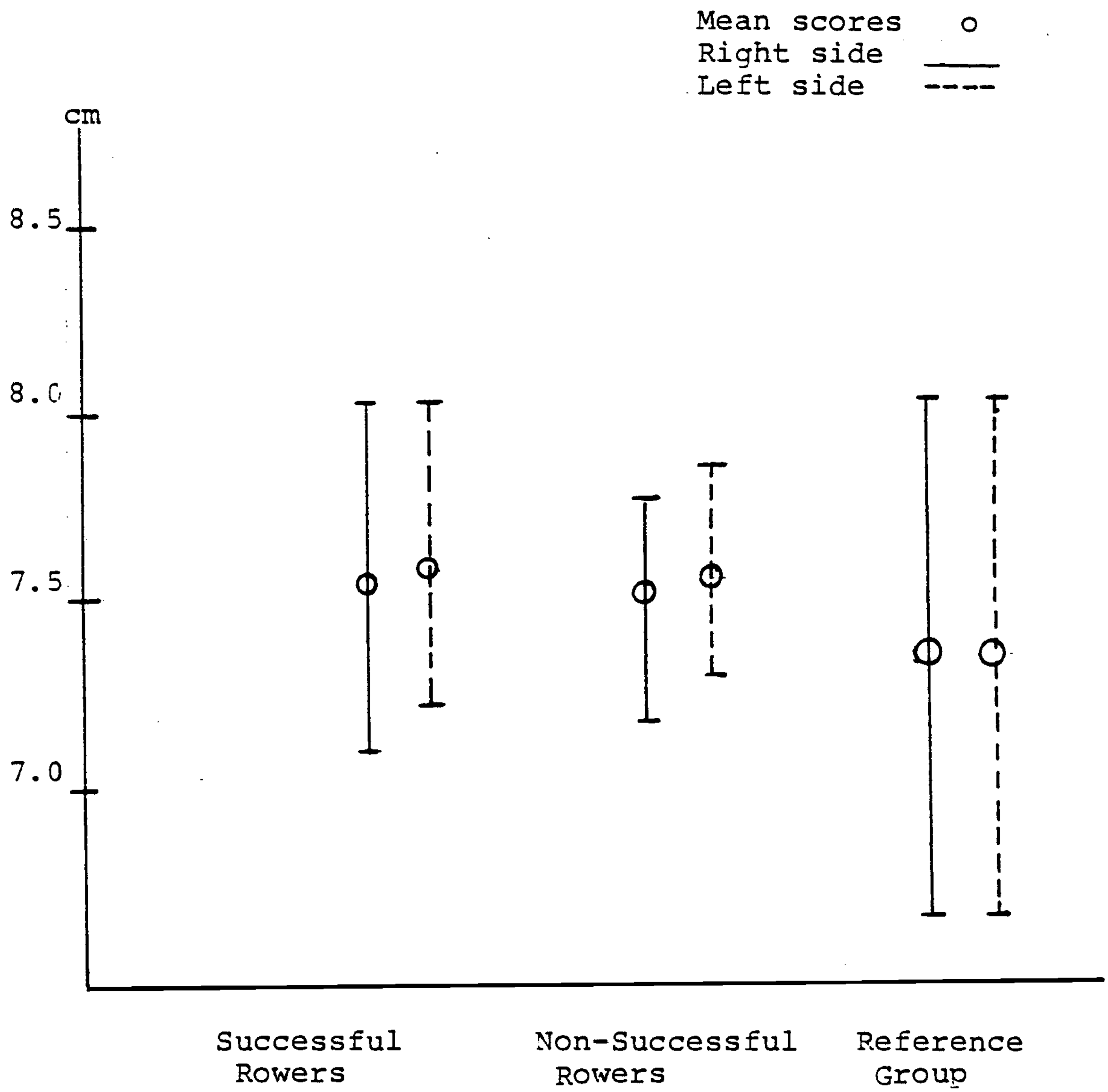

Figure 27: Mean scores and ranges of right and left arm length

TABLE XIII ANALYSIS OF RIGHT ARM LENGTH

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	16.18	1.81
2. Within Groups	41	8.91	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	75.31	2.72	71.1 - 81.3
2. Non-Successful	75.01	2.18	71.8 - 77.5
3. Reference Group	73.48	3.51	66.7 - 81.3

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	1.80	41.0	.08
2. Successful vs Non-Successful	.24	41.0	.81

TABLE XIV ANALYSIS OF LEFT ARM LENGTH

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	26.20	3.36*
2. Within Groups	41	7.80	
3. Total			

* *F* = 3.18 with: 2 and 43 df required for significance at the .05 level

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	75.72	2.36	72.14 - 81.3
2. Non-Successful Rowers	75.42	1.87	73.0 - 78.7
3. Reference Group	73.41	3.45	66.7 - 81.3

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	2.47	41.0	.02*
2. Successful vs Non-Successful	.26	41.0	.79

* *t* = 2.02 with: 41 df required for significance at the .05 level

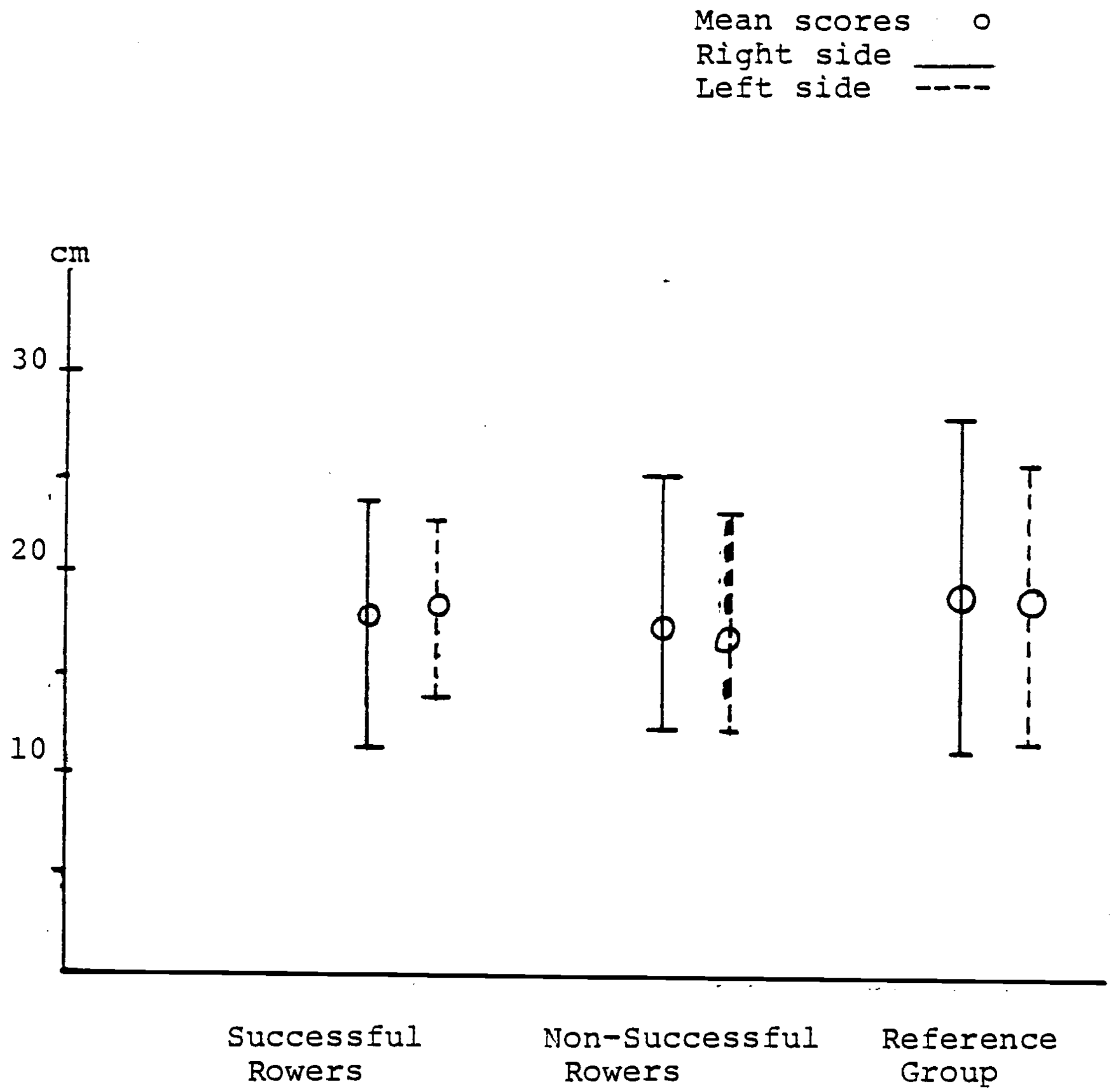

Figure 28: Mean and range scores of right and left tricep skinfold

TABLE XV ANALYSIS OF RIGHT TRICEPS SKINFOLD

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	F RATIO
1. Between Groups	2	9.67	0.54
2. Within Groups	41	17.87	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	17.88	3.56	11.0 - 23.5
2. Non-Successful Rowers	17.28	4.12	12.0 - 25.0
3. Reference Group	18.94	4.81	11.0 - 28.0

C. Contrast Variance

GROUPS	t VALUE	DF	t PROBABILITY
1. Rowers vs Reference	1.03	41.0	.31
2. Successful vs Non-Successful	.35	41.0	.73

TABLE XVI ANALYSIS OF LEFT TRICEP SKINFOLD

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	$\underline{F}$ RATIO
1. Between Groups	2	11.56	0.94
2. Within Groups	41	12.32	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	18.44	2.69	13.5 - 22.5
2. Non-Successful Rowers	16.78	3.67	12.0 - 23.0
3. Reference Group	18.67	4.07	11.5 - 25.5

C. Contrast Variance

GROUPS	$\underline{t}$ VALUE	DF	$\underline{t}$ PROBABILITY
1. Rowers vs Reference	.96	41.0	.34
2. Successful vs Non-Successful	1.15	41.0	.26

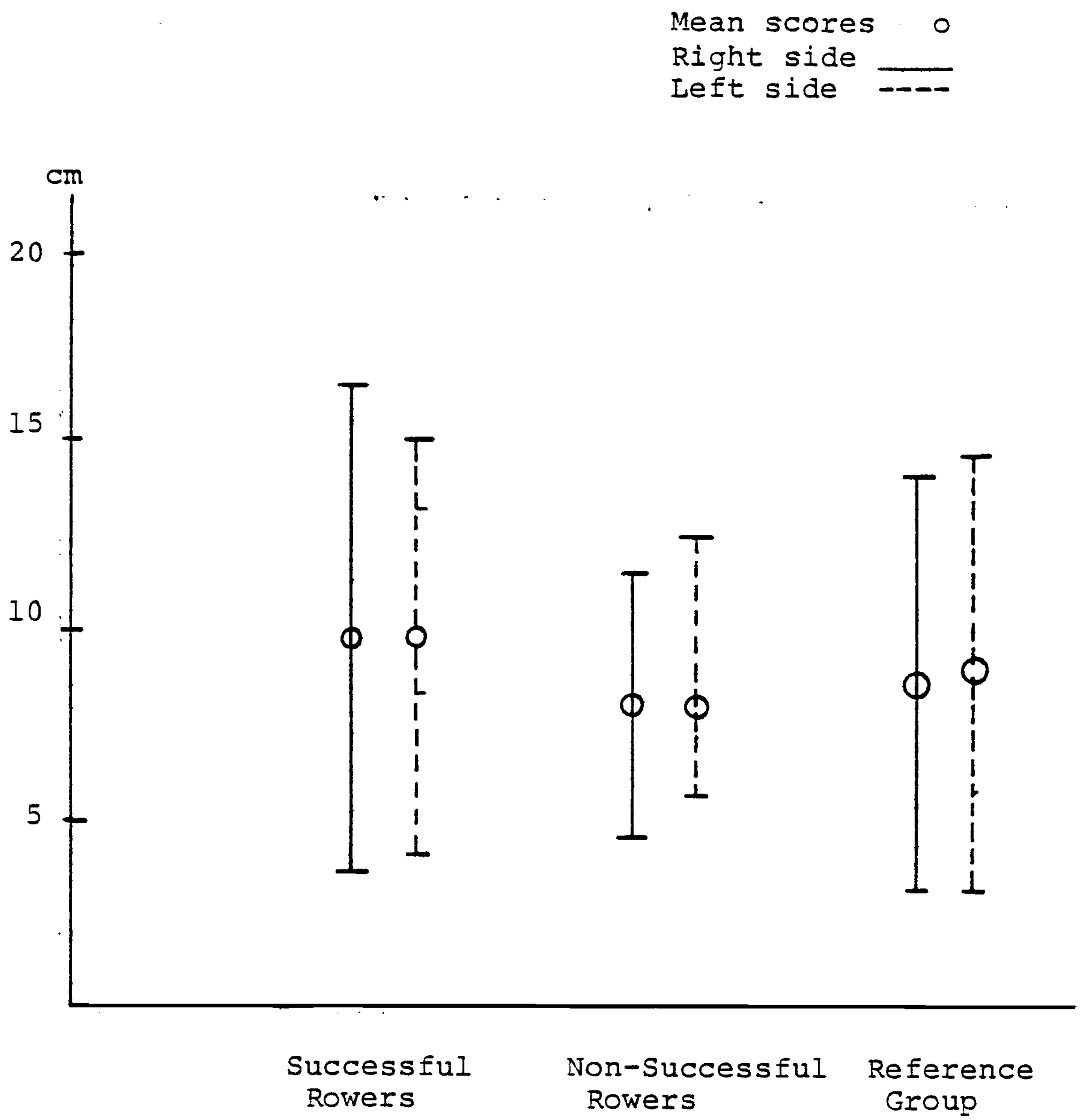

Figure 29: Mean scores and ranges of right and left bicep skinfold

TABLE XVII ANALYSIS OF RIGHT BICEP SKINFOLD

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	11.80	1.20
2. Within Groups	41	9.84	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	9.79	3.32	3.5 - 16.5
2. Non-Successful Rowers	7.94	2.48	4.5 - 11.5
3. Reference Group	8.58	3.23	3.0 - 14.0

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	.29	41.0	.77
2. Successful vs Non-Successful	1.43	41.0	.16

TABLE XVIII ANALYSIS OF LEFT BICEP SKINFOLD

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	F RATIO
1. Between Groups	2	11.43	1.26
2. Within Groups	41	9.04	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	9.77	2.95	4.0 - 15.0
2. Non-Successful Rowers	7.83	2.41	5.5 - 12.5
3. Reference Group	8.81	3.29	3.0 - 14.5

C. Contrast Variance

GROUPS	t VALUE	DF	t PROBABILITY
1. Rowers vs Reference	.01	41.0	.99
2. Successful vs Non-Successful	1.56	41.0	.13

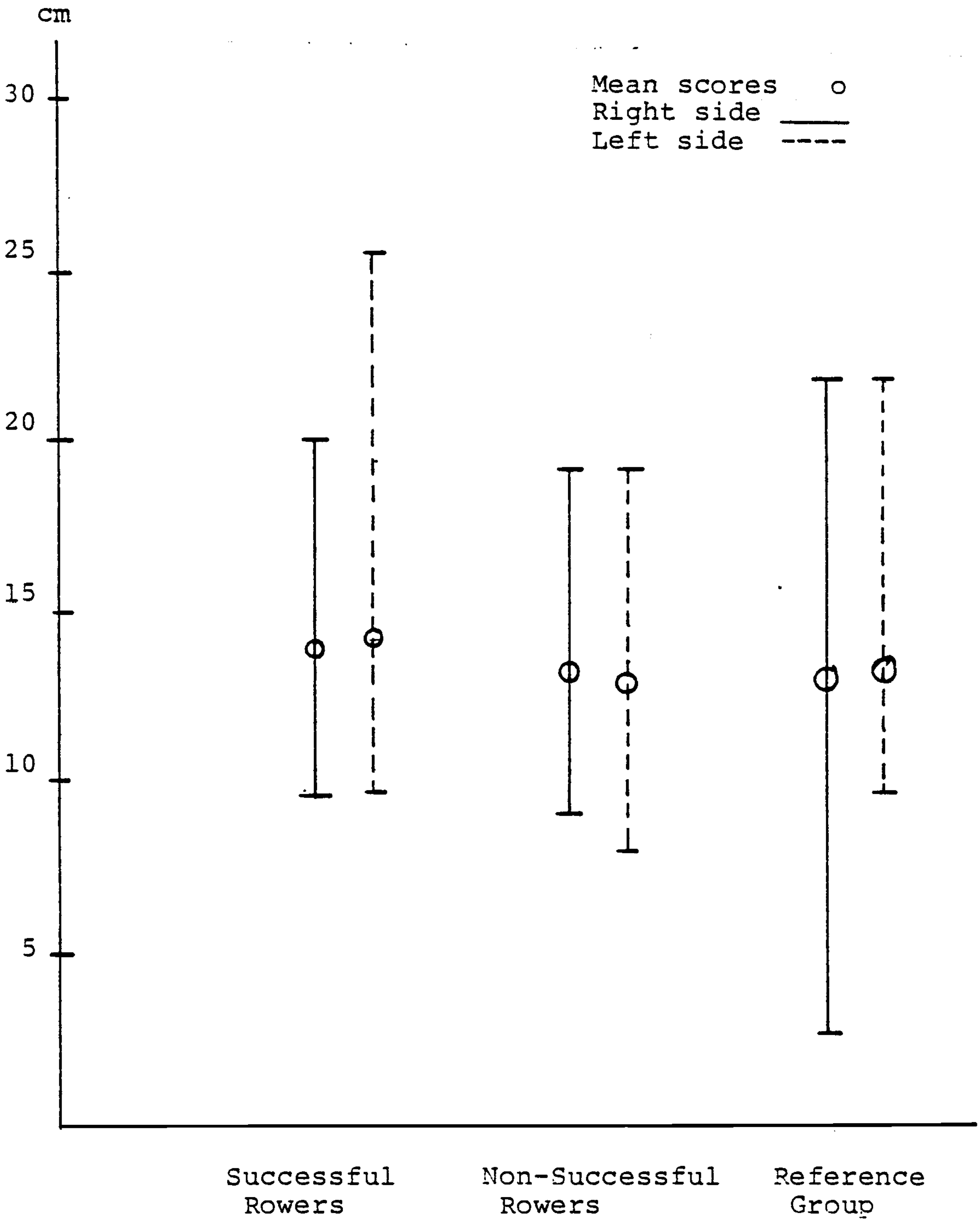

Figure 30: Mean scores and ranges of right and left subscapular skinfold

TABLE XIX ANALYSIS OF RIGHT SUBSCAPULAR SKINFOLD

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	4.56	0.32
2. Within Groups	41	14.38	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	13.79	3.47	9.5 - 20.0
2. Non-Successful Rowers	13.0	4.07	9.0 - 19.0
3. Reference Group	12.81	3.94	2.5 - 21.5

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	.50	41.0	.62
2. Successful vs Non-Successful	.51	41.0	.61

TABLE XX ANALYSIS OF LEFT SUBSCAPULAR SKINFOLD

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	8.57	0.57
2. Within Groups	41	14.99	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	14.32	4.27	9.5 - 25.5
2. Non-Successful Rowers	12.89	3.95	8.0 - 19.0
3. Reference Group	13.14	3.49	9.5 - 21.5

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	.39	41.0	.70
2. Successful vs Non-Successful	.90	41.0	.37

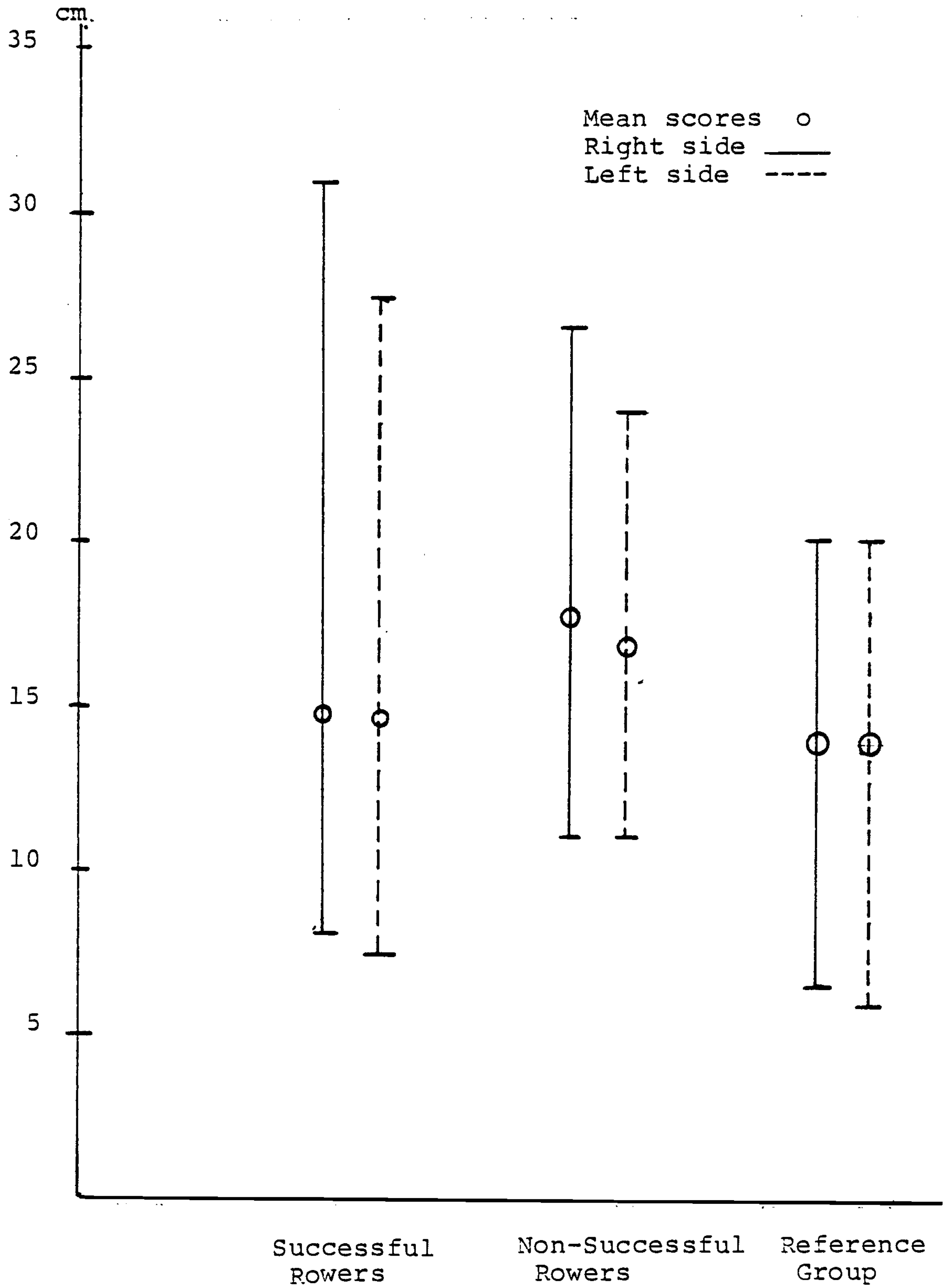

Figure 31: Mean scores and ranges of right and left suprailiac skinfold

TABLE XXI ANALYSIS OF RIGHT SUPRAILIAC SKINFOLD

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	F RATIO
1. Between Groups	2	42.38	1.83
2. Within Groups	41	23.19	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	14.73	5.42	8.0 - 31.0
2. Non-Successful Rowers	17.72	4.76	11.0 - 26.5
3. Reference Group	14.03	4.19	6.5 - 20.0

C. Contrast Variance

GROUPS	t VALUE	DF	t PROBABILITY
1. Rowers vs Reference	1.46	41.0	.15
2. Successful vs Non-Successful	1.51	41.0	.14

TABLE XXII ANALYSIS OF LEFT SUPRAILIAC SKINFOLD

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	F RATIO
1. Between Groups	2	23.23	1.23
2. Within Groups	41	18.90	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	14.47	4.81	7.5 - 27.5
2. Non-Successful Rowers	16.72	3.55	11.0 - 24.0
3. Reference Group	14.0	4.23	6.0 - 20.0

C. Contrast Variance

GROUPS	t VALUE	DF	t PROBABILITY
1. Rowers vs Reference	1.17	41.0	.25
2. Successful vs Non-Successful	1.26	41.0	.22

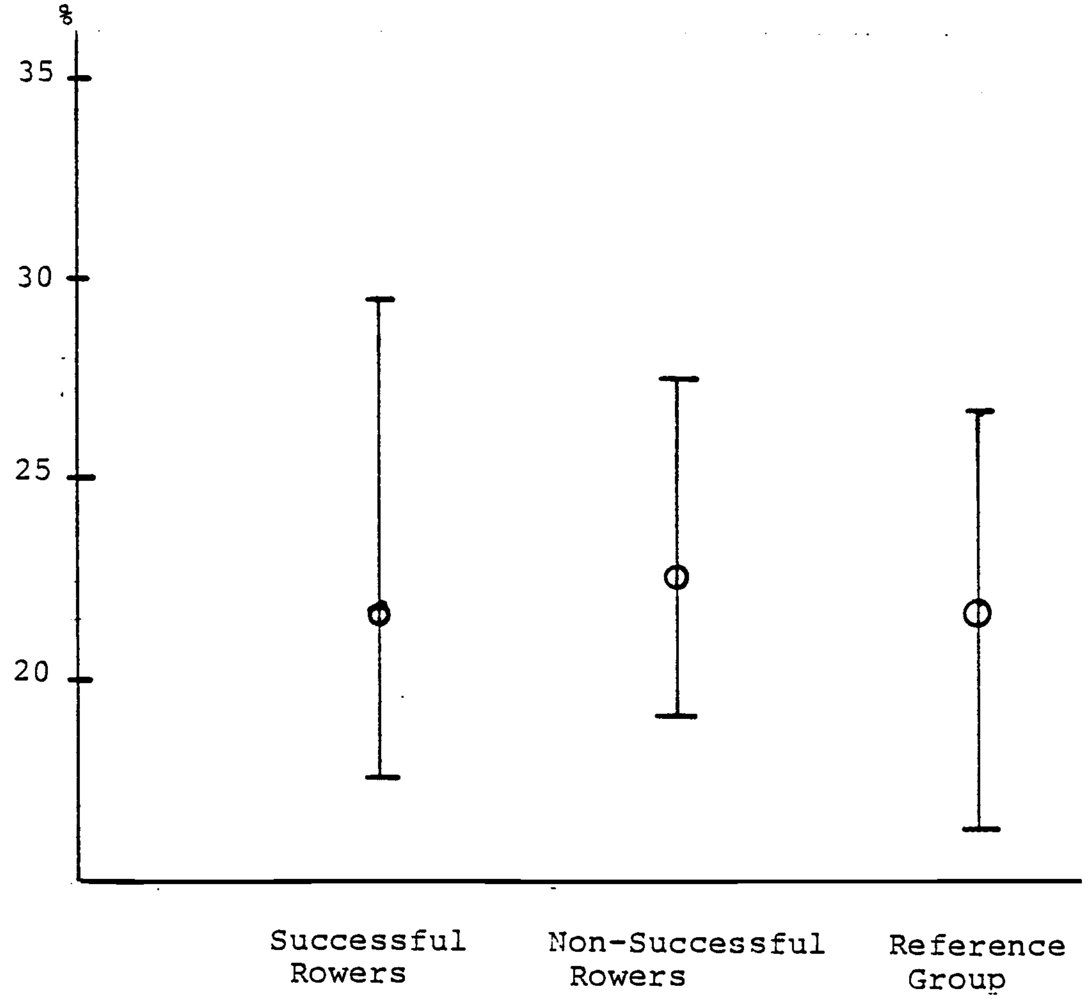

Figure 32: Mean scores and ranges of percent body fat

TABLE XXIII ANALYSIS OF PERCENT OF BODY FAT

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	2.46	0.28
2. Within Groups	41	8.77	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	21.51	2.91	17.5 - 29.5
2. Non-Successful Rowers	22.38	2.95	19.0 - 27.4
3. Reference Group	21.59	3.01	16.2 - 26.7

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	.38	41.0	.71
2. Successful vs Non-Successful	.71	41.0	.48

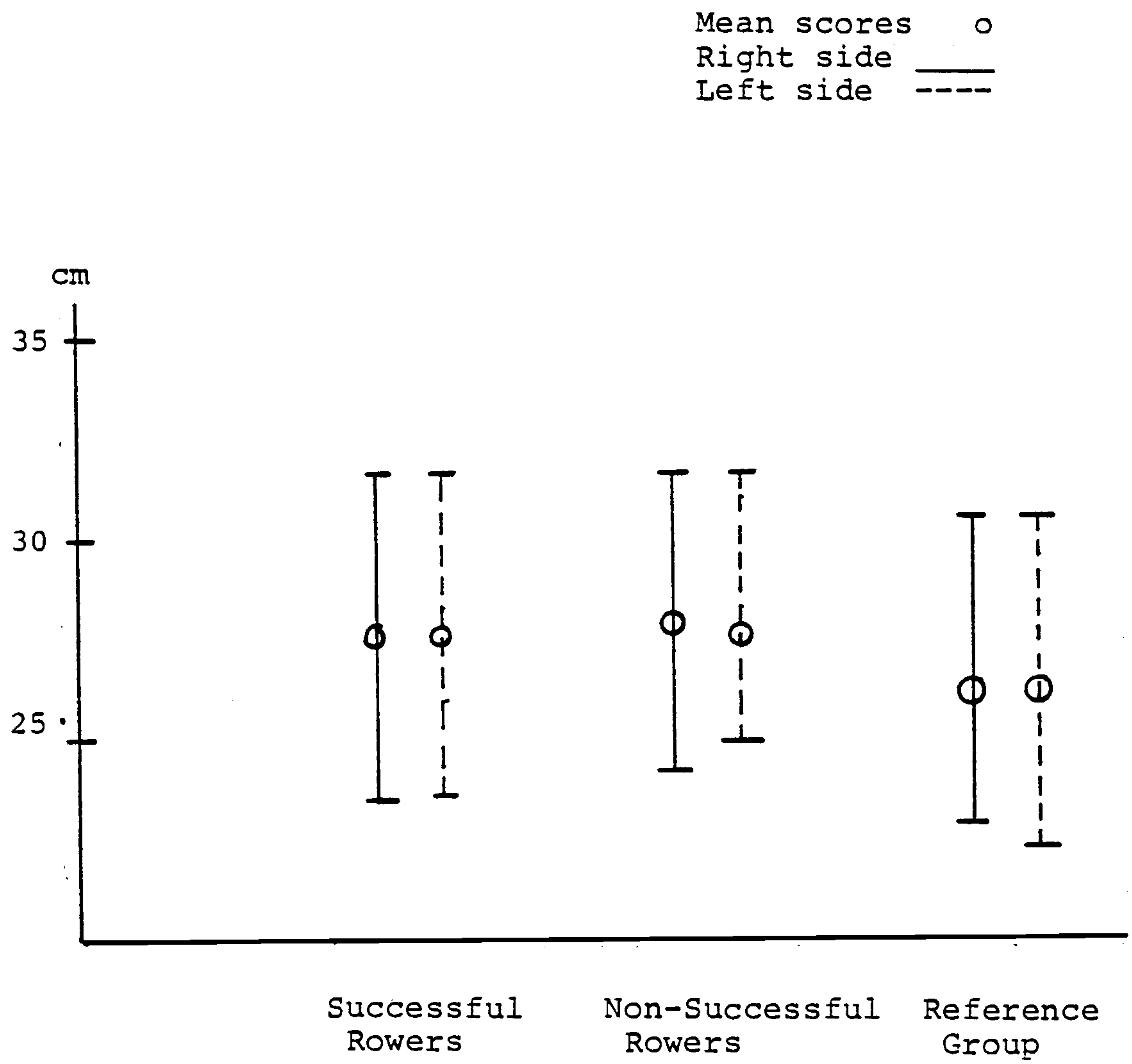

Figure 33: Mean scores and ranges of right and left upper arm circumference

TABLE XXIV ANALYSIS OF CIRCUMFERENCE OF RIGHT UPPER ARM

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	F RATIO
1. Between Groups	2	10.95	2.35
2. Within Groups	41	4.67	
3. Total	43		

B. Mean SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	27.49	2.20	23.5 - 31.7
2. Non-Successful Rowers	27.80	2.42	24.1 - 31.7
3. Reference Group	26.18	1.99	22.0 - 30.5

C. Contrast Variance

GROUPS	t VALUE	DF	t PROBABILITY
1. Rowers vs Reference	2.16	41.0	.04*
2. Successful vs Non-Successful	.34	41.0	.73

* t = 2.02 with: 41 df required for significance at the .05 level

TABLE XXV ANALYSIS OF CIRCUMFERENCE OF LEFT UPPER ARM

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	F RATIO
1. Between Groups	2	13.70	2.51
2. Within Groups	41	5.45	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	27.58	2.44	23.5 - 31.7
2. Non-Successful Rowers	27.66	2.29	24.8 - 31.7
3. Reverence Group	26.00	2.25	22.2 - 30.5

C. Contrast Variance

GROUPS	t VALUE	DF	t PROBABILITY
1. Rowers vs Reference	2.21	41.0	.03*
2. Successful vs Non-Successful	.08	41.0	.93

* t = 2.02 with: 41 df required for significance at the .05 level

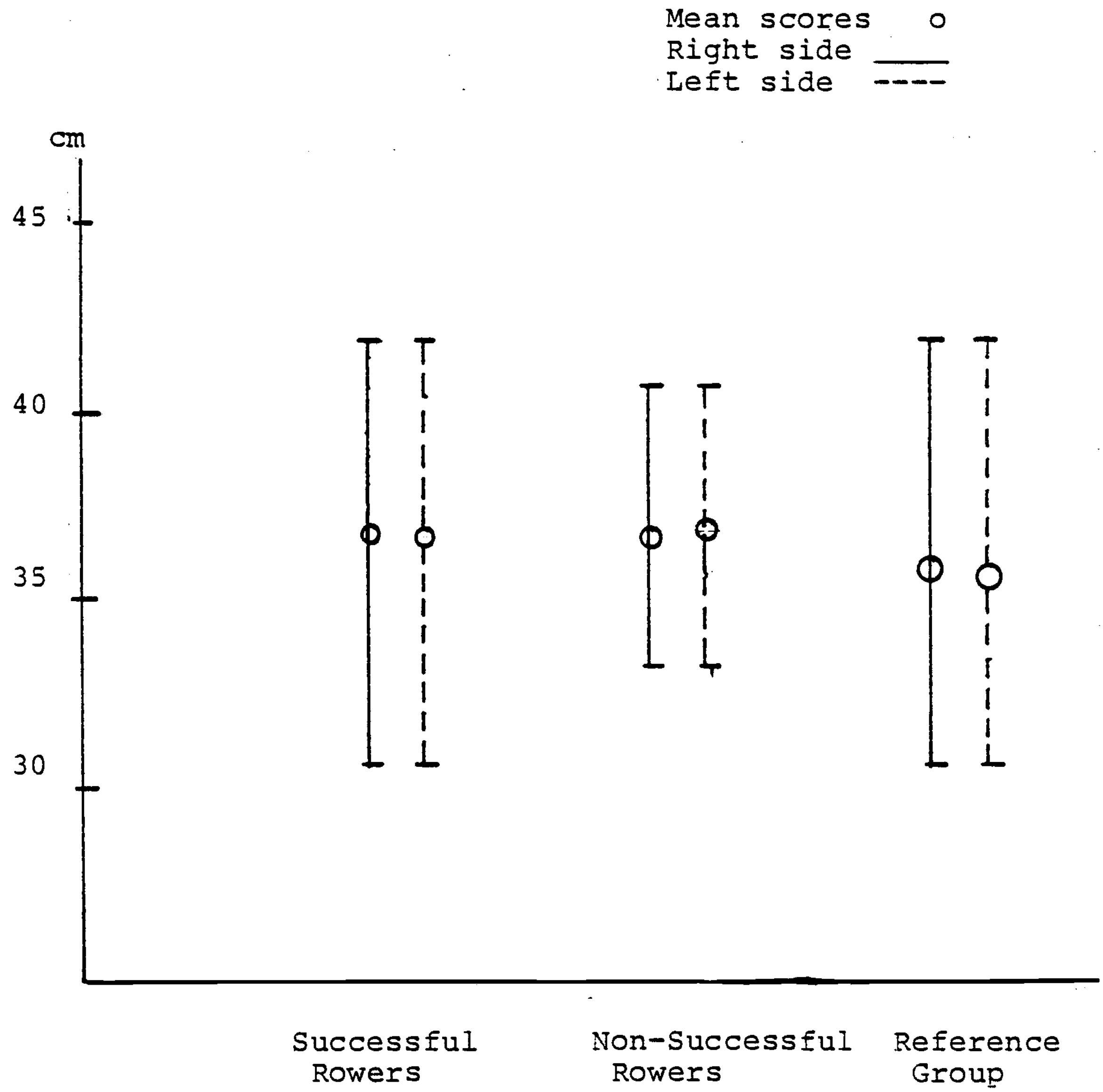

Figure 34: Mean scores and ranges of right and left calf circumference

TABLE XXVI ANALYSIS OF CIRCUMFERENCE OF RIGHT CALF

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	4.37	0.67
2. Within Groups	41	6.55	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	36.64	2.34	30.5 - 41.9
2. Non-Successful Rowers	36.57	2.11	33.2 - 40.6
3. Reference Group	35.71	2.92	30.5 - 41.9

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	1.11	41.0	.27
2. Successful vs Non-Successful	.07	41.0	.94

TABLE XXVII ANALYSIS OF CIRCUMFERENCE OF LEFT CALF

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	6.77	1.05
2. Within Groups	41	6.48	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	36.57	2.41	30.5 - 41.9
2. Non-Successful Rowers	36.63	2.08	33.2 - 40.6
3. Reference Group	35.46	2.85	30.5 - 41.9

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	1.43	41.0	.16
2. Successful ve Non-Successful	.07	41.0	.95

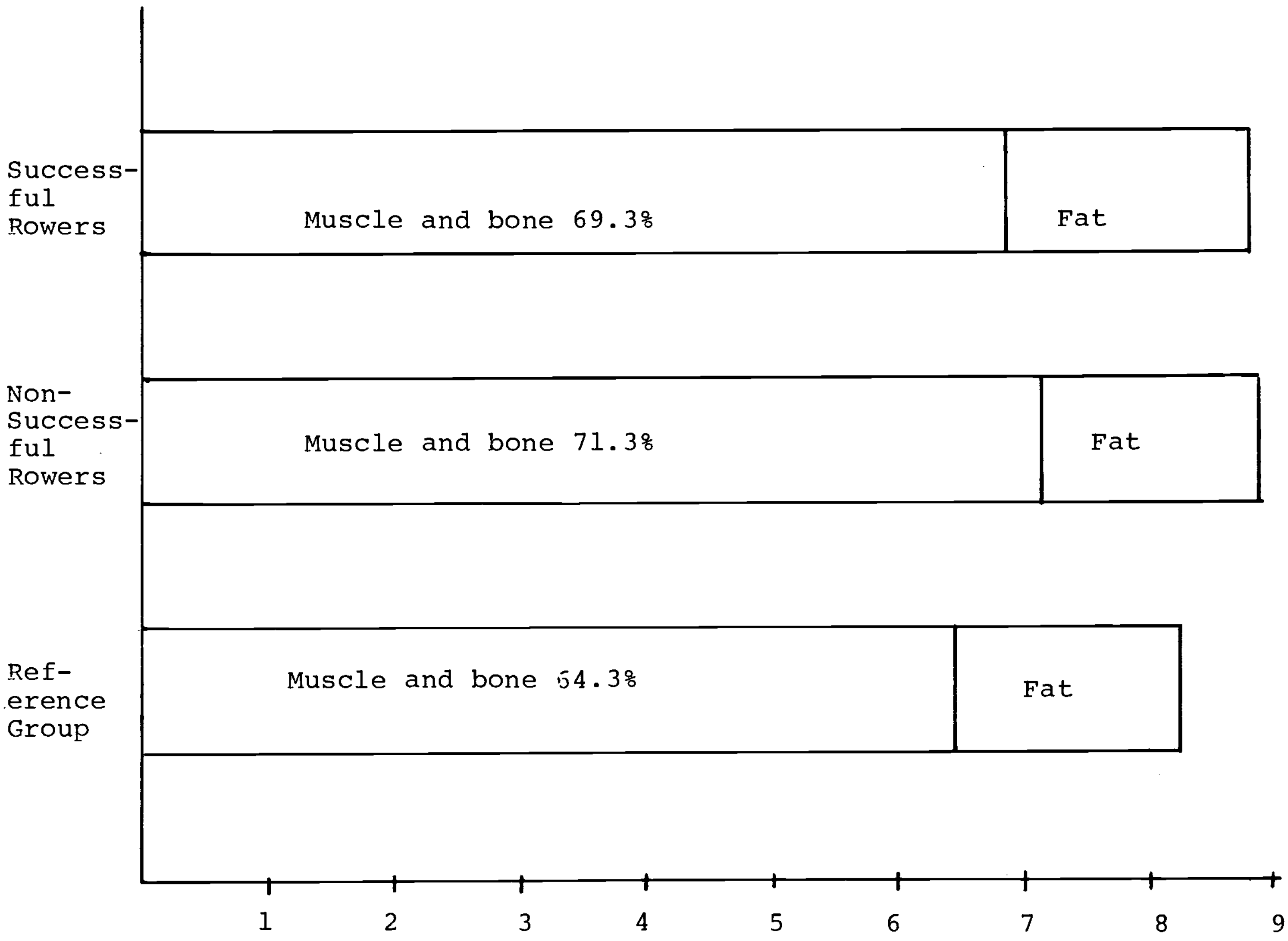

Figure 35: Fat vs muscle-bone

TABLE XXVIII ANALYSIS OF ARM DIAMETER

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	1.17	2.46
2. Within Groups	41	.48	
3. Total	43		

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	8.79	.72	7.5 - 10.1
2. Non-Successful Rowers	8.86	.76	7.7 - 10.1
3. Reference Group	8.34	.63	7.3 - 9.7

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	2.21	41.0	.03*
2. Successful vs Non-Successful	.24	41.0	.81

* *t* = 2.02 with: 41 df required for significance at the .05 level

TABLE XXIX ANALYSIS OF ARM-MUSCLE-BONE DIAMETER

A. Analysis of Variance

SOURCE	DF	MEAN SQUARES	*F* RATIO
1. Between Groups	2	1.81	5.30*
2. Within Groups	41	.34	
3. Total	43		

*F = 3.18 with: 2 and 43 df required for significance at the .05 level

B. Mean, SD and Range

GROUP	MEAN	SD	RANGE
1. Successful Rowers	6.93	.64	5.1 - 7.9
2. Non-Successful Rowers	7.13	.67	6.2 - 7.9
3. Reference Group	6.44	.47	5.7 - 7.3

C. Contrast Variance

GROUPS	*t* VALUE	DF	*t* PROBABILITY
1. Rowers vs Reference	3.25	41.0	.002*
2. Successful vs Non-Successful	.82	41.0	.41

* t = 2.02 with: 41 df required for significance at the .05 level

athletes.

No significant difference was found among the three groups with the following variables:

1. Height, sitting height, and sitting height/height ratio
2. Leg length
3. Right arm length
4. Biacromial and bicristal breadth
5. Left femoral bicondylar breadth

Skinfold Measurements:

Analysis of variance and contrast variance of the mean skinfold measurement scores revealed no significant difference existed among the three groups (Table XVA,C through XXIIA,C).

Girth Measurements:

Mean measurement scores of girth assessments among the three groups were not significant with right and left calf circumference and body fat percentage (Tables XXIIIA,C through Tables XXIXA,C). $\underline{F}$ values were not significant for the right and left upper arm circumference and the arm diameter. However, the $\underline{t}$ value was significant for the same measures when the athlete and non-athlete were contrasted ($\underline{t}$ = 2.16, $\underline{t}$ = 2.21, and $\underline{t}$ = 2.21 respectively). The variables with the greatest significance of difference was the arm-muscle-bone diameter. The $\underline{F}$ value was significant between groups ($\underline{F}$ = 5.30) and the $\underline{t}$ value (*t* = 3.25) was significantly different between the contrast variance of the athletes versus the non-athletes.

A summary of significant values is presented on (Table XXX).

First and Second Measurements of Successful Rowers

The first and second assessments of the rowers who completed the season were taken for the purpose of observing any possible changes resulting from conditioning for the sport. The results of the *t* test are presented in Table XXXI.

The results of the comparison of the two assessments for skeletal measurements were not significantly different except for the right femoral bicondylar breadth (*t* = 2.84). However, the reproducibility was low for biacromial breadth (*r* = .22), bicristal breadth (*r* = .41), bicondylar breadth of the right and left humerus (*r* = .66 and *r* = .58 respectfully), and sitting height/height ratio (*r* = .66).

The *t*-test treatment of the skinfold measurements showed a significant difference for the right and left subscapular skinfold (*t* = 3.72 and *t* = 3.11 respectively) and right and left suprailiac skinfold measurements (*t* = 2.14 and *t* = 2.26 respectively). Body fat percent was also significantly different (*t* = 2.63). The repeatability of both triceps (right *r* = .67 and left *r* = .64), both biceps (right *r* = .67 and left *r* = .69) and left subscapular skinfolds (*r* = .45) were low.

TABLE XXX SUMMARY OF SIGNIFICANT $\underline{F}$ RATIOS AND $\underline{t}$ VALUES

VARIABLES	$\underline{F}$ Ratios	$\underline{t}$ Value	Table Number	Page Number
Age	4.44		IA	63
a. Rowers vs Reference		2.42	IC	
b. Successful vs Non-Successful			IC	
Right Bicondylar Breadth(Femur)			IXA	79
a. Rowers vs Reference			IXC	
b. Successful vs Non-Successful		2.08	IXC	
Right Bicondylar Breadth(Humerus)	4.18		XIA	82
a. Rowers vs Reference		2.75	XIC	
b. Successful vs Non-Successful			XIC	
Left Bicondylar Breadth(Humerus)			VIA	83
a. Rowers vs Reference		2.42	XIIC	
b. Successful vs Non-Successful			XIIC	
Left Arm Length	3.36		XIVA	86
a. Rowers ve Reference		2.47	XIVC	
b. Successful vs Non-Successful			XIVC	
Circumference Right Upper Arm			XXIVA	102
a. Rowers vs Reference		2.16	XXIVC	
b. Successful vs Non-Successful			XXIVC	
Circumference Left Upper Arm			XXVA	103
a. Rowers ve Reference		2.21	XXVC	
b. Successful vs Non-Successful			XXVC	

TABLE XXX SUMMARY OF SIGNIFICANT F RATIOS AND t VALUES (continued)

VARIABLES	F Ratios	t Value	Table Number	Page Number
Arm Diameter			XVIIIA	108
a. Rowers ve Reference		2.21	XVIIIC	
b. Successful vs Non-Successful			XVIIIC	
Arm-Muscle-Bone Diameter	5.30		XXIXA	109
a. Rowers vs Reference		3.25	XXIXC	
b. Successful vs Non-Successful			XXIXC	

TABLE XXXI FIRST AND SECOND MEASUREMENTS OF WOMEN ROWERS

Variables	First Measurements Mean	SD	Second Measurements Mean	SD	Correlation[a]	t Value[b]
Age (yrs)	19.47	1.46	19.20	1.67	.96	2.65*
Weight (kg)	67.04	7.76	66.85	8.27	.93	0.24
Height (cm)	169.98	6.29	170.05	6.41	.99	0.39
Sitting Height (cm)	88.98	3.10	89.55	2.74	.91	1.68
Sitting Height/Height (%)	0.52	0.01	0.53	0.01	.66	1.60
Leg Length (cm)	81.00	3.64	80.51	4.32	.95	1.33
Biacromial Breadth (cm)	34.50	1.28	33.86	1.60	.22	1.36
Bicristal Breadth	28.52	1.53	28.21	1.21	.41	0.80
Bicondylar Width Right Humerus	6.31	0.27	6.40	0.40	.66	1.12
Bicondylar Width Left Humerus	6.35	0.24	6.41	0.43	.58	0.59
Bicondylar Width Right Femur	9.05	0.55	9.23	0.51	.89	2.84*
Bicondylar Width Left Femur	9.07	0.59	9.22	0.55	.84	1.75
Arm Length, Right	75.45	2.78	74.97	3.09	.85	1.12
Arm Length, Left	75.83	2.46	75.01	3.06	.83	1.87
Skinfold Triceps, Right	18.10	3.29	16.73	3.40	.67	1.94
Skinfold Triceps, Left	18.57	2.80	17.87	3.52	.64	0.99
Skinfold Biceps, Right	9.87	3.51	8.73	2.57	.67	1.67
Skinfold Biceps, Left	9.83	3.15	9.67	2.69	.69	0.28
Skinfold Subscapular, Right	13.50	3.35	11.20	2.93	.72	3.72*
Skinfold Subscapular, Left	14.03	4.29	10.93	2.52	.45	3.11*
Skinfold Suprailiac, Right	14.67	5.77	12.67	3.59	.80	2.14*
Skinfold Suprailiac, Left	14.47	5.11	12.73	3.36	.83	2.26*
Upper Arm Circumference, Right	27.51	2.04	27.30	2.19	.80	0.60
Upper Arm Circumference, Left	27.56	2.27	27.39	2.27	.87	0.57
Calf Circumference, Right	36.57	2.35	36.15	2.36	.96	2.32*
Calf Circumference, Left	36.53	2.39	36.23	2.26	.97	2.00
Arm Diameter	8.80	0.66	8.70	0.69	.81	0.93
Arm-Muscle-Bone Diameter	6.92	0.65	7.01	0.51	.68	0.69
Body Fat (%)	21.56	3.01	20.33	2.20	.80	2.63*

[a]p = .05 for r = 0.48 with 15 d.f. [b]p = .05 for t = 2.15 with 14 d.f.

The circumference values were not significantly different except for the right calf circumference (*t* = 2.32). The variables with the low reproducibility were the arm-bone-muscle diameter (*r* = .68).

DISCUSSION

Discussion of the results of this investigation will be presented in terms of the hypotheses stated in Chapter I and in terms of their potential contribution of describing the female competitive rower.

Skeletal Measurements

Hypothesis One, no significant difference existed between female rowers and the non-athletic population was accepted for most of the skeletal variables. However, the width elbows and left arm length were significantly different. The height (169.64 cm, 169.28 cm) of the women rowers were similar to the height of the volleyball players (169.92 cm) reported by Hosler, et al. (23), basketball players (170.6 cm) studied by Alexander (1), and the swimmers (168.0 cm) reported by Conger and MacNab (11). The reference group was slightly shorter at 166.12 cm which compared to the height reported by Conger and MacNab on basketball players (167.0 cm) and volleyball player (166.0 cm). Body weight of the athletes was also comparable to the findings of the height of the above-mentioned athletes. The non-athletes were slightly, but not significantly, lighter than the athletes.

Women rowers displayed a sitting height similar to the sitting height of the throwers reported by Malina, et al. (32). This same pattern was consistant among the reference groups of both studies. The athletes of this study possessed longer legs than the athletes of Malina's, et al. study. The range of variation in the sitting height/stature ratio revealed a smaller variation for the women rowers which is like the jumpers of Malina's, et al. investigation.

In regard to the measurements of body breadths, the shoulders and hips were not significantly different among the three groups. Shoulder width (34.3 cm and 34.67 cm) was comparable to the widths of the smaller sized women gymnasts (43) and women Nordic skiers (42). In comparing the hip widths (28.2 cm and 28.3 cm), the rowers were similar to the volleyball players (28.2 cm) (23), throwers (32), and Nordic skiers (42). Bicondylar breadths of the knee, though not significantly different among the groups, was greater for the successful rowers (9.02 cm). In terms of comparison, the successful rowers shared similar values to the throwers (32), basketball players (9.0 cm) (1), and gymnasts (8.8 cm) (43). A significance was revealed between athletes and non-athletes for right and left bicondylar breadth of the elbow. The same comparison of the knee width applied to the elbow width.

Skinfold Measurements

Hypothesis One, no significant difference existed between women rowers and the general population and Hypothesis Two, no significant difference existed between the rowers who completed the crew season and the rowers who did not complete the season was accepted only for all skinfold assessments. The rowers shared similar values of subcutaneous fat with the throwers of Malina's et al. study (32) for the sites of the biceps and triceps. They shared similar skinfold for the subscapular and suprailiac sites with the runners and jumpers.

No significant difference among the three groups prevailed for estimated percentages of body fat. The mean percentage of body fat for the women rowers was considerably greater than the gymnasts (15.3%) (43), Nordic skiers (16.1%) (42), the placers (16.8%) and non-placers (18.4%) (14) in gymnastics and Malina's, et al. (32) runners. The rowers of this study compared to the percentage of body fat of the lean jumpers (31), and volleyball players (22). The reference group possessed similar body fat percentages (21.6) with the values (20.1%, and 22.9%) of the non-athletes of Sloan, et al. (44) and Malina, et al. (32).

Limb Girths

Hypothesis One, no significant difference existed between female rowers and non-athletes was rejected for the right and left upper arm circumferences, arm diameter and muscle-bone diameter. The athletes possessed a greater mean value. The limb circumference represented a rough indication of musculature. The greater value for upper arm circumference provides an advantage for the strength requirement necessary for rowing. In comparing with other athletes, the rowers shared similar measurements (27.5 cm and 27.8 cm) with gymnasts (25.0 cm) (43), basketball players (26.2 cm) (1), and throwers of track and field events (32). Total arm diameter and estimated muscle-bone diameter were greater among the athletes than the non-athletes. The subcutaneous fat was eliminated in the muscle-bone diameter. However, the athletes did not share the heavy musculature of the throwers in the study by Malina, et al. (32). The relative value, however, showed the rowers to have more lean tissue than the throwers.

Hypothesis One, no significant difference existed between rowers and non-athletes, and Hypothesis Two, no significant difference existed between women rowers who successfully completed the crew season and the rowers who did not complete the season, were accepted for calf circumferences. No significant difference was found among the three groups. The mean calf girth was comparable to runners and jumpers (32), and basketball players (1).

First and Second Measurements of Successful Rowers

Results from the two measurements on the rowers showed significant difference in terms of the variables which demonstrated a conditioning effect. The variables included two skinfolds and right knee widths, right calf circumference and estimated body fat.

Significant changes in the subscapular and suprailiac skinfolds revealed a reduction of subcutaneous fat at those particular sites. The non-significance of the triceps and biceps skinfold thicknesses was unexpected because of the constant use of the arms in the rowing action. Significance of the right calf circumference and the close significance of the left circumference indicated again in lower leg musculature, another required advantage for leverage in rowing.

Estimated percentage of body fat decrease was significant to indicate a gain in lean body mass which provides added strength needed for the action of rowing. One rower decreased from 29.5% fat to 23%. Several rowers decreased their body fat to 15% and 17% from 18% and 19%. The decreased value was comparable to the fat percentage possessed by Olympic caliber women athletes.

Skeletal assessments were not significantly different between the two measurements with exception to the right knee width. However, the correlation of several assessments was quite low, particularly the shoulder width value (r =.22).

This correlation could explain the comparison of shoulder width with the smaller body type of the gymnast. The low correlation may have reflected the inexperience of this investigator to the performance of body assessments.

With exception to a few variables, no significant difference existed between the successful and non-successful rowers or between the rowers and the non-rowers. Body measurements of the rowers were comparable to the athletes in volleyball, basketball, and track and field. However, no literature was available for comparison of the physical characteristics of the female rowers of this study to other competitive female rowers, particularly those of Olympic caliber.

A successful performance in rowing depends in part on leverage and strength. Compared to other athletes, the rowers of this study were found to possess long legs. In addition to the leg length measurements, arm length assessments were taken for potential attributes for analysis of mechanical efficiency for successful rowing. The width of the elbows were significantly greater for the rowers than the non-rowers.

The women rowers of this study were tall with long legs, narrower shoulders and broad hips. They were fairly lean and muscular, especially in the arms. According to Parizkova (36), the increase in lean body mass improved the performance of gymnasts. Body adaptation to intensive training increases the utilization of fatty acids in the muscle during intense muscular work (8).

Summary

Generally speaking no significant difference was found among the women rowers and between the women rowers and the non-rowers. However, in comparison to other athletes, the oarswomen were among the taller athletes with long legs, broad hips, and slightly, narrower shoulders. They were relatively lean and muscular, particularly in the upper arms. The rowers exhibited a conditioning effect due to the intense training required for the skill of rowing.

CHAPTER V

SUMMARY

Specific body types for certain sports provide an asset for successful performance. Little research existed in terms of physiques of successful women athletes, particularly studies on female rowers. This study was assumed to attempt to describe the physique of competitive women rowers.

The purpose of this study was to provide a descriptive analysis of the physique of female crew members. The objective of the investigation was to find the following: a) a significant difference of body measurements between female rowers and non-athletes, and b) a significant difference between women rowers who successfully completed the crew season and those rowers who did not.

Subjects employed in this study consisted of the students seeking position on the Oregon State University women's crew team during the 1978-1979 school year. The reference group consisted of women employees of EBI Companies. The women rowers were assessed a second time for observations of a conditioning effect. The interval of time between the first and second measurement was six months.

An analysis of variance was used to test the significant differences among group means. The hypotheses stated in Chapter I were tested by F values obtained through the statistical analysis. The required significance to reject the null hypotheses was selected at the 0.05 level of confidence.

A summary of conclusions and the relationship to the stated hypotheses are as follows:

1) The only significant differences found among the three groups for the skeletal measurements were the right bicondylar width of the femur, right and left humeral bicondylar breadth, and left arm length. The majority of the skeletal measurements were not significantly different among the groups.

2) No significance among group means was found between groups in terms of skinfold assessments or body fat percentage.

3) A significant difference was indicated between athletes and non-athletes for right and left upper arm circumferences, arm diameter and arm-muscle-bone diameter. The athletes did not differ significantly in any of the girth measurements.

4) A significant difference was found between the first and second assessments of the successful rowers for age, right femoral bicondylar breadth, right and left subscapular skinfold, right and left suprailiac skinfold, and body fat measurements.

RECOMMENDATIONS

The results of this investigation suggests possible recommendations for further study:

1) A biomechanical study of women rowers in relation to the body type.

2) A study relating physical characteristics with the physiological demands of rowing.

3) A study utilizing female subjects of Olympic caliber.

4) Studies similar to the present study should include additional physical measurements, particularly in relation to body segments.

5) A comparison of physical characteristics of letter winners and non-letter winners.

6) A study of physical characteristics of conference champions to non-champions.

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APPENDICES

APPENDIX A

OREGON STATE UNIVERSITY

Committee for Protection of Human Subjects

Summary of Review

Title: The Physique of Competitive College Female Crew Members

Program Director: Donald E. Campbell (Donalyn Hammer)

Recommendation:

XX Approval

_____ Provisional Approval

_____ Disapproval

_____ No Action

Remarks:

Date: February 27, 1979

Signature:

W. Ralph Shay
Assistant Dean of Research
Phone: 754-3437

cc: Committee Chairman

mep

APPENDIX B

ACKNOWLEDGEMENT OF WILLINGNESS TO PARTICIPATE

The undersigned acknowledges the willingness to volunteer as a participant in the study of body physiques begin conducted at Oregon State University during the Fall term of 1978. The subject will be measured at different sites of the body to accrue a number of body measurements. These measurements involve the use of a skinfold caliper and an anthropometer.

Research on the use of skinfold calipers and anthropometer has shown no risks or discomforts relative to the subjects. However, the subject is free to withdraw from the study at any time. All information will be anonymous. Any inquiries pertaining to the procedures or the research will be answered by the investigator on a one-to-one basis.

Signed ______________________

Date ______________________

Address ______________________

Phone ______________________

Age ______________________

APPENDIX C

APPENDIX C

Dear Crew Member:

As you know, in recent years women's sports has experienced a voluminous growth in both participants and in spectator interest. Silver medals in the 1975 World Games and the Montreal Olympics have inspired an increasing number of female athletes to participate in this fine sport, crew. Studies of both male and female athletes have shown that there are certain physical characteristics that are required by certain sports for a successful performance. Therefore, do female rowers require a specific physique which is conducive to a successful performance? It will be the goal of this study to investigate the physique of female rowers.

The intent of this research is to note a) if the women trying out for the varsity crew team differ significantly in physical characteristics from the non-athletes or general population; and b) if the physiques of rowers selected for the varsity crew team differ significantly from the rowers who were not selected.

The measurements to be performed in the study include:

a) The use of an anthropometer to assess the width of the shoulder and pelvis; the width of the elbow and knee; and the sitting and standing height.
b) The use of skinfold calipers to measure the thickness of two folds of skin over the site of the triceps (arm), biceps (arm), subscapular (shoulder blade), and suprailiac (outer part of the abdomen).
c) The use of a linen measuring tape to assess the circumference of the upper arm and calf.

These assessments require as little clothing as possible. Suggested items would include swim wear or dance leotards.

Measurements will be taken from 8:00 a.m. to 4:45 p.m. on Thursday, November 2, 1978 and Friday, November 3, 1978. On Thursday, the measurements will be performed in Room 203 of the Women's Building. On Friday, they will be taken in Room 13A of the Women's Building. Sign-up sheets to schedule time for measurements will be provided.

Thank you.

Sincerely,

Donalyn Hammer

APPENDIX D

APPENDIX D

Please sign up below for a convenient time to be measured. Measurements on Thursday, November 2, 1978 will be taken in Room 203 of the Women's Building. Friday's measurements will be performed in Room 13A of the Women's Building. Assessments will take approximately 15 minutes. Thank you.

Thursday		Friday	
8:00		8:00	
8:15		8:15	
8:30		8:30	
8:45		8:45	
9:00		9:00	
9:30		9:30	
9:45		9:45	
10:00		10:00	
10:15		10:15	
10:30		10:30	
11:00		11:00	
11:15		11:15	
11:30		11:30	
11:45		11:45	
12:00		12:00	
1:45		12:20	
2:00		12:45	
2:15		1:00	
2:30		1:15	
2:45		1:30	
3:15		2:15	
3:30		2:30	
3:45		2:45	
4:00		3:00	
4:15		3:15	
4:30		3:45	
		4:00	
		4:15	
		4:30	

APPENDIX E

APPENDIX E

PARTICIPANT____
Last First MI

Participant Number____

Best Event: 1st______________ 2nd______________ 3rd______________

Weight

Biacromial breadth ____________________ cm.

Bicristal breadth ____________________ cm.

Bicondylar breadth of femur R__________ cm.

L__________ cm.

Bicondylar breadth of humerus R__________ cm.

L__________ cm.

(Front)

Skinfold

Triceps R____________mm L____________mm

Biceps R____________mm L____________mm

Subscapular R____________mm L____________mm

Suprailiac R____________mm L____________mm

Circumference of Upper Arm R____________cm

L____________cm

Circumference of Calf R____________cm

L____________cm

Arm Diameter = $\frac{\text{Upper Arm Circumference}}{3.1416}$ = ____________cm

Arm-Muscle-Bone Diameter = Arm Diameter____________

less Triceps_____ = ______

(Reverse)