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RELATIONSHIP BETWEEN PHYSICAL CHARACTERISTICS AND 2K ROWING ERGOMETER PERFORMANCE IN COLLEGIATE FEMALE ROWERS

By

Rebecca A. Battista

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Kinesiology

2004

ABSTRACT

RELATIONSHIP BETWEEN PHYSICAL CHARACTERISTICS AND 2K ROWING ERGOMETER PERFORMANCE IN COLLEGIATE FEMALE ROWERS

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Physical characteristics such as body size, proportions, and composition are important determinants of athletic performance (Maestu, Jurimae, & Jurimae, 2000; Malina, 1995; Shephard, 1998). These determinants may be particularly important in a sport such as rowing where technique as well as teamwork and synchronicity within the boat or crew are critical. Large muscular body sizes, similar body proportions and composition of the crew may be the advantageous in sweep rowing due to the heaviness of the boat and in turn, the force needed to accelerate the boat through the water. Despite a significant increase in women's crew in the past two decades, no studies have evaluated physical characteristics of female collegiate rowers.

The purposes of this study were to describe and compare the physical and functional characteristics of female collegiate rowers by level (novice versus varsity) and by year of college rowing experience (0, 1, 2 and 3 years), and to estimate the contribution of these characteristics to 2 kilometer (K) rowing performance. Participants included 90 female collegiate rowers from three Big Ten universities. Physical characteristics measured included: height, weight, sitting height, arm span, skinfolds, limb circumferences, skeletal breadths, low back flexibility, and vertical jump. Physical characteristics derived included: leg length, sitting height to height ratio, arm span to height ratio, sum of trunk and extremity adiposity, body composition, leg power and somatotype. The performance measure was a timed 2K race (seconds) on a rowing

ergometer. Descriptive statistics were performed for the total group, varsity and novice levels, and years of experience. A MANOVA ($P<0.05$) and a Bonferoni adjusted alpha level were used to determine differences between novice and varsity rowers and among years of rowing experience. For the prediction aspect of the study, a stepwise regression analysis was used to determine 2K time from physical characteristics.

The results indicated significant differences between novice and varsity rowers in years of rowing experience prior to college, vertical jump, 2K time and endomorphy. Varsity rowers had significantly more years of experience prior to entering college, significantly higher vertical jumps, and significantly faster 2K times. Among years of rowing experience, year 0 rowers were significantly slower versus year 3 rowers and year 2 rowers were significantly shorter versus year 2 rowers. Regression analysis revealed fat-free mass, experience in college rowing, height and years experience prior to rowing in college accounted for 57% of the variance ($r = 0.75$, $r^2 = 0.57$) in 2K performance time.

The primary implication from this study is that as an athlete progresses through a collegiate rowing career, her performance will improve. Improvement in performance may be a result of changes in fat-free mass and increased years of training and experience. Future studies should include longitudinal designs to observe changes in rowers' performance as impacted by training and improvement in technique over the course of a collegiate career.

ACKNOWLEDGEMENTS

There are many people who contributed to my completion of this degree. First and foremost I would like the thank the members of my dissertation committee, Jim Pivarnik, Gail Dummer, Bob Malina, and Norm Sauer. They are certainly appreciated for all of their time and effort toward the completion of my degree. A special thank you to Jim Pivarnik and Gail Dummer who somewhat "adopted" me over the past two years.

I would also like to thank my friends and colleagues for their undying support. First to my colleagues, who have encouraged me and supported me over my entire graduate career. This includes Jeremy Knous for his help in recording data for this project and Patti Bauer, my marathon training partner, and often sounding board during the 4 years here at Michigan State. Second, I would like to thank my friends for their never ending support, love and even harassment for being a student for over 12 years. Third, I would like to thank my roommate, colleague, and dear friend Cooker Perkins, for her support, encouragement and her uncanny ability to deal with me at times. And to my best friend Pam VanSant, who always been there for me offering never ending words of encouragement and support through all of my life changes.

I would also like to thank my undergraduate advisor from Lock Haven University, Jim Dolan, whom without his belief in me, I honestly would not be where I am today.

And last but certainly not least, I would like to thank my family. To my parents, Bill and Rosanne Battista, and my brother, Billy Battista. I thank you from the bottom of my heart for all the years of support, encouragement and, love. Without my family I would have never have had the many opportunities to pursue my dreams and turn them into reality. Thank you.

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Chapter 1

Introduction

Physical characteristics such as body size, proportions, and composition are important determinants of athletic performance, in addition to specific sports skills and training (Maestu, Jurimae, & Jurimae, 2000; Malina, 1995; Shephard, 1998). Demands of a sport may, in fact, dictate the morphology or physical make-up of the athlete who is likely to excel in the sport. For example, cross country runners are, on average, relatively short and light weight; basketball players are tall; throwers are tall and heavy; and swimmers are tall with relatively long arms. In a sport such as rowing, where proper technique is essential for high level performance, body size and proportions may be important for success. For example, skills necessary for sweep rowing typically require athletes with large body sizes (tall, heavy, etc.). A large body size is an advantageous physical characteristic of a sweep rower due to the heavy weight of the sweep boat and in turn the force needed to move the boat through the water (Secher, 1990; Shephard, 1998). A large body size includes characteristics such as height and weight greater than average and a muscular physique.

In addition to body size, body proportions may also be important in rowing. Proportions refer to relationships between different segments of the body. In the case of rowing, arm span relative to height and sitting height relative to height. With each stroke taken, the rower must exert sufficient force to reaccelerate the boat. Having long arms and long legs, hence long levers, increases the biomechanical advantage for sweep rowing (Bloomfield, Blanksby, & Elliott, 1973; Claessens et al., 2002).

Quantifying the physical characteristics of rowers and relating them to actual performances can be beneficial to a coach in terms of identification of potential talent and to an athlete in terms of potential success in the sport. This study focuses on physical characteristics (body size, segment length, limb circumferences, subcutaneous fatness), body proportions (sitting height to height ratio, arm span to height ratio), physique (somatotype), estimated body composition (fat mass, fat-free mass, percent body fat), power (vertical jump), flexibility (low back flexibility) and performance (2 kilometer ergometer time [2K]) of female collegiate rowers.

It is difficult for coaches to assess specific physical characteristics when deciding which athletes make a team, which athletes actually race in varsity and novice boats, and which athletes are assigned to specific positions. The task is daunting given the number of important variables, the short time period available for try outs, the number of athletes on a team and often their relative inexperience. A collegiate rowing team typically consists of approximately 40 to 80 women split into novice and varsity levels. Novice is defined as an athlete in her first year of collegiate rowing, while varsity is defined as an athlete in her second, third or fourth year of rowing. Most novices have never rowed prior to joining the intercollegiate team.

The top two boats from each level participate in collegiate rowing competitions. The top competitive boats for the varsity consist of 2 boats of 8 women (first varsity 8 and second varsity 8) and 2 boats of 4 women (first varsity 4 and second varsity 4). At the novice level, only 2 competitive boats consisting of 8 women (first novice 8 and second novice 8) ordinarily race. In other words, even though there may be 40 or more women in each respective level, only 24 will race for varsity, and for novice, only 16 will race. Therefore, coaches need a reasonably accurate, efficient and easy to administer screening tool to help determine tryout outcomes (on/off team), team status (competing/not competing), boat status (novice/varsity) and seat position (1 through 8). In this context, an evaluation of physical characteristics may be an asset for a coach to determine potential successful rowers for his/her team.

An experienced rowing coach may be subjective in his/her selection process and rely more on "eyeballing" qualities which he/she believes to be important in rowing performance. Perhaps anthropometry or easily obtainable field measures such as flexibility or vertical jump, may provide the coach with more objective tools to help identify future novice and varsity members, boat status, and seat position.

Significance of the Problem

Women's involvement in rowing has increased tremendously in the past 20 years. Among the advances in women's rowing include its recognition as an Olympic sport at the 1976 Olympic Games. In addition, the enactment of Title IX in 1972 (although it was not put into effect until 1975) may have influenced women's rowing by causing an increase in the number of collegiate teams. There can be as many as 80 women on a collegiate rowing team which ultimately increases the total number of athletes per school. This increase in female athletes helps athletic departments achieve compliance with Title IX. Further, the NCAA designated women's open weight rowing as an NCAA sanctioned sport in 1996.

The sport of rowing is unique in that it relies heavily on teamwork and synchronicity. Women's collegiate rowing has sweep boats of 8 or 4 athletes plus a coxswain. In order to move the boat through the water, each rower must perform the rowing stroke together. The movement of the boat through the water should be a continuous fluid motion at a consistent speed. Ideally, rowers with different leg and arm lengths adjust to each other in order to maximize speed potential. Therefore selecting athletes of similar sizes for each boat may promote the synchronicity required for successful rowing.

The combination of the increase in number of collegiate women's rowing teams and the uniqueness of the sport present the coach with the problem of recruitment and evaluation of the most capable female athletes to fit their novice and varsity teams. Coaches' decisions about tryout outcomes, team status, boat status, and seat position are important to a team's success. Success depends on the goals set forth by the respective coach and team. Success may include placing in the top half of the respective conference, placing at the regional championships and/or qualifying for the national championships. To a coach, success in rowing competitions is related to recruiting possibilities, as well as the financial support received from the athletic department, university, and community. To an athlete, success in rowing begins with making the team and being assigned to a competitive boat. Those who make the team and are assigned to the competitive boats are more likely to receive more coaching attention, and have opportunities to advance to higher levels (e.g., all-star or national or international teams).

Purposes of the Study

The purposes of the study were:

1. To describe the physical and functional characteristics of female collegiate rowers.

2. To compare the physical and functional characteristics of female collegiate rowers by level (novice versus varsity) and by year of college rowing experience (0, 1, 2 and 3 years).

3. To estimate the contribution of physical and functional body characteristics to two kilometer rowing performance.

Need for the Study

Women's rowing at the collegiate level is growing, as evidenced by the increasing number of teams and the size of teams. Many university athletic departments encourage large numbers on a team in an effort to help the entire athletic department comply with NCAA Title IX regulations. Coaches cannot rely totally on recruitment due to the limited number of high school rowing teams. As a result, they hold try outs which attract many potential athletes. This process may present a coach with a difficult task, objectively identifying the important physical characteristics of potential athletes; specifically which athletes make the team and, eventually, which athletes will participate in the competitions.

The difficulty in selecting potential athletes for rowing lies in the composition of a collegiate women's team. While rowing level is determined by years of experience, the coach decides placement into a specific boat within each level (competitive versus non-competitive) and seat position (seat one versus seat eight) in that boat. The current study was designed to examine the potential benefits of using a more objective or scientific basis versus subjective ("eyeball") basis of selecting athletes for the team. In addition to selection for the team, placement within a specific boat as well as in a specific seat position may also be affected.

Evaluating and selecting certain physical characteristics is important because not all body types are equally suited to the high intensity training demands of the sport (Secher, 1990; Shephard, 1998). Quantifying physical characteristics and using them to predict success may help a coach more objectively select potential novice and varsity athletes. The process would also provide the athlete with more definitive criteria of what may be important to make a collegiate team, competitive boat, or seat position in the boat. However, an athlete who exhibits none of these physical characteristics and still makes the team may compensate in another manner (e.g., having a short stature but compensating with strong, powerful legs).

Coaches would prefer to use practice time for conditioning and technique instruction rather than assessment of athletes. This concern is exacerbated by the NCAA limits placed on training time. Assessment of the characteristics of rowers should provide a coach with more time for conditioning and instruction.

Success in rowing is dependent on physiological (aerobic and anaerobic capacity), functional (power, speed), physical (e.g., anthropometry, somatotype, body composition), and behavioral characteristics, among other factors. However, it is also important to study physical characteristics because body size is related to strength and mechanical leverage, total weight of a boat and, in turn, drag of the boat through the water (Secher, 1990; Shephard, 1998). Currently, there is relatively little research describing the collegiate female rower and the relationship between her physical characteristics and performance.

As noted earlier, growth and increased popularity of women's rowing in the United States is to a large extent a result of attempts to maintain compliance with Title

IX. The addition of women's rowing as a varsity sport has significantly increased the total number of female athletes per school. For example, from 1981- 2000, the number of NCAA sanctioned women's rowing teams has increased dramatically (Division I, from 28 to 80 teams, Divisions II and III from 43 to 132 teams). The trend has been accompanied by an expansion of individual members per squad (Division I, from 30.8 to 54.7 members, Divisions II and III, from 27.6 to 46.3 members) (Bray, 2002). As a result of the increased interest in collegiate women's rowing, there are pressures for coaches to not only recruit large numbers of women, but also to retain them throughout a season and a collegiate athletic career.

The combination of issues surrounding the increase in numbers of collegiate teams and the uniqueness of the sport in its composition, competitions, and training, present the coach with the problem of recruiting and evaluating the most capable women to fit both novice and varsity teams. Therefore, the general intent of this study is first, to describe the female collegiate rower, and second, to evaluate the relationship between physical characteristics and performance.

Research Questions

Characteristics of Rowers

1. What are the physical characteristics of female collegiate rowers?

2. Among female collegiate Big Ten rowers, do varsity athletes differ from novice athletes in physical characteristics, body proportions, somatotype, body composition, relative muscularity, flexibility, leg power, and 2K rowing ergometer performance?

3. Among female collegiate Big Ten rowers, do athletes with 0, 1, 2, and 3 years of collegiate rowing experience differ in physical characteristics, body proportions,

somatotype, body composition, relative muscularity, flexibility, leg power, and 2K rowing ergometer performance?

Prediction of Rowing Performances

After determining possible correlations among variables:

4. What are the estimated contributions of physical characteristics, body proportions, body composition, somatotype, relative muscularity, flexibility, and leg power of female collegiate rowers to 2K rowing ergometer performance?

Delimitations

The study is delimited to the following:

1. Participants included female collegiate rowers who were members of Big Ten university women's rowing teams at the time of data collection. The Big Ten Conference is comprised of six varsity level women's rowing teams that compete in the Midwest Region. The Big Ten Conference is considered an elite conference because it has consistently placed at least three teams in the top 12 at the NCAA Championships within the past 2 years. For example, at the 2003 NCAA Championships, the University of Michigan placed fourth, Ohio State University placed eighth and Michigan State University placed eleventh.

2. Anthropometric dimensions were measured according to established techniques described by Lohman, Roche, and Martorell (1988).

3. The rowing ergometer is a training method used during the off-season and can be used as an indicator of actual racing performance. The rowing ergometer reports total time (seconds), power (watts), and stroke rate (strokes per minute).

4. Testing occurred at Michigan State University, the University of Michigan, and Indiana University.

Limitations

The study is limited by the following:

1. The sample was a cross-sectional representation of female collegiate rowers across years of experience or participation. As such, there is variation in age and experience.
2. Some participants during the course of the research project may have left or quit the team for various reasons. Some reasons may include the requirements and rigors of the sport, including coaching staff, training demands, academics, or being cut from the team.
3. Due to the use of more than one collegiate team, there was the possibility of variation in training protocols among the teams. Examples of training differences may be in the form of volume of work, amount of time spent on the water versus ergometers, weight training, and/or philosophical differences among coaches.
4. Considering the different experience level between the novice and varsity rowers, there will be training differences. During most of the year, novice and varsity rowers train similarly; however, technique is stressed at the novice level, with less emphasis on training volume.
5. Measurements were taken at the beginning of the spring racing season and two kilometer ergometer times were taken at the end of the preseason dry land training (March/April 2004).

Assumptions

It was assumed that:

1. All instruments (standing anthropometer, scale, tape measure, sliding calipers, skinfold calipers, sit and reach box, wall stadiometer, Concept II ergometer) used for measuring the variables were valid and reliable. The technician was consistent for each testing procedure.

2. There were no differences between the rowers from Indiana University, the University of Michigan and Michigan State University.

2. All participants were cooperative and motivated throughout the testing sessions.

3. The coach regularly conducted a 2K rowing ergometer test for each rower.

Definition of Terms

The following terms are defined to clarify their use in the study:

Anaerobic power. The power estimated from vertical jump, used to estimate leg power (Adams, 1994).

Anthropometry. A series of specific techniques used for measuring specific dimensions of the body (Lohman et al., 1988; Malina, 1995).

Body proportions. The relationship between specific pairs of linear anthropometric dimensions e.g. ratio of sitting height to height (Malina, 1995).

Body composition. The estimated composition of the body compartments expressed as fat mass and fat-free mass (Lohman et al., 1988; Malina, 1995).

Coxswain. The on-water rowing coach and the person responsible for steering the boat (US Rowing, 2002).

Flexibility. The range of motion of the lower back (flexion) as measured by the standard sit and reach test (Adams, 1994).

Junior level. A rower age 17 years or younger.

Novice. An athlete in her first year of collegiate rowing.

Physique. An individual's body form, or make-up of the entire body, most often expressed as somatotype (Malina, 1995).

Performance. A 2K timed row on a rowing ergometer.

Sculling. A rower that uses two oars or holds one oar in each hand. Scullers row in singles, doubles, and quads. (US Rowing, 2002).

Senior level. A rower age 18 or older.

Somatotype. An estimation of physique based on the contribution of three components: endomorphy (roundness), mesomorphy (muscularity), and ectomorphy (linearity) (Carter & Heath, 1990).

Successful. Placing in the top half of the respective conference, placing in the top half at the regional championships and/or qualifying for the NCAA championships.

Sweep. Rowers that use only one oar or hold one oar with both hands. Sweep rowers row in pairs, fours and eights. (US Rowing, 2002).

Varsity. An athlete in her second, third, or fourth year of collegiate rowing.

VO_2max. A person's capacity for aerobic metabolism during exercise.

CHAPTER 2

Review of Literature

Introduction

While the sport of rowing has been around the United States for approximately 200 years, involvement of women in the sport did not accelerate until the last 40-50 years. Rowing began to develop as a sport in the early 1800's, with the first boat club in the United States appearing in 1834 in the New York harbor. In 1872 a National Governing Body for rowing was established. This was the first National Governing Body for a sport in the United States. Whereas, women were rowing as early as 1877 at Wellesley College, primarily to be "healthful and recreational," it was not until 1962 that the National Women's Rowing association was established. Finally, women's rowing was introduced as an Olympic sport at the 1976 Montreal Olympic Games (US Rowing, 2002).

Women's rowing has grown considerably in the past 20 years at the collegiate level. As a result of the enactment of the Title IX legislation and more recently increased enforcement of the law, many universities have added women's rowing as a varsity sport. With such a large increase in collegiate women's rowing, it is important to understand the sport in terms of the physical and physiological demands placed on the athlete. While many investigators have evaluated rowers in terms of physiological characteristics, few have observed their physical characteristics. The studies that have considered physical characteristics have mainly been done on elite level and collegiate males, (Bourgois et al., 2001; Bourgois et al., 2000) and on junior elite level males and females (Claessens et al., 2002). The Montreal Olympic Games Anthropological Project (MOGAP) focused in part on the physical characteristics of female rowers (Hebbelink, Ross, Carter, & Borms, 1980). To this date, no study has evaluated the relationship of physical characteristics to performance in female collegiate rowers.

The focus of this literature review is to initially describe the sport of rowing and its unique demands placed on the athletes. The review then explores other sports that have used physical characteristics to estimate variation in performance.

Collegiate Rowing and Racing

Collegiate rowing competitions consist of sweep rowing, which involves a shell (boat) with one oar for each individual. The athletes are considered part of a "crew" and are identified according to position in the boat. They sit in configurations that have oars on alternate sides along the boat (port or left side and starboard or right side).

A collegiate team consists of crews of 8 or 4 athletes with a coxswain. The coxswain steers the boat and acts as an on-water coach. The eight person boats are approximately 60 feet long and weigh over 200 pounds whereas the four person boats are approximately 50 feet long and weigh over 100 pounds (M.Weise, Head Coach, Michigan State University, personal communication, June 11, 2004). To generate enough force to move the mass of the boat, including eight individuals in the boat, and to reaccelerate the boat through the water after each stroke, rowers may need to be tall and heavy. The additional weight of the coxswain adds additional drag and causes the crew to work harder.

Typical collegiate competitions consist of 2K races in 8 and 4 person sweep boats. Races usually are 6 to 7 minutes in duration. Racing in a collegiate competition consists of only the top two boats from each level from each participating school. Athletes are divided into two levels, novice and varsity. A novice level rower is one who has no collegiate rowing experience while a varsity level rower has one or more years of collegiate rowing experience. Varsity teams are allowed to race in boats of 8 and boats of 4 athletes while novice teams only officially race in boats of 8. These boats are called the first varsity 8, second varsity 8, first varsity 4, second varsity 4, first novice 8 and second novice 8. These top crews are the ones who participate in the racing competition. Considering there are approximately 40 to 80 athletes on each team, and only 24 athletes may race in varsity and 16 athletes may race in novice, this makes each athlete want to be in one of these top boats regardless of her team status.

Participating in the first or second 8 boats is important. Athletes also compete for seat positions. The seat position or number in the boat is also important. In an 8 person boat, the first person to cross the finish line is called the bow, while the last person to cross the finish line is called the stroke. The stroke is considered the most important member of the crew as she sets the rhythm of the boat. This individual is typically the most knowledgeable about rowing, the strongest in the boat, and has the best technique. Seat position in the boat moves down from the stern where the stroke or the number eight position sits, to the bow or the number one position. Seat positions are set up in pairs because each seat holds one oar. Even numbered seats hold the oar on the port (left) side while the odd numbered seats hold the oar on the starboard (right) side of the boat. While deciding whether an athlete should row port or starboard is not apparently a critical component, placing athletes into pairs or partners and in an appropriate order in the boat may be critical.

Elite Male and Female Rowers

Both male and female rowers are typically taller and heavier, have smaller skinfolds, longer limb lengths and greater limb circumferences, and lower percent body fat compared to average individuals (Bourgois et al., 2000; Bourgois et al., 2001; Hebbelinck et al., 1980; Ross, Ward, Leahy, & Day, 1982). With age of menarche as the criterion, elite female rowers tend to be average ("on time") in maturity status compared to non-athletes. Claessens et al. (2001, 2003) reported an age of menarche for elite level female junior rowers (N = 220) of 12.75 ± 1.2 years of age, which is comparable to the Flemish population (12.91 ± 1.3 years). Olympic rowers and canoeists at the Montreal Olympic Games had an age at menarche of 13.7 ± 1.1 years, which was slightly later than non-athletes (Malina, Bouchard, Shoup, Demirjian, & Lariviere, 1982). While elite female rowers may tend to be taller, heavier and generally larger versus the average individual, they are also of average maturity status, attaining menarche between 12.00 to 13.99 years of age (Malina, Bouchard, & Bar-Or, 2004).

Physical characteristics discriminate an elite male rower from a lower level male rower. At the junior level, more elite rowers show greater differences in physical characteristics compared to lower level rowers. In a large sample (N = 383) of junior level rowers, age 17.8 ± 0.7 years, the elite level male rowers, those ranked in the top 6 at the 1997 World Junior Rowing Championships, were characterized by greater heights, larger skeletal robustness, and greater muscle development compared to the remaining rowers participating at the championships. When finalists versus non-finalists were compared at the 1997 World Junior Rowing Championships, the former had significantly larger leg and arm lengths, biacromial breadths, arm and thigh girths, and body mass. Of interest, only one skinfold (triceps) showed a significant difference between finalists and non-finalists. Relative to the rowing stroke, rowers having longer legs may be at an advantage in that this characteristic may potentially increase the leg and drive phase of the rowing stroke (Bourgois et al., 2000). The advantages in size of more elite compared to lower level rowers may benefit rowing performance.

Characteristics that predict success in older male rowers are similar to those of the younger group in terms of larger body sizes. Among 48 Australian male rowers, height and weight-for-height were determinants in predicting top level performances. Of the six boats participating in a competition, the top three boats consisted of males who were taller and heavier, had a better index of body build [height (in)/ 22 * weight (lbs)], and a greater, estimated surface area, and a greater biacromial breadth (Bloomfield et al., 1973). However, the differences were simply plotted as standardized scores from the mean and standard deviation of the entire group and not statistically tested.

Female rowers at the Montreal Olympic Games showed similar trends in physical characteristics (Hebbelink et al., 1980) as evident in male rowers. Compared to male rowers, females were not different in proportion of body mass, but did differ in other physical characteristics. While male rowers showed greater skeletal breadths, segment lengths, and upper body girths compared to female rowers (Ross et al., 1982), these characteristics were larger in the female rowers compared to female non-rowers. Female rowers also had sum of skinfolds similar to canoeists and swimmers in the Montreal Olympic athlete sample (Carter, 1982).

Elite level junior and senior level rowers also show similar physical characteristics including large body sizes and muscular physiques. Female Olympic rowers at the Montreal Olympic Games were, on average, 23.8 years old, 174.3 cm tall, weighed 67.4 kg and were classified as mesomorphic and endomorphic (Carter, Sleet, & Climie, 1982). At the 1997 FISA World Rowing Championships, elite level junior rowers were on average, 17.5 years old, 174.9 cm tall, weighed 69.5 kg and were classified as mesomorphic and endomorphic (Claessens et al., 2002).

Delineating rowers by level, or in terms of finalist or non-finalist, differences also appear. As with the males, finalist female junior rowers were taller and heavier, had longer arms and legs, and larger girths (biceps flexed and relaxed, forearm and thigh) (Bourgois et al., 2001). They also had a greater arm muscle area and greater fat-free mass (Claessens et al., 2002). The heavier body weight of female rowers was probably due to a large, fat-free mass component (Claessens et al., 2002).

While height, weight, and proportions of limb lengths are important from a biomechanical perspective, body composition is also important physiologically. Partitioning the physical characteristics in terms of muscle mass and fat mass can help in understanding the qualities necessary to be successful in the sport. For example, in a study of male national team (Sweden) members, peak strength depended on muscle quantity not muscle quality (Larsson & Forsberg, 1980). Quantity of muscle was determined by the amount of muscle, while quality was determined by the fiber type, either fast or slow twitch that predominates in the muscle area. In this study, the quality of the muscle in the leg and arm consisted of predominately aerobic or slow twitch fibers. However, a strength test elicited such high peak strength values that the authors suggested it was the quantity of muscle, or the amount of muscle mass, versus the quality of muscle, that resulted in higher strength values in contrast to the quality of muscle, or the fact that the muscle consisted of predominately made of more aerobic fibers. This result was not expected. The authors noted that athletes with a large muscle mass and a high level of strength are usually characterized by a higher proportion of fast twitch or anaerobic fibers. This suggests that the amount of muscle mass seen in elite male rowers is important to success in rowing.

In lightweight rowing, thigh muscle mass is also often viewed as important. Male and female lightweight rowers had thigh girths and thigh lengths similar to Olympic rowers, suggesting that muscle mass may be the critical unit to rowing regardless of weight restriction (DeRose, Crawford, Kerr, Ward, & Ross, 1989).

As in many sports, there are different competitive levels in rowing. Levels are often associated with age, and athletes at lower levels are typically younger. Novices are typically the youngest as well as the least experienced among collegiate rowers. Therefore, age and level are important considerations in comparisons of rowers in predicting performance. For example, in a comparison of male rowers at three different ages and levels, physical characteristics were relatively more important in predicting performance in rowers 19-23 years, while biological and psychological factors were relatively more important in predicting the performance in the youngest (<19 years) and oldest (>23 years) rowers (Williams, 1977). In this study physical characteristics included height, weight, skinfolds, limb circumferences, and skeletal breadths while biological characteristics included heart rates at a given stroke rate during a six minute rowing ergometer performance. In an example of differences between levels of rowers, Claessens et al. (2001) showed elite level junior rowers of both sexes had specific morphological characteristics that differed among competition level (finalists versus non-finalists) (Claessens et al., 2001). Nonetheless, predictors of performance may vary with age and level of the rowers.

Variability among individuals within a boat may also be a factor in determining differences in physical characteristics, such as body composition, of rowers. Fifteen British female rowers (age = 26.3 ± 3.5 years) were measured for body composition using various methods, which included body mass index (BMI), skinfolds, densitometry, total body potassium, and bioelectrical impedance (BIA). After estimating body composition from the various methods, the authors concluded that: (a) the BMI was not a valid measure of body composition for rowers; (b) each body composition measure should be referenced against a norm or "gold standard"; and (c) it may be more beneficial to estimate the average percent body fat of athletes within a boat instead of by individual athletes due to the variability within a boat (Pacy et al., 1995). Coaches may view body composition in terms of an optimal level of leanness essential for successful performance. However, Pacy et al. (1995) emphasize that setting a standard body composition for a team may not be recommended. Individual differences are considerable so that a single standard may be misleading. One implication from this study suggests presenting individual estimates or averages in different manners. For example, estimates may be expressed according to a boat average instead of an individual or team average. This may decrease the amount of variability that may be seen in estimates of body composition among members of a large team.

Physical Characteristics and Rowing Performance

Understanding relationships between physical characteristics and sport-specific indicators of performance may provide insights into selection and coaching. Height, body composition (percentage fat, fat-free mass, muscle mass), skeletal structure, limb lengths, and overall physique are physical characteristics that may influence athletic performance in male and female athletes. Sport-specific requirements including motor skills, unique physiological demands, and biomechanical factors also contribute to the profile of a successful athlete in a sport.

Athletes in various sports have different physical and physiological profiles. Prudent use of such profiles may be useful in identifying individuals who have the potential to excel in a specific sport. Inter-individual variability probably reflects the specific demands of a sport as well as the position or specialty within a sport. Further, athletes at different levels in a sport may have similar physical and physiological characteristics, but may differ in the expression of traits and expected degree of association with functional demands (Carter, 1985; Hawes and Sovak, 1994).

The ability to understand how physical size can impact performance requires appreciation of both the biomechanical requirements of the sport and the physiological demands placed on the athlete (Carter, 1985). A sport that depends on a great deal on leverage may require a certain height for success, i.e., longer limbs potentially offer a greater biomechanical advantage. Body mass generally relates to physiological demands so that the proportion of mass that is fat versus fat-free mass may affect maximal oxygen consumption (Carter, 1985). And it is well documented that fat-free mass includes a major proportion of muscle tissue that is related to muscular strength.

Applications to Rowing

Body mass and, more specifically, the composition of body mass may contribute significantly to rowing performance. In a study of male rowers, body mass was one variable that predicted performance but weight-for-height was also an important predictor (Bloomfield et al., 1973). This suggests that absolute mass per se is central to rowing performance and that the proportion of mass to height is also important. Body mass was also an important predictor of 2K rowing ergometer time (r = -0.41) in elite schoolboy rowers (Russel et al., 1998), but body mass, the sum of eight skinfolds and height combined, accounted for 68% of the variance in 2K ergometer time in the schoolboy rowers. In contrast, metabolic variables including maximal oxygen consumption (VO_2 max), accumulated oxygen deficit, and net efficiency, accounted for only 25% of the variance in the schoolboy rowers (Russell et al., 1998). Of course, body mass includes fat mass and fat-free mass, and the absolute amount of fat-free mass is also an important predictor of rowing performance (Maestu et al., 2000). Fat-free mass is related to VO_2 max, which is a predictor of rowing performance. Further, in male light- and heavy-weight rowers who trained for five years, muscle mass was significantly related to VO_2 max. In female rowers, VO_2 max and experience explained 74% of the variance in predicting performance from 2500 meter (M) time (Kramer et al., 1994). With VO_2max being a significant predictor of rowing performance, and with the high correlation between fat-free mass and VO_2max, fat-free mass is perhaps the component of body mass that is the significant predictor of performance in rowers.

Other factors may also contribute to rowing performance. Experience in the sport, rank assigned by coaches, and VO_2max are significant predictors of 2500 M time (Kramer et al., 1994). Among male rowers, a timed test on a rowing ergometer differentiated those who made the Olympic team versus those who did not (Hagerman, Addington, & Gaensler, 1972). Faster times on the ergometer characterized the Olympic selections. Hence, a relatively simple test such as a timed row on an ergometer may be an appropriate variable as a study of predictors of rowing performance.

The relative distribution of muscle mass i.e., regional variation in the development of muscle throughout the body may also be an important factor in rowing performance. Specifically, power generated by muscles of the thigh region is important to rowing performance. The best predictors of success in male rowers were thigh muscle mass and cross-sectional area (Maestu et al., 2000). Lightweight female rowers at the X^{th} Pan American Games had similar thigh girths and lengths as heavyweight Olympic female rowers at the Montreal Games (DeRose et al., 1989). The similarities between lightweight and heavyweight female rowers suggest that muscle mass of the thigh region is important to success in the sport regardless of weight restriction associated with the former (DeRose et al., 1989). Thigh length, girth, and skinfolds may provide a non-invasive and useful estimate of muscle mass of the thigh for use with rowers.

Performance Predictors

An understanding of relationships between physical characteristics and rowing performance is potentially useful for a coach. For example, several anthropometric dimensions (height, weight, sitting height, skinfolds, circumference, skeletal breadths) and Heath-Carter anthropometric somatotypes were used to predict 10K race time in adult males (42.7 ± 10.3 years) and females (39.7 ± 9.2 years). Somatotype and the BMI were the significant contributors to running performance (Berg, Latin & Coffey, 1998). Endomorphy accounted for 41% of the variance in 10K time in females, while the BMI and mesomorphy accounted for 38% of the variance in 10K time for males. When male and female runners were combined in the analysis, only endomorphy contributed (22%) to 10K time.

A variety of anthropometric dimensions and derived indices were used to predict performance scores (as assigned by judges) of female artistic gymnasts (13.2-23.8 years) at a world championship competition (Claessens, Lefevre, Beunen, & Malina, 1999). There were significant negative correlations between the total performance score and skinfolds, endomorphy, body mass, and limb lengths and girths. However, most of the variance (32-46%) was explained by endomorphy and age. Endomorphy had a negative influence while age had a positive influence. Age probably corresponds to experience, with older competitors performing better than younger competitors. The negative contribution of endomorphy was somewhat surprising because female gymnasts as a group are not endomorphic. This raises the potential problem of judges (consciously or subconsciously) using a component of physique in assigning scores to performances.

Among elite level modern pentathletes, the only significant correlates of overall performance were dimensions related to fatness i.e., most skinfolds, predicted body density, percent fat, and endomorphy (Claessens, Hlatky, Lefevre, & Holdhaus, 1994). Using the total score in the five events as the criterion, the sum of 10 skinfolds had a negative influence while biacromial and epicondylar breadths had a positive influence.

Physical and physiological characteristics were related to a 200 m race time in 26 elite level sprint kayakers (Von Someran & Palmer, 2003). Relaxed and flexed upper arm and forearm circumferences, chest circumference and epicondylar breadth were negatively related to performance time (a lower time indicates better performance so larger dimensions are positively related to sprint performance), but did not contribute significantly to the explained variance. Rather, only a modified Wingate test, a measure of anaerobic power, accounted for 53% of the variance in sprint time. When the sprinters were classified as national and international caliber, epicondylar breadth of the humerus was a significant predictor of sprint performance ($r^2 = 0.52$) in the latter. The authors suggested even though arm and forearm circumferences (indicators of muscularity) did not add to the explained variance in performance in all sprinters, the significant relationship of arm and forearm circumferences to performance and the importance of the biepicondylar breadth to the performance of international caliber kayak sprinters emphasizes the importance of the morphology of the upper extremity in kayak sprint performance. By inference, dimensions of the upper limb may also have implications for rowing performance.

In a similar study, a variety of physiological tests and physical fitness measures were used to predict 7K race time in male endurance kayakers (Oliver & Coetsee, 2002). Relative VO_2 max estimated with an arm crank ergometry task had a significant positive relationship to race performance. Number of triceps dips and flexibility (sit and reach test) had a high negative relationship to race performance, indicating a positive association between upper body muscular strength and endurance (dips) and lower back flexibility and performance (note, a lower time is a better performance). Relative VO_2max based on the arm ergometer task was the best predictor of performance time and accounted for 66% of the variance. Number of dips significantly added to the explained variance, increasing it to 76%.

In a sample of 19 young elite male rowers (18 ± 2 years) anthropometric and physiological measures were used to predict 2K time on a rowing ergometer (Russell et al., 1998). There were significant inverse correlations between performance and absolute VO_2 max, knee extension strength and body mass meaning that as rowing time decreased, fitness, strength, and size increased. Subsequent analysis grouped variables into three categories in an attempt to predict 2K rowing performance: metabolic (absolute VO_2 max, aerobic oxygen efficiency, net efficiency), metabolic and anthropometric combined (body mass, absolute VO_2 max, skinfolds), and anthropometric (skinfolds, height, body mass). Anthropometric characteristics alone accounted for the largest proportion of variation in 2K ergometer performance (68%). In contrast, metabolic variables alone and the combination of metabolic and anthropometric variables accounted for 25% and 63% of the variance, respectively (Russell et al., 1998).

Summary

Physical characteristics are significantly related to successful performance in a variety of sports. Physiological characteristics are also related to success in several sports, especially those similar to rowing. Fat-free mass as it relates to maximal aerobic capacity is of specific importance.

Physical characteristics including height, absolutely and relatively long arms and long legs, and large thigh girths may be important for success in collegiate rowing. Estimated fat-free mass is another variable of importance. Although the physical characteristics of elite level female rowers have been reported, they are limited largely to international level competitors. The present study considers the physical characteristics of female collegiate rowers and also attempts to estimate the significance of the characteristics to rowing performance.

As noted earlier, level of competition and age are potentially important determinants of rowing performance. Rowers who differ in level of performance (e.g., higher versus lower levels) may differ in physical and/or physiological characteristics. The differences may reflect fewer years of experience and younger ages by inference less sport-specific training in rowing. Given the relative novelty of collegiate rowing for women and a relative lack of competitive rowing at the high school level, this may be the case. Novice collegiate rowers are younger and less experienced, and many are experiencing the sport for the first time. The present study uses a cross sectional approach to evaluate differences in physical characteristics and performance among collegiate rowers by level and age.

Rowing depends on the synchrony of each member of the boat. The rowers must move the mass of the boat through the water, and this requires in part physically large individuals. Previous research has identified height, body mass, limb lengths, limb circumferences, and skinfolds as important in rowing performance. These variables and several derived variables (e.g., somatotype) are incorporated into the present study, in addition to flexibility and leg power.

CHAPTER 3

Methods

Participants

Participants were 90 members (age = 18.1 – 23.4 years) of three women's intercollegiate rowing teams within the Big Ten Conference. Members of six Big Ten teams were initially selected to participate in the study based on location within a reasonable distance to the investigator at Michigan State University. The teams included the Ohio State University, the University of Wisconsin, the University of Minnesota, Michigan State University, the University of Michigan, and Indiana University. However, due to a lack of interest, coaching changes, and/or scheduling conflicts only Michigan State University, the University of Michigan, and Indiana University agreed to participate. While a convenience sample, we believe it is a good representation of the elite level female collegiate rower. The Big Ten has been ranked consistently in the top 20 in the nation and has placed in the top 12 at the NCAA Championships. In 2002, five of the seven Big Ten teams were ranked in the top 20 in the nation. In 2003, three Big Ten teams placed in the top 12 at the NCAA Championships. In the 2004 season, two of the three schools that participated in the study placed at the NCAA Championships in May 2004.

Recruitment of Participants

Coaches were contacted via telephone and e-mail for their approval to conduct the study. Initial contact was made with the coaches in February 2004. Testing at each university occurred between March and April 2004. Approval for rower participation was received from the Michigan State University Committee on Research Involving Human Subjects (Appendix A). All participants signed the informed consent (Appendix B) prior to participating in the study.

Once approval was received from the coaches, potential study participants were solicited by their respective coaches. The coaches informed the athletes about the study purpose and potential outcomes. Each coach was provided with a schedule of testing times which was then given to the rowers who signed up according to individual schedules. Athletes were then given a schedule of times for the two days of testing. Testing days corresponded to participants' class schedules. Monday, Wednesday or Friday was used in addition to a Tuesday or Thursday for the second day of testing. Athletes from Michigan State University were tested over a period of 3 weeks due to the proximity of the school to the investigator. Testing sessions were scheduled so that two athletes could be tested together in approximately 30 minutes.

Selection Criteria

Participants included all rowers participating on each university's respective varsity roster. Rowers were designated novice or varsity as determined by the coach of the respective teams. While novice means having no experience in collegiate rowing, a few athletes with no experience were placed on the varsity level. To determine how long each participant was involved with rowing in college, years of collegiate rowing experience was asked of each participant. The years were counted as follows: rowers in their first year (0 years), in their second year (1 year), in their third year (2 years) and in their fourth year (3 years). Coxswains were not included in this study.

Sample Size

The potential eligible sample from the schools that agreed to participate was 125 rowers. Overall, 90 (72%) female collegiate rowers participated in this study. Of the rowers who did not participate in the study, reasons for not participating included the following: conflict with academic schedule, illness or injury, and/or missed testing sessions. In addition, some athletes did not regularly perform 2K tests on the rowing ergometer. Table 3.1 provides information concerning the number of participating rowers in the sample according to level on the team and years of rowing experience. Of the teams that participated in the study 32 out of 45 participated from school A, 21 out of 34 participated from school B, and 37 out of 46 participated from school C. While 90 rowers participated in the study, injury precluded two from performing the vertical jump and two from performing the 2K rowing ergometer test. In addition, the supraliac skinfold measure was not obtained from one participant.

Power Analysis

The study was powered using the main outcome measure of interest, 2K race time. Previous testing in our laboratory resulted in an average (±SD) 2K time of 456 (±15) seconds, using varsity rowers. We felt that finding a difference of 7-8 seconds between varsity and novice rowers would be meaningful to coaches. This equates to an effect size of ~0.50, based on our previous pilot data. Given the desired effect size, sample size calculations indicated that 62 participants (31 novice, 31 varsity) would be needed to achieve a statistical power of 0.80, at an alpha level of $P<0.05$. Given the final sample size actually used ($N = 90$), statistical power was slightly higher than this a priori estimate.

Background Information

Upon arrival of the rower to the designated testing area, informed consents were given and questions (Appendix C) were asked of each rower. Questions included current team status (novice or varsity level), date of birth, recalled age of menarche, years of rowing experience in college, and years of rowing experience prior to college. Prompts including: in or out of school, in or out of the sports season, season of the year, and/or major holiday were used to assist the rower in recalling age at menarche. Chronological age and age at menarche were expressed as decimal ages. Previous experience in organized sports (Figure 3.1) was also included among the questions, specifically which sports were played in high school and/or for an extended period of time (greater than four years).

Instrumentation

Physical Characteristics of Rowers

Measurements were taken during the spring semester 2004. Dimensions were taken according to accepted protocols (Lohman, et al., 1988; Malina, 1995). Bilateral measurements were taken on the right side of the body. Participants wore light clothing (sports bra and shorts) but no shoes. Circumferences were taken twice with the mean being used in the analysis. Skinfolds were taken three times with the mean being used in the analysis.

Height

Stature (height) was measured using a free standing field anthropometer. The participant stood erect with eyes looking straight forward (Frankfort horizontal plane), weight evenly distributed between feet, heels together, and arms hanging relaxed by the side. Height was measured as the distance from the floor to the top of the head (vertex) to the nearest 0.1 centimeter (cm).

Body Mass

Body mass (weight) was measured using a standard portable scale. The participant stood on the scale with weight evenly distributed between her feet. Weight was measured to the nearest 0.1 kilogram (kg).

Sitting Height

Sitting height was measured as the distance from the sitting surface to the top of the head. The participant was seated on a flat bench with hands resting on the thighs and eyes looking straight ahead. Sitting height was measured to the nearest 0.1 cm with the lower two sections of the field anthropometer.

Arm Span

Arm span is a measure of the length of the upper extremities plus the span of the shoulders. It was measured with a non-stretchable tape. The participant was standing with her back against a wall and arms held out laterally with palms facing forward. The tape measure was taped on the wall and placed at approximately shoulder level. The measurement was taken from middle finger of the right hand to the middle finger of the left hand to the nearest 0.1 cm (Martin, et al., 1988).

Skeletal Breadths

Skeletal breadths provide a measure of robustness of the skeleton. Four skeletal breadths were measured using the upper end of the portable anthropometer to the nearest 0.1 cm. Bicristal (hip) breadth was measured as the distance across the iliac crests with the caliper held at a 45 degree angle. Biacromial (shoulder) breadth was measured as the distance across the right and left acromial processes of the scapulae. Biacromial and bicristal measures were performed from the rear of the participant. Bicondylar (knee) breadth was taken across the condyles of the right femur with the participant sitting and the right knee flexed at 90 degrees. The caliper was held at an angle downward. Biepicondylar (elbow) breadth was taken across the epicondyles of the humerus with the participant standing and the right arm flexed at 90 degrees. The upper end of the field anthropometer was used and was held at a slight angle. All skeletal breadths were measured to the nearest 0.1 cm.

Limb Circumferences

Four limb circumferences were measured with a flexible, non-stretchable tape to the nearest 0.1 cm. The measuring tape was in contact with, but did not indent the skin. For relaxed arm circumference, the participant was standing with the arms at the sides. The midpoint between the acromial and olecrenon processes was marked. Flexed arm circumference was taken at the same level with the participant maximally flexing the biceps i.e., “make a muscle”. Thigh circumference was measured at the point midway between the inguinal crease and the proximal border of the patella. Calf circumference was measured at the maximum circumference of the calf with the participant standing with the body weight evenly distributed between the feet.

Skinfolds

Eight skinfold thicknesses (triceps, biceps, subscapular, thigh, medial calf, lateral calf, suprailiac, abdominal) were measured to the nearest 0.5mm using a Lange skinfold caliper. All skinfolds were taken using a double fold of skin and underlying soft tissue raised with the thumb and index finger about 1 cm above the chosen measurement site. The triceps skinfold was taken on the back of the arm over the triceps muscle at the level marked for arm circumference. The biceps skinfold was taken on the anterior aspect of the arm at the same level as the triceps skinfold. The arm was hanging in a relaxed manner at the side for measurement of the triceps and biceps skinfolds. The subscapular skinfold was taken just below the inferior angle of the scapula following the natural contour lines of the skin. The thigh skinfold was taken on the anterior thigh at the midpoint level previously marked for thigh circumference. The medial and lateral calf skinfolds were taken at the same level as calf circumference on the medial and lateral aspects of the calf, respectively. The suprailiac skinfold was taken at a point just above the iliac crest in the midaxillary line. The abdominal skinfold was taken 3 cm lateral and 1 cm inferior to the umbilicus. All skinfolds were measured three times and the average of the three measures used in the analysis.

Flexibility

Flexibility was measured with a sit and reach box. The apparatus was placed against the wall. The participant sat on the floor with the legs straight, shoes off, and feet placed flat against the box. Instructions to the participants emphasized that the goal of the test is to reach or stretch as far as possible while pushing the measuring device without letting the knees come off the floor (Adams, 1994). The participant extended her arms with palms down and bent and pushed the device. Three trials were performed and recorded to the nearest cm; the furthest distance used in the analysis.

Vertical Jump

Vertical jump was used as a measure of leg power. Standing reach was measured prior to the jumps. The jump was performed from a still position with no step, but the participant was permitted to use her arms in a pumping action (Adams, 1994). Instructions were given to each participant and a demonstration jump was performed to ensure the participants understood the technique. Each participant jumped three times, with a brief rest between jumps. The best jump (distance between the reaching height and height of the jump) of the three trials was used for analysis. Vertical jump was measured to the nearest inch.

Derived Measures

Several additional variables were derived: (a) estimated leg length is equal to height minus sitting height; (b) sitting height to height ratio is equal to sitting height divided by height and multiplied by 100; (c) sum of trunk skinfolds (subscapular, abdominal, suprailiac); (d) sum of extremity skinfolds (triceps, biceps, mid-thigh, medial calf, lateral calf); and (e) arm span to height ratio is equal to arm span divided by height.

Leg (subischial) Length. Leg length was estimated as height minus sitting height.

Sitting Height/Height Ratio. The ratio provides an indication of the relative contribution of the upper segment (trunk, neck, head) to stature (Malina, 1995). It was calculated as sitting height divided by height and multiplied by 100.

Arm Span to Height Ratio. Arm span to height ratio provides an indication of the relative length of the arms to height (Martin et al., 1988; Babington & Stager, 2000). It was calculated as arm span divided by height.

Trunk Subcutaneous Adiposity. Trunk subcutaneous adiposity was estimated as the sum of three trunk skinfolds – subscapular, suprailiac, and abdominal.

Extremity Subcutaneous Adiposity. Extremity subcutaneous adiposity was estimated as the sum of the five extremity skinfolds – triceps, biceps, mid-thigh, medial calf, and lateral calf.

Limb Muscle Mass. Estimated arm muscle circumference was derived from relaxed arm circumference and in conjunction with triceps and biceps skinfolds as follows:

- Estimated arm muscle circumference (cm) = $[C_a - \pi/2(S_t + S_b)]$

where C_a = arm circumference, S_t = triceps skinfold and S_b = biceps skinfold (Malina, 1995).

Estimated calf muscle circumference was derived from calf circumference and the medial and lateral calf skinfolds as follows:

- Estimated calf muscle circumference (cm) = $C_c - \pi/2(S_m + S_l)$

where C_c = calf circumference, S_m = medial calf skinfold and S_l = lateral calf skinfold (Malina, 1995).

Body Composition. Estimates of body composition included percent body fat, fat mass (FM), and fat-free mass (FFM) estimates. Fat-free mass was estimated using the formula of Warner, Fornetti, Jallo and Pivarnik (2004). Their model (shown below) has been shown to be a valid indicator of body composition in collegiate female athletes.

{FFM (kg) = 8.57 + (0.808*weight) – (0.181*abdominal skinfold) – (0.222*thigh skinfold)}.

This equation was validated versus fat-free mass measured by dual energy x-ray absorptiometry. The predictive ability was high ($r^2 = 0.97$) and the standard error of the estimate was 1.1 kg (Warner et al., 2004). Fat mass was estimated by subtraction (body weight – fat-free mass) and percent fat was estimated as fat mass divided by body mass multiplied by 100.

Leg power. Leg power was estimated from body mass and the best vertical jump using the protocol of Adams (1994):

Leg power = 2.21 * (weight) * √distance jumped.

Somatotype

Somatotype was estimated with the Heath Carter Anthropometric protocol using algorithms provided by Heath and Carter (1990).

Endomorphy = $-0.7182 + 0.1451(x) - 0.00068(x^2) + 0.0000014(x^3)$

where x is the sum of triceps, subscapular and suprailiac skinfolds multiplied by 170.18/height (cm);

Mesomorphy = [(0.858*biepicondylar breadth) + (0.601*bicondylar breadth) + (0.188*corrected arm circumference) + (0.161*corrected calf circumference)] – (height*0.131) + 4.50;

where the corrected arm circumference is flexed arm circumference (cm) minus the triceps skinfold (cm) and the corrected calf circumference (cm) is the calf circumference minus the medial calf skinfold (cm).

Ectomorphy = HWR*0.732 - 28.58

where HWR is the height (cm) divided by the cube root of the weight (kg). If the HWR is less than 40.75 but more than 38.25m then the following will be used for calculating ectomorphy = HWR*0.463 – 17.63, and if the HWR is equal to or less than 38.25, a rating of 0.1 will be given. The somatotype of the individual is defined by the three components in the following order: endomorphy (first), mesomorphy (second) and endomorphy (third).

Rowing Performance

A 2K all out row for time (seconds) was performed on a rowing ergometer (Concept II; Morrisville, VT). The 2K test was performed during a regular practice session designated by the coach during the normal training routine of each team. Total time (seconds) was used for the performance measure. Rowers performed a warm-up, as designated by the coach, prior to the test. Total time in minutes and seconds was retrieved from the computer on the ergometer and reported to the coach. Each 2K rowing ergometer test was performed during practice sessions and administered by the coaching staff. Either the coach or the athlete reported the 2K times to the investigator at the respective testing sessions performed at each school. Two K times were then converted from minutes and seconds into seconds for use in the regression analysis. The 2K time used in the study were derived from tests performed during the months of March or April 2004. A timed 2K is performed in every rowing program, and is considered one of the best predictors of success by coaches. It is also highly correlated with performance on the water (Secher, 1983).

Data Collection Procedures

Testing Schedule

The testing schedule was set up by the coach and the investigator. Rowers signed up for specific time slots. Testing took place in the ergometer room of the respective schools, or in the Human Energy Research Lab at Michigan State University. Testing sessions lasted approximately 30 minutes. Two athletes were scheduled during each 30 minute session.

Testing Procedures

When rowers arrived at the designated area, they initially read and signed the informed consent forms. Then, the details of the study were explained to them. Background information was then solicited via interview. Anthropometric dimensions were taken in the following order: height, body mass, sitting height, arm span, skeletal breadths, limb circumferences, and skinfolds. The sit and reach was then performed followed by the vertical jump. As noted earlier, the 2K rowing ergometer performance was performed during regular practice time as designated by the coach. Warm-up and cool-down for the 2K task was performed according to the protocols set by the respective coaching staffs.

Personnel

All physical characteristics and questionnaires were administered by the investigator. The investigator had previous experience in anthropometry which included working with athletes in various sports. A single assistant was used with one of the university teams. The assistant recorded the data as the investigator performed each measurement.

Measurement Variability and Reliability

The primary investigator collected all of the anthropometric data. The weighing scale and anthropometric equipment (anthropometer, skinfold calipers, tape measure) were checked and calibrated on the day testing took place. Intra-observer error measurement variation (Table 3) was estimated for height, weight, and sitting height. Every tenth participant was measured twice in each of these measures. Replicates were taken on the same day. Technical error of measurement was calculated according to the following formula:

$$\sigma_e = \sqrt{}Sd^2/2N$$

where d is equal to the difference between replicate measurements and N is the number of participants (Malina, 1995). To estimate within day reliability, intercorrelations (via repeated measures ANOVA) were performed for measures which were taken two or three times. Table 3.3 shows the resultant values.

Data Analyses

The respective analysis for each question was conducted using the SPSS (Version 11.5) statistical software. The following are the research questions and each statistical technique that corresponds to the question. Statistical concerns in a study of this scope include determination of power and mutlicollinearity. Small sample sizes and many dependent variables contribute to a lack of power. With low statistical power, it may be difficult to determine a regression model that can truly predict the outcome variable. Prior to testing, statistical power was determined. Many physical characteristics have high correlations to each other and provide similar information concerning body morphology. Multicollinearity was not a major issue in the analysis as only two relationships among all dependent variables were greater than $r = 0.80$. Specifically, the correlation between height and leg length was 0.85, and leg power and fat-free mass was 0.80.

Research Question 1: Physical Characteristics

What are the physical characteristics of female collegiate rowers?

Research Question 2: Novice and Varsity

Among female collegiate Big Ten rowers, do varsity athletes differ from novice athletes in physical characteristics, body proportions, somatotype, body composition, relative muscularity, flexibility, leg power, and 2K rowing ergometer performance?

Research Question 3: Collegiate Rowing Experience

Among female collegiate Big Ten rowers, do athletes with 0, 1, 2, or 3 years of collegiate rowing experience differ in physical characteristics, body proportions, somatotype, body composition, relative muscularity, flexibility, leg power, and 2K rowing ergometer performance?

Analysis for Research Question 1

Descriptive statistics were calculated for the entire group and separately for level (varsity and novice) and years of experience (0, 1, 2, or 3 years). Descriptive statistics included means and standard deviations.

Analyses for Research Question 2 and 3

Differences between levels of the independent variables were determined using a multivariate analysis of variance (MANOVA). An overall MANOVA was performed due to the relationships that exist between the various physical characteristics. A MANOVA ($P < 0.05$) with Wilks's lambda as the test statistics was used to determine differences between novice and varsity rowers and to determine differences among years experience of the rowers. If the MANOVA values were significant, a Bonferoni adjusted alpha level was used. Comparisons were made using Hotelling's T^2 with a Bonferroni adjusted alpha level to determine which components contributed to the significant differences. This technique was used to determine where the differences between the groups existed and to control for family wise error rates.

Research Question 4: 2K Performance

What is the estimated contribution of physical characteristics, body proportions, body composition, somatotype, relative muscularity, flexibility, and leg power of female collegiate rowers to 2K rowing ergometer performance?

Analyses for Research Question 4

Pearson product moment correlations were performed using physical characteristics and 2K time and between each of the physical characteristics. To maximize performance prediction, only those variables that resulted in a significant relationship with 2K time ($r > 0.20$) but a low relationship with each other ($r < 0.50$) were included in the regression model. Next, a stepwise regression equation was used to determine 2K time from physical characteristics.

Table 1

Attributes of Collegiate Female Rowers

	Novice (N = 34)	Varsity (N = 56)	Total (N = 90)
Collegiate experience (yrs)			
0	34	5	39
1	0	25	25
2	0	15	15
3	0	11	11
University			
Team A	12	20	32
Team B	6	15	21
Team C	16	21	37

Figure 1

Previous Sports Participation of Female Collegiate Rowers

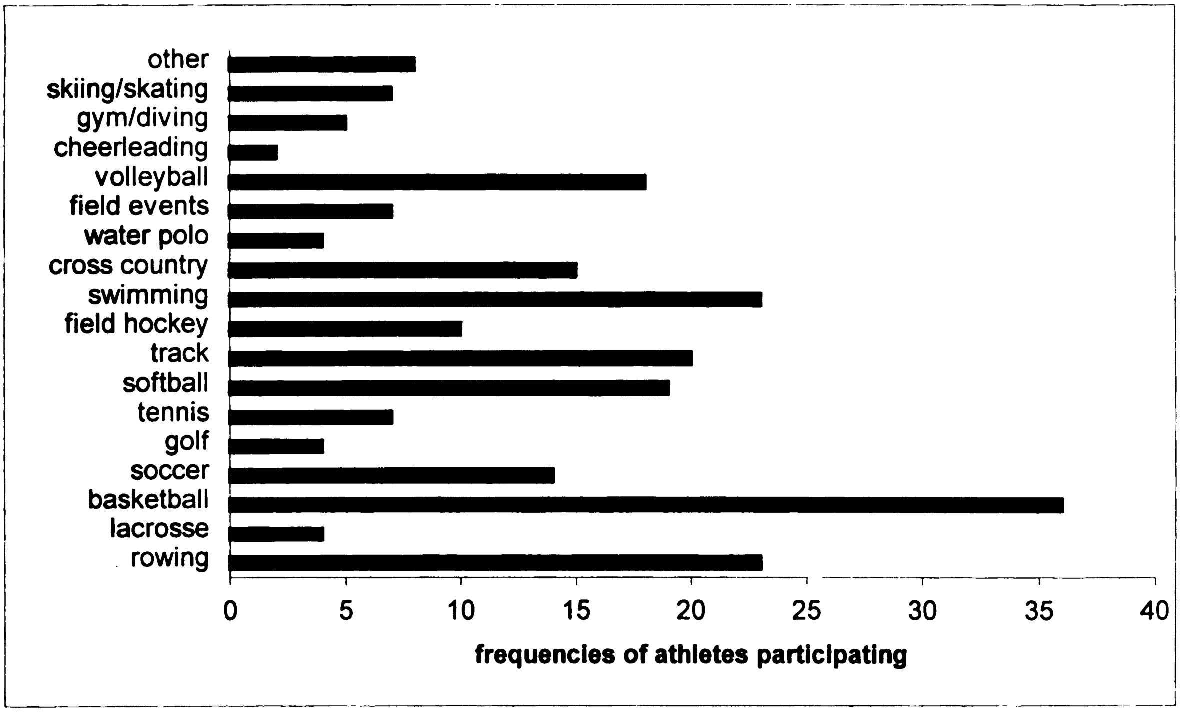

Table 2

Technical Error of Measurement for Height, Weight, and Sitting Height

	Technical Error of Measurement
Height	0.46 cm
Weight	0.00 kg
Sitting Height	0.49 cm

Table 3

Within Day Correlations for Intra-tester Reliability

Variables	Correlation
Skeletal Breadths (cm)	
Biacromial	0.87
Biepicondylar	0.85
Bicristal	0.93
Bicondylar	0.83
Circumferences (cm)	
Triceps	0.99
Flexed arm	0.99
Thigh	0.99
Calf	0.98
Skinfolds (mm)	
Triceps	0.97
Subscapular	0.96
Biceps	0.95
Abdominal	0.97
Suprailiac	0.97
Thigh	0.95
Medial calf	0.97
Lateral calf	0.95

CHAPTER 4

Results

Descriptive statistics (means and standard deviations) for the physical characteristics of female collegiate rowers are presented. Novice and varsity rowers differed significantly only in years of experience prior to and including rowing in college, the vertical jump, and 2K rowing ergometer time. Only height and 2K rowing ergometer time differed significantly among rowers by years of experience. Further analysis revealed year 2 rowers were shorter versus year 3 and year 3 rowers were faster versus year 0 rowers. Physical characteristics that predicted performance included fat-free mass, experience in college rowing, experience prior to college rowing and height.

Research Question 1: Physical Characteristics

Descriptive statistics for the sample are summarized in Tables 4 and 5. Data are reported by level (novice, varsity), and years of experience (0-3 years). All measures were normally distributed as shown by the skewness statistic and histogram plots.

Research Question 2: Novice and Varsity

Results of the MANOVAs ($P < 0.05$) comparing rowers by level are summarized in Table 4. The results indicate significant differences between varsity and novice rowers (Wilks' $\Lambda = 0.41$, with a Bonferoni adjusted alpha level, $P < 0.05$) in years of experience prior to college (EXP), vertical jump (VJ) and 2K time (2K). Varsity rowers have significantly more years of rowing experience prior to entering college by almost 0.5 years. Varsity rowers have a significantly higher vertical jump, but; interestingly, leg power does not differ significantly by level. Varsity rowers are also significantly faster in 2K time by almost 25 seconds. Although not significant, skinfold thicknesses are slightly less in varsity rowers. The remaining variables showed similarities between novice and varsity rowers as shown in Table 4.

Descriptive statistics for Heath-Carter anthropometric somatotypes of novice and varsity rowers and years of college rowing experience are presented in Tables 4 and 5. The MANOVA (Wilks' $\Lambda = 0.89$) significant differences ($P < 0.05$) between novice and varsity rowers. Post-hoc comparisons indicated that only endomorphy was significantly different ($P = 0.03$) between novice and varsity rowers.

Research Question 3: Collegiate Rowing Experience

Results of the MANOVAs comparing rowers by years of experience prior to the 2003-2004 season are summarized in Tables 4.3. A first year rower is classified as 0 years, a second year rower was classified as 1 year, a third year rower was classified as 2 years and a fourth year rower was classified as 3 years experience. Height (HT) and 2K time (2K) differ significantly among rowers by years of rowing experience (Wilks' Λ = 0.14, with a Bonferonni adjusted alpha level, $P < 0.05$). Two kilometer time decreases with years of experience, but only when comparing year 0 with year 3 rowers. Height differs significantly only between rowers in year 2 (shortest) compared to rowers in year 3; the other pairwise comparisons for height are not significant. The other dimensions, ratios and derived variables do not differ among years of rowing experience. In contrast, somatotype does not differ significantly among rowers by years of experience (Wilks' Λ = 0.83, $P = 0.07$) and no further analyses were conducted.

Research Question 4: 2K Performance

Results of the stepwise regression to predict 2K time from physical characteristics are summarized in Table 7. Model development began by performing

Pearson Product Moment Correlations among 2K time and each physical characteristic (Appendix D). To maximize performance prediction, only those variables that resulted in a significant relationship with 2K time ($r > 0.20$) but a low-moderate relationship ($r < 0.50$) with each other were included in the regression model. While ($r > 0.20$) does not insure that a high correlation exists, it was important to obtain variables which fit all criteria, a significant relationship with 2K time, a low relationship with other variables and a representation of different constructs. The following variables have a significant relationships with 2K time: years experience prior to rowing, years experience in college, age, age at menarche, height, weight, sitting height, leg length, arm span, biacromial breadth, biepicondylar breadth, bicristal breadth, biepicondylar breadth, triceps circumference, flexed arm circumference, thigh circumference, fat-free mass, fat mass, leg power, arm muscle circumference, arm muscle area, calf muscle circumference, calf muscle area. All variables showed an inverse relationship with 2K time, meaning rowers with larger dimensions had lower 2K times.

Allowing for sample size ($N = 90$), nine variables were entered into the regression model. Variables entered into the regression model included those that had a low relationship with each other ($r < 0.50$) and, variables that represented different constructs, i.e., body size, body proportions, body composition, rowing experience, and performance measures. Correlations of the variables entered into the regression model are located in Table 6. It is not clear from the literature on rowers to identify variables from each construct that are significantly related to 2K and not highly related to each other. At least one variable from each construct was retained for the regression model: years of experience rowing prior to entering college (EXP), years of experience in college rowing

(EXC), age of menarche (AOM), HT, leg length (LL), biacromial breadth (BIAC), leg power (LP), fat-free mass (FFM), and thigh circumference (THIGH). Fat-free mass, EXC, HT, and EXP all entered the final model and together explained 57% of the variance ($r = 0.75$, $r^2 = 0.57$). The following is the regression equation:

$$y = -0.35(FFM) + (-0.33)(EXC) + (-0.31)(HT) + (-0.25)(EXP).$$

Table 4

Performance Measures, Physical Characteristics, Body Proportions, Somatotypes, Body Composition, and Relative Muscularity of Novice and Varsity Female Collegiate Rowers

Variable	Novice Rowers (*N*=34)	Varsity Rowers (*N*=56)	*F* ratio	*p*	Partial ω^2
Age					
Age (yrs)	19.2 ± 0.8	20.8 ± 1.1	50.40	.00	.378
Age at menarche (yrs)	13.3 ± 1.4	13.2 ± 1.2	0.11	.74	.001
Rowing Experience					
Pre-collegiate (yrs)	0.7 ± 0.0	1.3 ± 0.0	4.22	.04	.048
Collegiate (yrs)	0.0 ± 0.0	1.6 ± 0.9	101.89	.00	.551
Performance Measures					
2K rowing ergometer time (sec)	474.0 ±17.4	449.1 ± 23.7	25.76	.00	.237
Sit-and-reach flexibility (cm)	38.4 ± 7.1	38.8 ± 7.7	.03	.86	.000
Vertical jump (in)	13.9 ± 2.8	15.1 ± 2.4	4.27	.04	.049
Leg power (kpm/min)	97.1 ± 15.8	102.3 ± 14.7	1.91	.17	.023
Physical Characteristics					
Weight (kg)	74.2 ± 8.3	74.9 ± 8.6	.05	.82	.056
Height (cm)	172.8 ± 5.4	173.0 ± 5.8	.04	.84	.055
Sitting height (cm)	90.8 ± 3.3	90.9 ± 2.9	.07	.80	.058
Arm span (cm)	174.0 ± 10.7	172.1 ± 8.9	1.37	.25	1.371
Leg length – estimated (cm)	82.0 ± 4.0	82.0 ± 4.2	.01	.93	.008
Biacromial breadth (cm)	31.3 ± 1.7	31.5 ± 2.0	.03	.86	.000
Biepicondylar breadth (cm)	6.3 ± 0.6	6.4 ± 0.6	.00	.95	.000
Bicristal breadth (cm)	28.0 ± 1.7	28.1 ± 1.8	.00	.97	.000
Bicondylar breadth (cm)	8.8 ± 0.9	8.9 ± 0.6	1.89	.17	.022

Table 4, *continued*

Variable	Novice Rowers (n=34)	Varsity Rowers (n=56)	F ratio	p	Partial $\hat{\omega}^2$
Relaxed arm circumference (cm)	30.9 ± 2.6	31.1 ± 2.5	.08	.79	.001
Flexed arm circumference (cm)	31.4 ± 2.3	31.8 ± 2.1	.53	.47	.006
Thigh circumference (cm)	57.8 ± 3.6	58.0 ± 3.6	.01	.92	.000
Calf circumference (cm)	38.3 ± 2.0	38.4 ± 2.4	.36	.55	.004
Triceps skinfold (mm)	22.2 ± 4.3	20.7 ± 4.3	2.18	.14	.026
Subscapular skinfold (mm)	19.4 ± 5.9	17.4 ± 4.5	2.22	.14	.026
Biceps skinfold (mm)	13.1 ± 4.1	12.0 ± 4.3	.97	.33	.012
Abdominal skinfold (mm)	27.2 ± 6.8	25.7 ± 6.2	.77	.38	.009
Suprailiac skinfold (mm)	22.6 ± 6.4	19.9 ± 6.7	3.13	.08	.036
Thigh skinfold (mm)	29.1 ± 6.1	27.7 ± 4.7	.82	.37	.010
Medial calf skinfold (mm)	19.3 ± 5.1	18.7 ± 4.8	.00	.95	.000
Lateral calf skinfold (mm)	19.0 ± 4.4	18.7 ± 4.8	.01	.95	.000
Body Proportions					
Sitting height to height ratio (%)	52.5 ± 1.4	52.6 ± 1.3	.00	.96	.003
Arm span to height ratio	1.0 ± 0.0	1.0 ± 0.0	.21	1.63	.244
Somatotype					
Endomorphy	6.0 ± 1.1	5.5 ± 1.1	4.77	.03	.051
Mesomorphy	3.9 ± 1.1	4.1 ± 1.1	1.12	.29	.013
Ectomorphy	1.7 ± 0.9	1.6 ± 0.9	.06	.81	.001
Body Composition					
Fat free mass (mm)	57.1 ± 5.6	58.3 ± 6.1	.38	.54	.005
Fat mass (mm)	17.1 ± 3.4	16.6 ± 3.1	.28	.60	.003
Percent body fat	22.8 ± 2.8	22.1 ± 2.2	1.29	.26	.015
Sum of trunk skinfolds (mm)	68.9 ± 18.2	63.4 ± 15.7	2.25	.14	.026
Sum of extremity skinfolds (mm)	102.2 ± 19.5	98.6 ± 19.3	.68	.41	.008

Table 4, *continued*

Variable	Novice Rowers (N=34)	Varsity Rowers (N=56)	F ratio	p	Partial $\acute{\omega}^2$
<u>Relative Muscularity</u>					
Arm muscle circumference - corrected (cm)	25.4 $\pm$ 1.8	25.9 $\pm$ 1.9	1.61	.21	.019
Calf muscle circumference - corrected (cm)	32.3 $\pm$ 1.9	32.6 $\pm$ 2.3	.48	.49	.006

Table 5

Performance Measures, Physical Characteristics, Body Proportions, Somatotypes, Body Composition, and Relative Muscularity of Female Collegiate Rowers with 0, 1, 2, and 3 Years of Rowing Experience

Variable	0 Years Experience (N=39)	1 Years Experience (N=25)	2 Years Experience (N=15)	3 Years Experience (N=11)	F ratio	p	Partial ω^2
Age							
Age (yrs)	19.2 ± 0.8	20.3 ± 0.6	21.3 ± 0.7	22.1 ± 0.7	61.88	.00	.696
Age at menarche (yrs)	13.3 ± 1.3	13.3 ± 1.0	13.4 ± 1.9	13.2 ± 1.0	.11	.96	.004
Rowing Experience							
Pre-collegiate (yrs)	1.1 ± 0.0	0.9 ± 0.0	1.0 ± 0.0	1.6 ± 0.0			
Collegiate (yrs)	0	1	2	3			
Performance Measures							
2K rowing ergometer time (sec)	469.1 ± 20.9	454.2 ± 24.9	452.1 ± 26.1	437.0 ± 15.8	6.45	.00	.194
Sit-and-reach flexibility (cm)	38.4 ± 7.1	38.1 ± 7.6	39.0 ± 9.7	40.0 ± 5.4	.08	.97	.003
Vertical jump (in)	13.8 ± 2.7	15.1 ± 2.3	15.7 ± 2.4	15.2 ± 2.7	2.74	.05	.092
Leg power (kpm/min)	96.9 ± 15.1	101.6 ± 13.6	102.6 ± 19.1	106.6 ± 13.1	1.28	.29	.045
Physical Characteristics							
Weight (kg)	74.3 ± 7.8	74.4 ± 8.7	73.3 ± 10.2	78.1 ± 7.9	.41	.75	.015
Height (cm)	172.9 ± 5.2	172.7 ± 5.7	170.1 ± 6.2	177.0 ± 4.0	3.36	.02	.111
Sitting height (cm)	91.0 ± 3.4	90.6 ± 2.5	89.5 ± 2.5	93.0 ± 2.4	2.45	.07	.083
Arm span (cm)	173.7 ± 10.1	171.5 ± 10.7	170.9 ± 8.2	175.5 ± 7.1	.79	.50	.029
Leg length - estimated (cm)	81.9 ± 3.8	82.1 ± 4.6	80.6 ± 4.3	84.0 ± 3.5	1.83	.15	.063
Biacromial breadth (cm)	31.3 ± 1.7	31.6 ± 2.0	31.4 ± 2.1	31.2 ± 2.0	.22	.88	.008
Biepicondylar breadth (cm)	6.4 ± 0.7	6.3 ± 0.4	6.3 ± 0.3	6.4 ± 0.4	.52	.67	.019
Bicristal breadth (cm)	28.1 ± 1.8	28.3 ± 1.7	27.7 ± 1.8	27.8 ± 1.5	.74	.53	.027
Bicondylar breadth (cm)	8.7 ± 0.9	8.8 ± 0.9	9.0 ± 0.5	9.1 ± 0.5	.93	.43	.033

Table 5, *continued*

Variable	0 Years Experience (*N*=39)	1 Years Experience (*N*=25)	2 Years Experience (*N*=15)	3 Years Experience (*N*=11)	*F* ratio	*p*	Partial ω^2
Relaxed arm circumference (cm)	31.0 ± 2.4	31.0 ± 2.7	31.1 ± 2.8	31.4 ± 2.4	.06	.98	.002
Flexed arm circumference (cm)	31.5 ± 2.2	31.5 ± 2.2	31.6 ± 2.3	32.2 ± 1.9	.20	.90	.007
Thigh circumference (cm)	57.9 ± 3.4	57.2 ± 3.5	57.7 ± 3.7	59.5 ± 3.9	.63	.60	.023
Calf circumference (cm)	38.1 ± 2.0	38.5 ± 2.1	38.6 ± 2.7	39.0 ± 2.8	1.22	.31	.043
Triceps skinfold (mm)	22.4 ± 4.1	20.4 ± 4.5	20.0 ± 4.8	21.0 ± 3.5	1.19	.32	.042
Subscapular skinfold (mm)	19.2 ± 5.7	17.2 ± 4.1	16.7 ± 6.0	18.4 ± 2.8	1.12	.35	.040
Biceps skinfold (mm)	12.9 ± 3.9	12.1 ± 4.2	12.5 ± 5.1	11.5 ± 4.1	.33	.80	.012
Abdominal skinfold (mm)	26.7 ± 7.0	26.7 ± 6.5	24.3 ± 6.3	26.2 ± 4.8	.34	.80	.012
Suprailiac skinfold (mm)	22.2 ± 6.5	21.1 ± 7.5	17.4 ± 6.0	21.2 ± 5.0	1.47	.23	.052
Thigh skinfold (mm)	29.2 ± 5.8	26.9 ± 4.7	27.1 ± 4.0	29.7 ± 5.9	1.58	.20	.055
Medial calf skinfold (mm)	19.2 ± 5.0	18.6 ± 4.9	18.0 ± 6.0	20.7 ± 5.6	.08	.47	.030
Lateral calf skinfold (mm)	19.1 ± 4.4	17.9 ± 3.9	19.0 ± 5.0	19.8 ± 6.2	.69	.56	.025
Body Proportions							
Sitting height to height ratio (%)	52.6 ± 1.4	52.5 ± 1.5	52.6 ± 1.0	52.5 ± 1.3	.17	.92	.006
Arm span to height ratio	1.0 ± 0.0	1.0 ± 0.1	1.0 ± 0.0	1.0 ± 0.0	.60	.62	.022
Somatotype							
Endomorphy	5.9 ± 1.2	5.6 ± 1.1	5.3 ± 1.1	5.7 ± 0.7	1.38	.25	.046
Mesomorphy	3.9 ± 1.0	4.0 ± 1.2	4.5 ± 1.0	3.9 ± 1.3	1.11	.35	.038
Ectomorphy	1.7 ± 0.9	1.7 ± 0.9	1.4 ± 0.8	1.8 ± 1.0	.65	.58	.022
Body Composition							
Fat free mass (mm)	57.2 ± 5.3	57.9 ± 5.9	57.4 ± 7.6	60.3 ± 5.2	.43	.74	.016
Fat mass (mm)	17.0 ± 3.2	16.5 ± 3.3	15.9 ± 3.1	17.6 ± 3.0	.48	.70	.017
Percent body fat	22.8 ± 2.7	22.1 ± 2.4	21.6 ± 2.2	22.6 ± 2.2	.57	.64	.021
Sum of trunk skinfolds (mm)	68.2 ± 18.2	65.0 ± 16.8	60.0 ± 16.4	64.9 ± 10.5	.82	.49	.030
Sum of extremity skinfolds (mm)	102.2 ± 19.0	95.8 ± 18.8	98.5 ± 20.1	104.6 ± 22.1	.74	.53	.027

Table 5, *continued*

Variable	0 Years Experience (*N*=39)	1 Years Experience (*N*=25)	2 Years Experience (*N*=15)	3 Years Experience (*N*=11)	*F* ratio	*p*	Partial ω^2
Relative Muscularity							
Arm muscle circumference - corrected (cm)	25.4 $\pm$ 1.7	25.9 $\pm$ 2.0	26.1 $\pm$ 2.1	26.0 $\pm$ 1.9	.54	.54	.020
Calf muscle circumference - corrected (cm)	32.0 $\pm$ 2.0	32.8 $\pm$ 2.0	32.8 $\pm$ 2.5	33.0 $\pm$ 2.8	1.02	.39	.036

Table 6.

Correlations of 2K Rowing Ergometer Time and Variables Used in the Regression Model

	2K ergometer	Prior rowing	College rowing	Age menarche	Height	Leg length	Biacromial breadth	Leg power	Fat free mass	Thigh circum
2K ergometer (sec)	1.00	-0.31	-0.41	-0.24	-0.51	-0.41	-0.24	-0.40	-0.56	-0.32
Prior rowing (yrs)	-0.31	1.00	0.07	-0.05	-0.02	0.01	0.04	-0.01	0.05	0.10
College rowing (yrs)	-0.41	0.07	1.00	-0.01	0.09	0.07	-0.01	0.22	0.13	0.10
Age menarche (yrs)	-0.24	-0.05	-0.01	1.00	0.25	0.30	0.12	0.30	0.22	0.14
Height (cm)	-0.51	-0.02	0.09	0.25	1.00	0.85	0.29	0.41	0.53	0.18
Leg length (cm)	-0.41	0.01	0.07	0.30	0.85	1.00	0.32	0.34	0.39	0.00
Biacromial breadth (cm)	-0.24	0.04	-0.01	0.12	0.29	0.32	1.00	0.27	0.28	0.07
Leg power (kpm/min)	-0.40	-0.01	0.22	0.30	0.41	0.34	0.27	1.00	0.80	0.59
Fat free mass (mm)	-0.56	0.05	0.13	0.22	0.53	0.39	0.28	0.80	1.00	0.68
Thigh circum (cm)	-0.32	0.22	-0.04	0.05	0.01	0.00	0.01	0.20	0.21	1.00

* All relationships are negative; a larger dimension corresponds to a faster (lower) 2K time.

Table 7

Regression Analysis of Prediction of 2K Performance Using Physical Characteristics

	R	R square	SEE
Fat-free mass	0.56	0.31	20.7
Experience in college	0.66	0.44	18.8
Height	0.50	0.49	17.8
Years prior experience	0.75	0.57	16.8

CHAPTER 5

Discussion

The purposes of this study were to: (a) describe the physical characteristics of female collegiate rowers; (b) determine differences between rowers by level (novice and varsity); (c) determine differences among rowers by years of rowing experience; and (d) predict performance from physical characteristics.

Participants were members of three female collegiate rowing teams within the Big Ten Conference. The teams were selected based on proximity to the investigator, size of the team, and willingness to participate in the study. All coaches acknowledged that the rowers, at the time of the study, were in the beginning to middle of racing season; it was, therefore, assumed they had similar training volumes and frequencies. Rowers from two of the schools were similar in physical characteristics and 2K times, while rowers from the third school were the smaller and had slower 2K times

Characteristics of Rowers

Selected physical characteristics of the Olympic rowers, elite junior sweep and sculling rowers, and collegiate rowers are summarized in Table 8. Compared to Olympic level rowers of almost 30 years ago (Hebbelinck et al., 1980) and current elite level junior rowers (Bourgois et al., 2001), female collegiate rowers had similar heights, lengths, and thigh and calf girths. Skeletal breadths were also similar, with the exception of the biacromial breadth. Allowing for the similar biacromial breadths among the elite rowers, the data for the present sample may reflect a measurement bias that should be noted in making comparisons. In contrast to linear, girth and breadth measurements, female collegiate rowers were heavier, had larger skinfolds, and larger arm circumferences. In other words, while collegiate female rowers were similar in body size and narrower across the shoulders, they also had relatively more weight for height and more fat mass compared to elite level rowers. The sample of collegiate female rowers had an average of 1 year of experience in rowing prior to entering college. Corresponding information on experience was not reported for the elite junior and senior level rowers.

Somatotypes of collegiate rowers were predominately endomorphic and slightly mesomorphic (5.7 – 4.0 – 1.6). Elite level senior and junior rowers were endomorphic and mesomorphic (3.1 – 3.9 – 2.8, 3.4 – 3.7 – 2.6, respectively). The primary differences between collegiate rowers and the elite rowers are in endomorphy and ectomorphy. Collegiate rowers are, on average, more endomorphic and less ectomorphic. This corresponds with the heavier weights, larger skinfolds and larger girths of the collegiate females rowers compared to the more elite Olympic and junior rowers.

Differences in weight, skinfolds and girths of the collegiate rowers compared to the elite rowers may be a result of sampling variation. The Olympic and junior rowers are probably more select samples and also include both scull and sweep rowers. Sweep and sculling rowers were not clearly differentiated in the sample of senior rowers. The junior level rowers were differentiated into sweep ($N = 108$) and sculling ($N = 111$). The former were significantly taller and heavier, and had greater fat-free mass than the latter (Bourgois et al., 2001). Sweep rowers may be taller and heavier because sweep boats are typically heavier compared to sculling boats. As a result, sweep boats may require larger individuals due to the force needed to move the heavier boat through the water (Secher, 1990; Shephard, 1998). The collegiate rowing sample includes only sweep rowing.

Mean ages at menarche were similar between the Olympic and collegiate rowers, 13.7 years and 13.3 years respectively. The junior level rowers had a slightly younger mean age at menarche, 12.8 years (Claessens et al., 2003). The mean age of menarche for American White females, based on the status quo method, is 12.6 years (Malina et al., 2004). Mean recalled age at menarche for White college women surveyed between 1987 and 1984 was 12.9 years (Malina et al., 2004), while mean recalled age at menarche for White collegiate athletes in seven sports surveyed between 1985 and 1994 was 13.9 years (Malina et al., 1997). The mean age at menarche of the sample of collegiate rowers falls midway between collegiate athletes and students.

In the present study, novice and varsity rowers differed only in years of experience prior to entering college, vertical jump and 2K time. On the other hand, among more elite rowers, top-ranked rowers or finalists differed significantly in many physical characteristics compared to non-ranked or non-finalists (Bourgois et al., 2000; Bourgois et al., 2001; Claessens et al., 2002).

Varsity rowers had significantly more years of experience rowing prior to entering college versus the novice. Although the definition of novice is a rower in her first year of collegiate rowing, it is legal for a coach to place a freshman athlete with prior experience on the varsity level. This was done in a few (5) cases in this study. Thus, this removed some of the experience level from the novice class and created a somewhat artificial group effect.

To explore the "early varsity status" effect further, the rowers with no collegiate experience who were moved up to varsity by the coach were retained with the novices for additional analysis. As expected, the novice group improved in 2K time and vertical jump, but not significantly. However, years experience prior to entering collegiate rowing is no longer significantly different between the groups. New descriptive statistics are revealed in Table 9. The addition of the five members from varsity back to novice added a total of 18 years of experience to the novice levels and thus resulted in no difference between the two levels in rowing experience prior to entering college.

Two performance indicators, vertical jump and 2K time, were significantly better in varsity than in novice rowers. The differences may reflect the influence of more training and experience in the varsity rowers, although the study design does not permit such a conclusion. Nevertheless, training is associated with improved 2K times in collegiate rowers. For example, 2.5K rowing ergometer time and vertical jump improved in 28 novice and experienced female rowers after a 9 week off season training program (Kramer, Morrow & Leger, 1993), and 2K rowing ergometer time improved after a 12 week fall training program in 10 Division I University male rowers (Womack et al., 1996). Among the female rowers, time improved in both the novice and experienced rowers, but the latter still rowed faster, even after training (Kramer et al., 1993).

Years of experience may have an additional part in the better 2K times observed in varsity rowers. More years of experience may translate into better technique and in turn, faster times. Kramer et al. (1993) suggested that the better ergometer times of experienced rowers may reflect the combined influence of heavier body weights, a longer history of weight training, and a longer history of training on an ergometer. Thus, more years of rowing experience probably includes more training for the 2K trial and in turn exerts a positive influence on 2K tests on a rowing ergometer. Familiarity with the 2K time trials is thus a factor associated with more experience in rowing. This is implicit in a study of 8 male high school varsity rowers who performed three consecutive 2K time trials on a rowing ergometer (Schabort, Hawley, Hopkins & Blum, 1999). On average, times on the third trial were five seconds faster than those on the first trial. The faster times seen on the third trial were accompanied by lower heart rates, higher mean power, and more even pacing at each 500M split. Thus, as a rower becomes more familiar with a 2K test, rowing times may decrease. Further study of the 2K performance over a collegiate career, including stroke rate analysis, power outputs, and 500M split times may contribute to a better understanding of the role of years of experience and improved technique in rowing performance.

In the present study, 2K times improve, on average, as years of college rowing experience increase. However, the differences in the present sample were significant only between rowers in year 0 and year 3. In other words, the most experienced collegiate rowers had significantly faster times than the least experienced. However, year 1 and year 2 rowers had similar 2K times. Thus, 2K times do not increase significantly until the last year of participation in collegiate rowing suggesting that more years of training and competition at the varsity level is associated with better performance times.

Although novice and varsity rowers did not differ in physical characteristics, they did differ in somatotype (Table 4). Novice rowers were significantly more endomorphic than varsity rowers. On the other hand, somatotype did not differ among collegiate rowers by years of experience. Varsity rowers have been involved in rowing for at least one season, and therefore may have been exposed to strength training as well as sport specific training. Comparisons to Olympic rowers and canoeists are shown in Table 10. On average, the collegiate sample is more endomorphic compared to the elite level athletes. However, endomorphy may also be a characteristic of rowers in general, compared to their peers from other sports. When comparisons were made among Olympic athletes, the rowers showed the highest values in endomorphy compared to the other athletes (Carter, 1981).

Prediction of Rowing Performance

It was expected that physical characteristics would contribute to the prediction of rowing performance. Physical characteristics were used to predict performance times in kayaking, a sport similar to rowing (Oliver & Coetsee, 2002; Von Someran & Palmer, 2003). Kayak performance was predicted in both studies with upper extremity physical characteristics which including arm span, skeletal breadths, and arm circumferences. Anthropometric dimensions including height, body mass, skinfolds, and limb circumferences provided the best prediction of performance in male rowers (Russell et al., 1998; Williams, 1977). In the latter study Williams (1977), physical characteristics predicted performance only among male rowers 19-23 years of age, but not in those younger or older.

Relationships between physical characteristics and 2K time indicated many significant correlations in the female collegiate rowers (Appendix D, Table 6). A larger body size and larger lengths, girths and breadths were associated with better 2K times. However, the correlations ranged from low to moderate. Allowing for sample size, the number of variables used to predict 2K performance in the collegiate rowers was limited. The best regression model included four variables that accounted 57% of the variance in 2 K performance. Of these, only two were physical characteristics: estimated fat-free mass and height; the remaining two were experience in college and experience prior to college. The two variables accounted for the majority of the variance in 2K performance of female collegiate rowers: fat-free mass (31%) and experience in college rowing (13%). The results suggest a significant role for training in 2K performance. This observation is consistent with other studies of rowers (Kramer et al., 1993; Womack et al., 1996) in which performance times on a rowing ergometer improved after a period of training. Fat-free mass was also a predictor of rowing ergometer performance in other studies (Cosgrove, Wilson, Watt, & Grant, 1999; Yoshiga & Higuchi, 2003). Nevertheless, it is important to note that fat-free mass may increase during college as a result of late adolescent growth (Malina et al., 2003) and this increase in lean tissue may contribute significantly to performance.

It has been suggested that the high correlations between anthropometric dimensions and ergometer rowing performance may be a result of either training or genetics (Russell et al., 1998). The interaction between genotype and training is an additional factor (Bouchard, Malina, & Perusse, 1997). In this study, the highest correlations between anthropometry and 2K performance were only moderate: height (r = -0.51), weight (r = -0.50), and fat-free mass (r = -0.56). Weight and fat-free mass can be altered with training, specifically a program that includes a significant resistance component.

In summary, the present study considered the physical characteristics of female collegiate rowers relative to experience in the sport and to 2K ergometer rowing performance. Differences in physical characteristics between novice (less experience) and varsity (more experience) rowers were small. Physical characteristics, experience and 2K rowing ergometer performance were related in collegiate female rowers. Fat-free mass, height, and experience in rowing before and during college were significant predictors of 2K erogmeter rowing time.

As with any study, there are several limitations. Of the three schools from the Big Ten Conference that participated in this study, 2 placed in the top 12 at the 2004 NCAA championships while the third team failed to qualify. The team that failed to qualify hired a new coach as of the 2003-2004 season and the rowers were still learning his techniques and training regimen. One of the teams typically recruits in Canada, and therefore, had several athletes with prior rowing experience before entering college on their team. If technique and years of experience are indeed important in the sport of rowing, this may have influenced the results.

The design of the present study was cross-sectional. Hence, any inferences about potential training effects are speculative. There is a need for longitudinal study of collegiate rowers from the time of entry into a program (i.e., freshman year) through four years of systematic training in the sport. Such a study would permit a better understanding of changes in body composition and technique during a collegiate career and their potential impact on 2K performance.

Allowing for these limitations and perhaps others, results of this study suggest that experience and in turn training are important in the sport of rowing. Female collegiate rowers in the present study were tall and heavy with a generally endomorphic somatotype. Although novice and varsity rowers differed in 2K performance times, there were no significant differences in physical characteristics. For a coach to choose rowers from the results of this study, they would select an athlete who is tall, lean and experienced in the sport.

Table 8

Comparisons of Physical Characteristics of Olympic Rowers, Junior Sweep RowersJunior Sculling Rowers, and Collegiate Varsity Rowers

	Olympic Rowers[1] (*N* = 51)	Junior Sweep Rowers[2] (*N* = 108)	Junior Scullers[2] (*N* = 111)	Varsity Rowers (*N* = 52)
Age (years)	23.8 ± 2.7			20.8 ± 1.1
Age of Menarche (yrs)	13. 7 ± 1.1			13.2 ± 1.3
Height (cm)	174.3 ± 4.8	176.3 ± 5.4	173.5 ± 6.5	172.6 ± 5.8
Weight (kg)	67.4 ± 5.3	71.6 ± 5.6	67.4 ± 6.1	74.6 ± 8.8
Sitting height (cm)	92.1 ± 2.5	91.3 ± 2.9	90.3 ± 3.0	90.7 ± 2.8
Leg length (cm)		85.0 ± 3.7	82.8 ± 4.5	81.9 ± 4.2
Biacromial breadth (cm)	37.4 ± 1.5	37.8 ± 1.5	37.3 ± 1.6	31.4 ± 1.9*
Biepicondylar breadth (mm)	6.7 ± 0.3	6.7 ± 0.3	6.5 ± 0.3	6.3 ± 0.4
Bicristal breadth (mm)	28.2 ± 1.8	29.8 ± 1.4	29.0 ± 1.8	28.0 ± 1.7
Bicondylar breadth (mm)	9.3 ± 0.4			9.0 ± 0.5
Triceps circumference (cm)	27.6 ± 1.5	27.8 ± 1.5	27.2 ± 1.7	31.1 ± 2.5
Thigh circumference (cm)	57.5 ± 2.9	59.1 ± 2.9	57.8 ± 2.9	57.8 ± 3.6
Calf circumference (cm)	37.0 ± 0.6			38. 5 ± 2.5
Triceps skinfold (mm)	14.6 ± 4.1	14.5 ± 3.2	13.5 ± 3.3	20.7 ± 4.4
Subscapular skinfold (mm)	9.1 ± 2.7	10.5 ± 2.7	9.8 ± 2.5	17.6 ± 4.5
Suprailiac skinfold (mm)	6.6 ± 2.6	9.9 ± 3.7	8.8 ± 3.3	19.9 ± 6.7
Thigh skinfold (mm)	21.5 ± 5.7			27.9 ± 4.7
Medial calf skinfold (cm)	12.8 ± 4.3			19.0 ± 5.2
Somatotype	3.1–3.9–2.8			5.5–4.1–1.6

Data are from [1]Hebbelink et al, 1980, [2]Bourgois et al, 2001. * Biacromial breadth may be biased (see discussion).

Table 9

Performance of Novice and Varsity by Classification

	Old Novice (N = 34)	New Novice (N = 39)	Old Varsity (N = 56)	New Varsity (N = 51)
2K time (sec)	474.1 ± 17.4	470.1 ± 20.6	449.1 ± 23.7	450.5 ± 24.6
Vertical Jump (in)	13.9 ± 2.8	13.8 ± 2.7	15.1 ± 2.4	15.3 ± 2.4
Pre-collegiate experience (yrs)	0.7 ± 0.0	0.9 ± 1.6	1.3 ± 0.0	1.2 ± 1.8

Table 10

Comparisons of Somatotype of Female Collegiate Rowers, Olympic Rowers and Olympic Canoeists

	Collegiate Novice (*N* = 34)	Collegiate Varsity (*N* = 56)	Olympic Rowers* (*N* = 51)	Olympic Canoeist* (*N* = 8)
Height (cm)	172.8 ± 5.4	173.0 ± 5.8	174.3 ± 4.8	170.7 ± 6.9
Weight (kg)	74.2 ± 8.3	74.9 ± 8.6	67.4 ± 5.3	63.0 ± 8.0
Endomorphy	6.0 ± 1.1	5.5 ± 1.1	3.1 ± 0.8	2.8 ± 0.3
Mesomorphy	3.0 ± 1.1	4.1 ± 1.1	3.9 ± 0.9	4.1 ± 0.8
Ectomorphy	1.7 ± 0.9	1.6 ± 0.9	2.8 ± 0.8	2.9 ± 0.6

* Data are from the Montreal Olympic Games as reported by Carter, 1981 and Hebbelink et al., 1980.

APPENDICES

APPENDIX A

UCRIHS Approval

MICHIGAN STATE
UNIVERSITY

November 26, 2003

TO: James PIVARNIK
3 I.M. Sports Circle

RE: **IRB # 00-416 CATEGORY: 1-4 EXEMPT**

APPROVAL DATE: May 21, 2003

EXPIRATION DATE: April 21, 2004

TITLE: EXERCISE TESTING OF INTERCOLLEGIATE ATHLETES

The University Committee on Research Involving Human Subjects' (UCRIHS) review of this project is complete and I am pleased to advise that the rights and welfare of the human subjects appear to be adequately protected and methods to obtain informed consent are appropriate. Therefore, the **UCRIHS APPROVED THIS PROJECT'S REVISION.**

REVISION REQUESTED: September 25, 2003

REVISION APPROVAL DATE: November 25, 2003

This letter notes approval for the changes made in study investigators and target population.

REVISIONS: UCRIHS must review any changes in procedures involving human subjects, prior to initiation of the change. If this is done at the time of renewal, please use the green renewal form. To revise an approved protocol at any other time during the year, send your written request to the UCRIHS Chair, requesting revised approval and referencing the project's IRB# and title. Include in your request a description of the change and any revised instruments, consent forms or advertisements that are applicable.

PROBLEMS/CHANGES: Should either of the following arise during the course of the work, notify UCRIHS promptly: 1) problems (unexpected side effects, complaints, etc.) involving human subjects or 2) changes in the research environment or new information indicating greater risk to the human subjects than existed when the protocol was previously reviewed and approved.

If we can be of further assistance, please contact us at (517) 355-2180 or via email UCRIHS@msu.edu

Sincerely,

Peter Vasilenko, Ph.D.
UCRIHS Chair

OFFICE OF
RESEARCH ETHICS AND STANDARDS

University Committee on Research Involving Human Subjects

Michigan State University
202 Olds Hall
East Lansing, MI
48824

517/355-2180
FAX 517/432-4503

Web: www.msu.edu/user/ucrihs
E-Mail: ucrihs@msu.edu

PV: rt

cc: Rebecca Battista
39 IM Circle

APPENDIX B

Informed Consent

Consent Form

Title: Anthropometric characteristics and performance of female collegiate rowers.

I, ____________________, grant my permission to enroll in a study to examine the variables characteristic to rowing. The entire time required per participant is about 30 minutes total.

Physical characteristics including body size, body proportions and body composition are important in physical performance. As women's collegiate rowing continues to expand across the country, learning more information about this newly growing group becomes vital. The purpose of this study is to describe the physical characteristics of female collegiate rowers and to estimate the contribution of these physical characteristics to rowing performance.

On the test day, the following measures will be obtained: height, weight, sitting height, shoulder and hip breadth, limb circumferences, and skinfold thicknesses of arm, hip, thigh, back, and abdomen. A single female investigator will perform all measurements. Flexibility will be measured using a sit and reach box. Vertical jump will be measured using a standing anthropometer.

There are always possible unforeseen risks with any study, but in this case, any risk should be extremely small. The physical measures will be those typically obtained by coaches and athletic trainers during the normal course of the season. Neither the investigator, nor her faculty sponsor has ever seen any injury occur from any of the measures that will be obtained.

If the participant has any medical condition (e.g., injury to leg, injury to back) which might be a reason not to perform the sit and reach, vertical jump or rowing performance, the investigator should be informed prior to any testing.

A record of each woman's participation in the study will be kept in a confidential file at Michigan State University. Each participant's privacy will be protected to the maximum allowable by law. She is free to withdraw from the study at any time and for any reason. Such withdrawal will not jeopardize her future treatment. There will be no cost for participating in this study.

My signature below, acknowledges my voluntary participation in this research project. Such participation does not release the investigators, institutions, sponsor, or granting agency from their professional and ethical responsibility to me.

If there are any questions regarding this research project, including those regarding participant's rights as human subjects, feel free to contact any of the following individuals: Becki Battista, Project Coordinator (517) 432-7121, James Pivarnik, Ph.D., Project Supervisor (517) 353-3520; Peter Vasilenko, Ph.D., Chair of the University Committee on Research Involving Human Subjects (517) 355-2180.

I have read this consent form and received answers in those areas, which were not clear.
I am willing to give consent to participate in this study.

____
Participant (printed)

______________________________ __________
Participant (signature) Date

____
Investigator
Becki Battista
39 IM Circle
Michigan State University
East Lansing, MI 48823
(517) 432-3798

UCRIHS APPROVAL FOR
THIS project EXPIRES:

APR 21 2004

SUBMIT RENEWAL APPLICATION
ONE MONTH PRIOR TO
ABOVE DATE TO CONTINUE

APPENDIX C

Data Sheet and Questionnaire

NAME	____________________		**SUBJECT #**	[ ]
DATE	________ **am/pm** ________		**date of birth**	________
TEAM	NOVICE VARSITY			
BODY SIZE				
HEIGHT	________ cm			
WEIGHT	________ kg			
SITTING HEIGHT	________ cm			
ARM SPAN	________ cm			
BREADTH				
BIACROMIAL	________ cm	________ cm		
BIEPICONDYLAR	________ cm	________ cm		
BI-ILIAC	________ cm	________ cm		
BICONDYLAR	________ cm	________ cm		
CIRCUMFERENCE				
TRICEP	________ cm	________ cm		
FLEXED ARM	________ cm	________ cm		
THIGH	________ cm	________ cm		
CALF	________ cm	________ cm		
SKINFOLD				
TRICEPS	________ mm	________ mm	________ mm	
SUBSCAPULAR	________ mm	________ mm	________ mm	
BICEPS	________ mm	________ mm	________ mm	
ABDOMINAL	________ mm	________ mm	________ mm	
THIGH	________ mm	________ mm	________ mm	
MEDIAL CALF	________ mm	________ mm	________ mm	
LATERAL CALF	________ mm	________ mm	________ mm	

SUBJECT # ______

SIT AND REACH 1 ______ 2 ______ 3 ______

VERTICAL JUMP 1 ______ 2 ______ 3 ______

standing reach ______

Years rowing prior to college

Years college rowing

Previous sport

Age of menarche

When was your first menstrual cycle?

Menstrual cycle

How many days has it been since your last full cycle?

APPENDIX D

Correlations of 2K time and Descriptive Variables in Female Collegiate Rowers

Appendix D:

Correlations of 2K time and Descriptive Variables in Female Collegiate Rowers

	2K time	Exp Prior	Exp Coll.	Age	Age of men.	Ht	Wt	Sitting height	Leg length
2K time (sec)	1.0	-0.31*	-0.41*	-0.41*	-0.24*	-0.51*	-0.50*	-0.38*	-0.41*
Experience prior (yrs)	-0.31*	1.0	0.07	-0.02	-0.05	-0.02	0.09	-0.06	0.01
Experience college (yrs)	-0.41*	0.07	1.0	0.84*	-0.01	0.09	0.09	0.07	0.07
Age (yrs)	-0.41*	-0.02	0.84*	1.0	-0.01	0.11	0.12	0.07	0.11
Age Menarche (yrs)	-0.24*	-0.05	-0.01	-0.01	1.0	0.25*	0.21*	0.06	0.30*
Height (cm)	-0.51*	-0.02	0.09	0.11	0.25*	1.0	0.47*	0.70*	0.85*
Weight (kg)	-0.50	0.09	0.09	0.11	0.21*	0.47*	1.0	0.43*	0.32*
Sitting height (cm)	-0.38	-0.06	0.07	0.07	0.06	0.70*	0.43*	1.0	0.22*
Leg length (cm)	-0.41*	0.01	0.07	0.11	0.30*	0.85*	0.32*	0.22*	1.0
Sitting height/height	0.15	-0.05	-0.02	-0.05	-0.24	-0.37	-0.04	0.41*	-0.80*
Arm span (cm)	-0.26*	-0.04	-0.01	0.12	0.19	0.61*	0.35*	0.28*	0.63*
Arm span/height	0.04	-0.03	-0.07	0.07	0.05	0.03	0.10	-0.16	0.16
Biacromial breadth (cm)	-0.24*	0.04	-0.01	0.01	0.12	-0.29*	0.25*	0.11	0.32
Biepicondylar breadth (cm)	-0.23*	0.14	-0.03	0.08	0.03	0.17	0.35*	0.27*	0.03
Bicristal breadth (cm)	-0.32*	0.06	-0.06	0.00	0.14	0.39*	0.74*	0.30*	0.31*
Bicondylar breadth (cm)	-0.44*	0.11	0.19	0.18	0.21*	0.26*	0.46*	0.08	0.29*
Triceps circumference (cm)	-0.29*	0.14	0.04	0.04	0.15	0.12	0.81*	0.16	0.04
Flexed arm circumference (cm)	-0.36*	0.12	0.08	0.09	0.15	0.20	0.81*	0.20	0.12
Thigh circumference (cm)	-0.32*	0.10	0.10	0.09	0.14	0.18	0.78*	0.32*	0.00
Calf circumference (cm)	-0.21	-0.01	0.14	0.18	0.08	0.07	0.70*	0.10	0.02
Corrected arm circumference (cm)	-0.40*	0.09	0.15	0.19	0.13	0.16	0.68*	0.12	0.09
Corrected calf circumference (cm)	-0.23*	-0.13	0.13	0.26*	0.05	0.03	0.47*	0.09	-0.03
Triceps skinfold (mm)	-0.02	0.19	-0.17	-0.26	0.09	0.05	0.54*	0.06	0.03
Subscapular skinfold (mm)	-0.14	0.13	-0.12	-0.12	0.13	0.09	0.55*	0.07	0.07

Appendix D, *continued*

	2K time	Exp Prior	Exp Coll.	Age	Age of men.	Ht	Wt	Sitting height	Leg length
Suprailiac skinfold (mm)	-0.06	-0.01	-0.11	-0.14	0.11	0.09	0.58*	0.03	0.07
Thigh skinfold (mm)	-0.03	0.22*	-0.04	-0.17	0.05	0.01	0.42*	0.19	-0.10
Medial calf skinfold (mm)	-0.04	0.11	0.03	-0.13	0.05	0.06	0.51*	0.03	0.06
Lateral calf skinfold (mm)	0.04	0.20	0.03	-0.05	0.05	0.06	0.25*	0.01	0.07
Biceps skinfold (mm)	0.02	0.08	-0.10	-0.11	0.11	-0.05	0.61*	0.04	-0.09
Abdominal skinfold (mm)	-0.08	0.04	-0.08	-0.14	0.09	0.07	0.57*	0.07	0.04
Fat-free mass (mm)	-0.56*	0.05	0.13	0.20	0.22*	0.52*	0.96*	0.45*	0.39*
Fat mass (mm)	-0.29*	0.14	0.00	-0.05	0.16	0.27*	0.87*	0.32*	0.13
Percent fat	-0.01	0.15	-0.09	-0.21	0.09	-0.00	0.49*	0.10	-0.08
Flexbility (cm)	-0.02	0.09	0.06	0.11	0.06	-0.06	-0.03	0.01	-0.09
Vertical jump (in)	-0.05	-0.11	0.25*	0.19	0.23*	0.09	0.10	-0.04	0.15
Leg power	-0.40	-0.01	0.22*	0.22*	0.31*	0.41*	0.79*	0.30*	0.34*
Σ Trunk skinfolds (mm)	-0.10	0.05	-0.11	-0.14	0.12	0.09	0.62*	0.06	0.08
Σ Extremity skinfolds (mm)	-0.01	-0.20	-0.06	-0.17	0.08	0.03	0.56*	0.09	-0.02
Endomorphy	-0.02	0.10	-0.15	-0.19	0.10	-0.04	0.58*	-0.03	-0.03
Mesomorphy	-0.14	0.14	0.09	0.15	0.00	-0.42*	0.48*	-0.22*	0.41*
Ectomorphy	0.04	-0.13	-0.03	-0.02	0.00	0.41*	-0.58	0.20	0.41*

Appendix D, *continued*

	Sitting height/Ht	Arm Span	Arm span/Ht	Biac. breadth	Biepi. breadth	Bicristal breadth	Bicond. breadth
2K time (sec)	0.15	-0.26*	0.43	-0.24*	-0.24*	-0.32*	-0.44*
Experience prior (yrs)	-0.05	-0.04	-0.03	0.04	0.15	0.06	0.11
Experience college (yrs)	-0.02	-0.01	-0.07	-0.01	-0.03	-0.06	0.19
Age (yrs)	-0.05	0.12	0.07	0.01	0.08	0.00	0.18
Age Menarche (yrs)	-0.24*	0.19	0.05	0.12	0.03	0.14	0.21*
Height (cm)	-0.37*	0.61*	0.03	0.29*	0.17	0.39	0.26*
Weight (kg)	-0.04	0.35*	0.10	0.25*	0.35*	0.74*	0.46*
Sitting height (cm)	-0.41*	0.28*	-0.16	0.11	0.27*	0.30*	0.08
Leg length (cm)	-0.80*	0.63*	0.16	0.32*	0.03	0.31*	0.29*
Sitting height/height	1.0	-0.41*	-0.25*	-0.22*	0.13	-0.10	-0.22*
Arm span (cm)	-0.41*	1.0	0.81*	0.31*	0.03	0.31*	0.30*
Arm span/height	0.25*	0.81*	1.0	0.18	-0.09	0.11	0.19
Biacromial breadth (cm)	-0.22*	0.31*	0.31*	1.0	0.04	-0.38*	0.16
Biepicondylar breadth (cm)	0.13	0.03	-0.09	0.04	1.0	0.29*	-0.24*
Bicristal breadth (cm)	-0.10	0.31*	0.11	0.38*	0.29*	1.0	0.24*
Bicondylar breadth (cm)	-0.22	0.30*	0.19	0.16	-0.24*	0.24*	1.0
Triceps circumference (cm)	0.05	0.12	0.06	0.16	0.34*	0.60*	0.31*
Flexed arm circumference (cm)	0.02	0.14	0.03	0.21*	0.36*	0.60*	0.28*
Thigh circumference (cm)	0.19	0.06	-0.06	0.07	0.36*	0.48*	0.30*
Calf circumference (cm)	0.04	0.03	-0.01	0.14	0.28*	0.46*	0.27*
Corrected arm circumference (cm)	0.03	0.12	0.04	0.21*	0.26*	0.51*	0.28*
Corrected calf circumference (cm)	0.08	0.03	0.01	0.21*	0.15	0.32*	0.20
Triceps skinfold (mm)	0.01	0.06	0.03	0.03	0.34*	0.40*	0.19
Subscapular skinfold (mm)	-0.02	0.12	0.08	0.02	0.10	0.33*	0.41*
Biceps skinfold (mm)	0.11	0.05	0.10	-0.02	0.22*	0.45*	0.20
Abdominal skinfold (mm)	0.01	0.05	0.02	0.04	0.18	0.41*	0.28

Appendix D, *continued*

	Sitting height/Ht	Arm span	Arm span/Ht	Biac. breadth	Biepi. breadth	Bicristal breadth	Bicond. breadth
Suprailiac skinfold (mm)	-0.07	0.14	0.10	0.02	0.06	0.38*	0.41*
Thigh skinfold (mm)	0.23*	-0.07	-0.09	0.01	0.27*	0.26*	0.09
Medial calf skinfold (mm)	-0.04	-0.02	-0.06	-0.10	0.20	0.35*	0.23*
Lateral calf skinfold (mm)	-0.06	0.04	0.00	-0.05	0.22*	0.13	0.03
Fat-free mass (mm)	-0.09	0.41*	0.13	0.28*	0.32*	0.73*	0.46*
Fat mass (mm)	0.07	0.17	0.02	0.14	0.35*	0.62*	0.37*
Percent fat	0.13	-0.05	-0.07	-0.00	0.25*	0.33*	0.19
Flexbility (cm)	0.08	0.03	0.09	0.04	-0.12	-0.07	0.11
Vertical jump (in)	-0.16	-0.02	-0.09	0.17	0.05	0.14	-0.03
Leg power	-0.13	0.26	0.02	0.27*	0.28*	0.64*	0.32*
Σ Trunk skinfolds (mm)	-0.03	0.11	0.07	0.03	0.12	0.41*	0.40*
Σ Extremity skinfolds (mm)	0.07	0.01	-0.01	-0.03	0.30*	0.38*	0.18
Endomorphy	0.01	0.04	0.08	-0.02	0.14	0.36*	0.37*
Mesomorphy	0.25*	-0.23*	0.02	0.01	0.43*	0.28*	0.27*
Ectomorphy	-0.25*	0.19	-0.06	0.01	-0.25*	-0.41*	-0.22*

Appendix D, *continued*

	Triceps circum.	Flexed arm circum.	Thigh circum.	Calf circum.	Triceps skinfold	Subscap skinfold	Biceps skinfold	Abd. skinfold
2K time (sec)	-0.29*	-0.36*	0.32*	-0.21	-0.02*	-0.14	0.02	-0.08
Experience prior (yrs)	0.14	0.12	0.10	-0.01	0.19	0.13	0.08	0.04
Experience in college (yrs)	0.04	0.08	0.10	0.14	-0.17	-0.12	-0.10	-0.08
Age (yrs)	0.04	0.09	0.09	0.18	-0.26*	-0.12	-0.11	-0.14
Age Menarche (yrs)	0.15	0.15	0.14	0.08	0.09	0.13	0.11	0.09
Height (cm)	0.12	0.20	0.18	0.07	0.05	0.09	-0.05	0.07
Weight (kg)	0.81*	0.81*	0.78*	0.70*	0.54*	0.55*	0.61*	0.57*
Sitting height (cm)	0.16	0.20	0.32*	0.10	0.06	0.07	0.04	0.07
Leg length (cm)	0.04	0.12	0.00	0.02	-0.03	0.07	-0.09	0.04
Sitting height/height	0.05	0.02	0.19	0.04	0.12	-0.02	0.11	0.01
Arm span (cm)	0.12	0.14	0.06	0.03	0.06	0.12	0.05	0.05
Arm span/height	0.06	0.03	-0.06	-0.01	0.03	0.08	0.10	0.02
Biacromial breadth (cm)	0.16	0.21*	0.07	0.14	0.03	0.02	-0.02	0.04
Biepicondylar breadth (cm)	0.34	0.36*	0.36*	0.28*	0.34*	0.10	0.22*	0.18
Bicristal breadth (cm)	0.60	0.59*	0.48*	0.46*	0.40*	0.33*	0.45*	0.41*
Bicondylar breadth (cm)	0.31	0.28*	0.30*	0.27*	0.19	0.41*	0.20	0.28*
Triceps circumference (cm)	1.0	0.94*	0.70*	0.56*	0.64*	0.49*	0.67*	0.60*
Flexed arm circumference (cm)	0.94*	1.0	0.71*	0.57*	0.57*	0.41*	0.57*	0.44*
Thigh circumference (cm)	0.70*	0.71*	1.0	0.67*	0.60*	0.48*	0.59*	0.51*
Calf circumference (cm)	0.55*	0.57*	0.67*	1.0	0.40*	0.34*	0.48*	0.34*
Corrected arm circumference (cm)	0.89*	0.87*	0.52*	0.42*	0.27*	0.25*	0.30*	0.36
Corrected calf circumference (cm)	0.36*	0.41*	0.38*	0.81*	-0.02	0.10	0.15	0.07
Triceps skinfold (mm)	0.64*	0.57*	0.60*	0.40*	1.0	0.56*	0.69*	0.61*
Subscapular skinfold (mm)	0.49*	0.41*	0.48*	0.34*	0.56*	1.0	0.61*	0.71*
Biceps skinfold (mm)	0.67*	0.57*	0.59*	0.48	0.69*	0.61*	1.0	0.63*

Appendix D, *continued*

	Triceps circum.	Flexed arm circum.	Thigh circum.	Calf circum.	Triceps skinfold	Subscap skinfold	Biceps skinfold	Abd. skinfold
Abdominal skinfold (mm)	0.60*	0.44*	0.51*	0.34*	0.61*	0.71*	0.63*	1.0
Suprailiac skinfold (mm)	0.61*	0.44*	0.54*	0.38*	0.62*	0.62*	0.61*	0.82*
Thigh skinfold (mm)	0.37*	0.35*	0.63*	0.48*	0.60*	0.41*	0.09	0.38*
Medial calf skinfold (mm)	0.43*	0.37*	0.58*	0.27*	0.72*	0.51*	0.23*	0.55*
Lateral calf skinfold (mm)	0.20	0.20	0.38*	0.66*	0.52*	0.22*	0.03	0.26*
Fat-free mass (mm)	0.74*	0.79*	0.68*	0.62*	0.39*	0.41*	0.46*	0.38*
Fat mass (mm)	0.76	0.70	0.82*	0.36*	0.72*	0.69*	0.37*	0.80*
Percent fat	0.51*	0.40*	0.62*	-0.02	0.71*	0.64*	0.19	0.82
Flexbility (cm)	0.06	0.06	-0.06	0.26	-0.21*	-0.16	0.11	-0.23*
Vertical jump (in)	0.08	0.20	0.03	0.26*	-0.08	-0.10	-0.03	-0.05
Leg power	0.64*	0.71*	0.59*	0.66*	0.34*	0.35*	0.32*	0.38*
Σ of Trunk skinfolds (mm)	0.63*	0.47*	0.57*	0.38*	0.66*	0.86*	0.40*	0.93*
Σ of Extremity skinfolds (mm)	0.55*	0.49*	0.68*	-0.50*	0.85*	0.56*	0.18	0.59*
Endomorphy	0.64*	0.51*	0.59*	0.40*	0.79*	0.85*	0.37*	0.83
Mesomorphy	0.65*	0.64*	0.57*	0.67*	0.41*	0.34*	0.27*	0.34
Ectomorphy	-0.71*	-0.67*	-0.63*	-0.63*	-0.54*	-0.50*	-0.22*	-0.55

Appendix D, *continued*

	Supra-iliac skinfold	Thigh skinfold	Medial calf skinfold	Lateral calf skinfold	Fat-free mass	Fat mass	Percent fat	Σ Trunk skinfold
2K time (sec)	-0.06	-0.03	-0.04	0.04	-0.56*	-0.29*	-0.01	-0.10
Experience prior (yrs)	-0.01	0.22*	0.11	0.20	0.05	0.14	0.15	0.05
Experience college (yrs)	-0.11	-0.04	0.03	0.03	0.13	0.00	-0.09	-0.11
Age (yrs)	-0.14	-0.17	-0.13	-0.05	0.20	-0.05	-0.21	-0.14
Age Menarche (yrs)	0.11	0.05	0.05	0.05	0.22*	0.16	0.09	0.12
Height (cm)	0.09	0.01	0.06	0.06	0.53*	0.27*	-0.00	0.09
Weight (kg)	0.58*	0.42*	0.51*	0.25*	0.96*	0.87*	0.49*	0.62*
Sitting height (cm)	0.03	0.19	0.03	0.01	0.45*	0.32*	0.10	0.06
Leg length (cm)	0.07	-0.10	0.06	0.07	0.39*	0.13	-0.08	0.08
Sitting height/height	-0.07	0.23*	-0.04	-0.06	-0.09	0.07	0.13	-0.03
Arm span (cm)	0.14	-0.07	-0.02	0.04	0.41	0.17	-0.05	0.12
Arm span/height	0.10	-0.09	-0.06	0.00	0.13	0.02	-0.07	0.07
Biacromial breadth (cm)	0.02	0.01	-0.10	-0.05	0.28	0.14	-0.00	0.03
Biepicondylar breadth (cm)	0.06	0.27	0.20	0.22*	0.32*	0.35*	0.25*	0.12
Bicristal breadth (cm)	0.38*	0.26*	0.35*	0.13	0.73*	0.62*	0.33*	0.41*
Bicondylar breadth (cm)	0.41*	0.09	0.23*	0.03	0.46*	0.37*	0.19	0.40*
Triceps circumference (cm)	0.61*	0.37*	0.43*	0.20	0.74*	0.76*	0.51*	0.63*
Flexed arm circumference (cm)	0.44*	0.35*	0.37*	0.20	0.79*	0.70*	0.40*	0.47*
Thigh circumference (cm)	0.54*	0.63*	0.58*	0.38*	0.68*	0.82*	0.62*	0.56*
Calf circumference (cm)	0.35*	0.38*	0.48*	0.27	0.66*	0.62*	0.36*	0.38*
Corrected arm circumference (cm)	0.38*	0.10	0.35*	-0.05	0.70	0.52*	0.21	0.37*
Corrected calf circumference (cm)	0.08	-0.03	-0.08	-0.29	0.54*	0.25*	-0.05	0.37*
Triceps skinfold (mm)	0.62*	0.60*	0.72*	0.52*	0.39*	0.72*	0.71*	0.66*
Subscapular skinfold (mm)	0.70*	0.41*	0.51*	0.22*	0.41*	0.69*	0.64*	0.86*
Biceps skinfold (mm)	0.61*	0.51*	0.65*	0.36*	0.48*	0.73*	0.65	0.68*

Appendix D, *continued*

	Supra-iliac skinfold	Thigh skinfold	Medial calf skinfold	Lateral calf skinfold	Fat-free mass	Fat mass	Percent fat	Σ trunk skinfold
Abdominal skinfold (mm)	0.82*	0.38*	0.55*	0.26*	0.38*	0.80*	0.82*	0.94*
Suprailiac skinfold (mm)	1.0	0.41*	0.55*	0.26*	0.43*	0.74*	0.71*	0.94*
Thigh skinfold (mm)	0.41*	1.0	0.66*	0.56*	0.21*	0.72*	0.83*	0.44*
Medial calf skinfold (mm)	0.55*	0.66*	1.0	0.62*	0.35*	0.70*	0.69*	0.59*
Lateral calf skinfold (mm)	0.26*	0.56*	0.62*	1.0	0.13	0.43*	0.49*	0.27*
Fat-free mass (mm)	0.43*	0.21*	0.35*	0.13	1.0	0.71*	0.25*	0.45*
Fat mass (mm)	0.74*	0.72*	0.70*	0.43*	0.71*	1.0	0.85*	0.80*
Percent fat	0.71*	0.83*	0.69*	0.49*	0.25*	0.85*	1.0	0.80*
Flexbility (cm)	-0.05	-0.16	-0.32*	-0.18	0.04	-0.16	-0.24*	-0.16
Vertical jump (in)	-0.14	-0.16	-0.12	-0.15	0.16	-0.03	-0.12	-0.11
Leg power	0.34*	0.20	0.30*	0.10	0.80*	0.62*	0.29*	0.39*
Σ Trunk skinfolds (mm)	0.94*	0.44*	0.59*	0.27*	0.45*	0.82*	0.80*	1.0
Σ Extremity skinfolds (mm)	0.59*	0.83*	0.90*	0.75*	0.37*	0.81*	0.82*	0.63*
Endomorphy	0.91*	0.53*	0.65*	0.36*	0.40*	0.79*	0.80*	0.95*
Mesomorphy	0.32*	0.32*	0.31*	0.15	0.43*	0.49*	0.35*	-0.36
Ectomorphy	-0.51*	-0.43*	-0.48*	-0.25*	-0.48*	-0.66*	-0.55*	-0.57*

Appendix D, *continued*

	Σ Extremity skinfold	Flexibility	Vertical Jump	Leg Power	Arm circum.	Calf circum.
2K time (sec)	-0.01	-0.02	-0.05	-0.40*	0.40*	-0.23*
Experience prior (yrs)	0.20	0.09	-0.11	-0.01	0.09	-0.13
Experience in college (yrs)	-0.06	0.06	0.25*	0.22*	0.15	0.13
Age (yrs)	-0.17	0.11	0.19	0.22*	0.19	0.26*
Age Menarche (yrs)	0.08	0.06	0.23*	0.30*	0.13	0.05
Height (cm)	0.03	-0.06	0.09	0.41*	016	0.03
Weight (kg)	0.56*	-0.03	0.09	0.79*	0.68*	0.47*
Sitting height (cm)	0.09	0.01	-0.04	0.30*	0.18	0.09
Leg length (cm)	-0.02	-0.09	0.15	0.34*	-0.03	0.02
Sitting height/height	0.07	0.08	-0.16	-0.13	0.03	0.08
Arm span (cm)	0.01	0.03	-0.02	0.26*	0.12	0.03
Arm span/height	-0.01	0.09	-0.09	0.02	0.04	0.01
Biacromial breadth (cm)	-0.03	0.04	0.17	0.27*	0.21*	0.21*
Biepicondylar breadth (cm)	0.30*	-0.12	0.05	0.28*	0.26*	0.15
Bicristal breadth (cm)	0.38*	-0.07	0.14	0.64*	0.51*	0.32*
Bicondylar breadth (cm)	0.18	0.11	-0.03	0.32*	0.28*	0.19
Triceps circumference (cm)	0.55*	0.06	0.08	0.64*	0.89*	0.36*
Flexed arm circumference (cm)	0.49*	0.06	0.20	0.59*	0.86*	0.41*
Thigh circumference (cm)	0.68*	-0.06*	0.03	0.66*	0.52*	0.38*
Calf circumference (cm)	0.49*	-0.02	0.26	0.34*	0.42*	0.81*
Corrected arm circumference (cm)	0.17	0.21*	0.16	0.59*	1.0	0.21*
Corrected calf circumference (cm)	0.57*	0.25*	-0.05	0.16	0.09	0.25*
Triceps skinfold (mm)	0.85*	-0.21	-0.08	0.34*	0.27*	-0.02
Subscapular skinfold (mm)	0.56*	-0.16	-0.10	0.35*	0.25*	0.10
Biceps skinfold (mm)	0.77*	-0.17	-0.04	-0.42*	0.30*	0.15
Abdominal skinfold (mm)	0.59*	-0.23*	-0.05	0.38*	0.36*	0.07
Suprailiac skinfold (mm)	0.59*	-0.05	-0.14	0.34*	0.38*	0.08
Thigh skinfold (mm)	0.83*	-0.16	-0.16	0.20	0.10	-0.03
Medial calf skinfold (mm)	0.90*	-0.32*	-0.12	0.30*	0.35*	-0.08
Lateral calf skinfold (mm)	0.75*	-0.18	-0.14	0.10	-0.05	-0.29

Appendix D, *continued*

	Σ of extremity	Flexibility	Vertical jump	Leg power	Arm circum	Calf circum
Fat-free mass (mm)	0.37*	0.04	0.16	0.80**	0.70*	0.54*
Fat mass (mm)	0.81*	-0.16	-0.03	0.62*	0.52*	0.25*
Percent fat	0.82*	-0.24*	-0.12	0.29*	0.21	-0.05
Flexbility (cm)	-0.26*	1.0	0.20	0.09	0.21*	0.16
Vertical jump (in)	-0.14	0.20	1.0	0.68*	0.16	0.37*
Leg power	0.33*	0.09	0.68*	1.0	0.59*	0.57*
Σ Trunk skinfolds (mm)	0.63*	-0.16	-0.11	0.39*	0.37*	0.09
Σ Extremity skinfolds (mm)	1.0	-0.26*	-0.14	0.33*	0.17	-0.07
Endomorphy	0.74*	-0.15	-0.14	0.35*	0.33*	0.06
Mesomorphy	0.40*	0.09	0.13	0.42*	0.56*	0.56*
Ectomorphy	-0.56*	-0.02	-0.07	-0.47*	-0.55*	-0.42*

Appendix D, *continued*

	Endomorphy	Mesomorphy	Ectomorphy
2K time (sec)	-0.02	-0.14	0.04
Experience prior (yrs)	0.10	0.14	-0.13
Experience in college (yrs)	-0.15	0.09	-0.03
Age (yrs)	-0.19	0.15	-0.02
Age of Menarche (yrs)	0.10	0.00	0.00
Height (cm)	-0.04	-0.42*	0.41*
Weight (kg)	0.58*	-0.48*	-0.58*
Sitting height (cm)	-0.03	-0.22	0.20
Leg length (cm)	-0.03	0.41*	0.41*
Sitting height/height	0.01	0.25*	-0.25
Arm span (cm)	0.04	-0.23*	0.19
Arm span/height	0.08	0.02	-0.06
Biacromial breadth (cm)	-0.02	0.01	0.01
Biepicondylar breadth (cm)	0.14	0.28*	-0.25*
Bicristal breadth (cm)	0.36*	0.64*	-0.41*
Bicondylar breadth (cm)	0.37*	0.32*	-0.22*
Triceps circumference (cm)	0.64*	0.64*	-0.71*
Flexed arm circumference (cm)	0.50*	0.59*	-0.66*
Thigh circumference (cm)	0.59*	0.66*	-0.63*
Calf circumference (cm)	0.40*	0.34*	-0.63*
Corrected arm circumference (cm)	0.33*	0.56*	-0.55*
Corrected calf circumference (cm)	0.06	0.56*	-0.42*
Triceps skinfold (mm)	0.79*	0.34*	-0.54*
Subscapular skinfold (mm)	0.85*	0.35*	0.50*
Biceps skinfold (mm)	0.72*	-0.42*	0.64*
Abdominal skinfold (mm)	0.83*	0.38*	-0.55*
Suprailiac skinfold (mm)	0.91*	0.32*	-0.51*
Thigh skinfold (mm)	0.53*	0.32*	-0.43*
Medial calf skinfold (mm)	0.65*	0.31*	-0.48*
Lateral calf skinfold (mm)	0.36*	0.15	-0.24*
Fat-free mass (mm)	0.40*	0.43*	-0.48*
Fat mass (mm)	0.79*	0.49*	-0.66*
Percent fat	0.80*	0.35*	-0.55*
Flexbility (cm)	-0.15	0.09	-0.02
Vertical jump (in)	-0.14	0.13	-0.07
Leg power	0.35*	0.42*	-0.47*
Σ of Trunk skinfolds (mm)	-0.95	0.36*	-0.57*
Σ of Extremity skinfolds (mm)	0.74*	0.40*	-0.56*
Endomorphy	1.0	0.45*	-0.65*
Mesomorphy	0.45*	1.0*	-0.86*
Ectomorphy	-0.65*	-0.86*	1.0

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