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Title: The Effect of Somatotype on Indirect Assessment of Aerobic Capacity

Abstract approved: Patricia J McSwegin, Ph.D.

The purpose of this study was to determine the differences in performance of individuals, classified according to Heath-Carter anthropometric somatotype ratings, on the YMCA bicycle ergometer test, 1.5-mile endurance run and the Queens College step test. Heath-Carter anthropometric somatotypes were determined for 141 male college students who were enrolled in a required physical education course at Emporia State University. A sample (n=60) of 15 endotypes, 30 mesotypes, and 15 ectotypes, representing the proportion of individuals classified in each somatogroup of the subject pool (n=141), was randomly selected. All subjects in the sample were evaluated in terms of their performance on the YMCA bicycle ergometer test, 1.5-mile endurance run and Queens College step test. These indirect tests of aerobic capacity were used to obtain estimates of max VO_2 (ml/kg/min) for each subject in the sample. A fixed effects model of ANOVA showed significant differences

to exist within the data base for the main effects of somatotype and aerobic capacity. The interaction term was found to be insignificant. Therefore, the main effects were interpreted. A Tukey post-hoc analysis was used to clarify ANOVA results.

From the Tukey analysis, it was determined that significant differences existed between the grand mean values of estimated max VO_2 (ml/kg/min) for the mesotype and endotype somatogroups, and between the grand mean values of estimated max VO_2 (ml/kg/min) for the ectotype and endotype somatogroups, across all tests of aerobic capacity. No significant difference was found to exist between the grand mean values of estimated max VO_2 (ml/kg/min) for the mesotype and ectotype somatogroups, across all tests of aerobic capacity. It was concluded that a high degree of the first component, endomorphy, in one's somatotype appears to be a limiting factor in the performance of selected indirect tests of aerobic capacity.

Further Tukey analysis showed significant differences to exist between all of the grand mean values of estimated max VO_2 (ml/kg/min) elicited by the YMCA bicycle ergometer test, 1.5-mile endurance run, and Queens College step test, across all somatogroups. Although significant differences existed between the magnitude of the max VO_2 (ml/kg/min) estimates produced by each indirect test of aerobic capacity, across all somatogroups, the question of which test provides the most effective estimate of max VO_2 was not addressed. The study does suggest that the Queens College step test tends to produce the most liberal estimates of max VO_2 (ml/kg/min) when compared to the estimates of max VO_2 (ml/kg/min) produced by the 1.5-mile endurance run and the YMCA bicycle ergometer test. The YMCA bicycle ergometer test tends to elicit the most conservative estimates of max VO_2 (ml/kg/min). It was concluded that the indirect aerobic capacity test of choice in a given research or practical application, then, is a function of the philosophy and purpose inherent in the evaluation.

Ph. D.

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The Effect of Somatotype on Indirect Assessment of Aerobic Capacity

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Chapter 1

Introduction

An important goal of the physical fitness profession is to test an individual's ability to meet the demands of various types of work. Physical fitness is a combination of several aspects rather than a single characteristic. The components of physical fitness are classified as performance related and health related. Performance related fitness aspects refer to power, speed, agility, balance, coordination and reaction time which directly influence achievement of motor skills. The health related aspects refer to cardiovascular fitness, body composition, flexibility and muscular strength and endurance. The health related fitness aspects are important to the entire population, non-athletes as well as athletes, because of their close association to one's general health (Falls, Baylor and Dishman, 1980). Determining the degree to which an individual possesses the health related components of physical fitness is the basis for test development and application in this field.

The single most important component of health related fitness is cardiovascular endurance (aerobic capacity), that is, the efficiency with which the heart and lungs are able to provide the working body with sufficient quantities of oxygen for use as a fuel. It has been theorized that the better fit cardiovascular system provides a decreased risk for the development of, or acts to delay the onset of, coronary heart disease which is a major cause of death in the adult populations of industrialized nations (deVries, 1980).

An increased efficiency of the cardivascular system usually requires an increased efficiency of many other body systems associated with the total development of physical fitness. Body composition is a health related aspect of fitness that affects aerobic capacity (Laubach, Hollering and Goulding, 1971). Body composition is based on the relative percentages of lean tissue (i.e., muscle, organs, bones and body fluids) and fat tissue in the total body make up. Body composition represents one approach to the measurement of human physique. An alternative approach to the quantitative description of human physique is somatotype. A somatotype is a three-numeral rating, consisting of sequential numerals always in the same order. Each sequential numeral represents evaluation of a primary component of physique which describes individual variation in body composition and morphology: endomorphy (fatness or relative leanness), mesomorphy (lean body mass per unit of height) and ectomorphy (relative linearity). Every human innately possesses varying degrees of endomorphy, mesomorphy and ectomorphy, which can be determined by a somatotype rating. A somatotype rating is based on several body (anthropometric) measurements including height, weight, muscle girths, bone diameters and skinfolds (Carter, 1972). All three components of an anthropometric somatotype rating are associated with body composition (Lohman, Slaughter, Selinger and Boileau, 1978).

Aerobic capacity in relation to body composition has been a concern in the field of physical fitness. Previous studies have demonstrated that lean body mass and percent body fat affect aerobic capacity measurement in various populations (Katch, Girandola and Katch, 1971); Laubach, Hollering and Goulding, 1971; Welch, Reindeau, Crisp and

Isenstein, 1958; Buskirk and Taylor, 1957). However, there is a discrepancy as to the relationship between measures of cardiovascular fitness and anthropometric measurements. It has been reported that it is important to emphasize the total physique through somatotyping, rather than relying on simple body measurements, when determining relationships between body measurements and physical performance. What needs to be done is to investigate the influence of somatotype on selected indirect measures of aerobic capacity.

The most common direct measurement technique used to determine maximal aerobic capacity (max VO_2) requires the subject to perform an all-out exertion run on a treadmill during which an amount of expired gas is collected and analyzed in order to determine the value of max VO_2. Because the direct measurement is not practical in terms of expense, complexity of use and safety to the subject, many indirect tests have been developed for estimating max VO_2. The most widely used indirect tests of aerobic capacity include distance runs, bicycle ergometer tests and bench stepping tests (Astrand and Rodahl, 1977).

Both direct and indirect techniques are used to evaluate body composition. Direct assessment of body composition is invasive, which requires a chemical analysis of the human cadaver. Indirect assessments include hydrostatic weighing, skinfolds, anthropometric measurements and somatotype. Although the direct technique provides the theoretical validity for the indirect techniques, it is the indirect procedures that enable fitness specialists to evaluate the fat and lean components of living people (McArdle, Katch and Katch, 1981).

Indirect assessment of the health related aspects of fitness is an efficient way to determine the degree to which an individual possesses various components of fitness. However, because indirect methods can provide estimates only, care must be taken when making the measurements. Furthermore, one must select the assessment method which best fits the characteristics of the subject. These characteristics might include somatotype. In this investigation, the Queens College step test, 1.5-mile run and YMCA bicycle ergometer test were administered to a sample of male college students who were classified according to their Heath-Carter anthropometric somatotype, with the purpose of determining differences in aerobic capacity.

Statement of the Problem

Indirect methods of testing are used to estimate maximal aerobic capacity for subjects exhibiting a wide range of physical characteristics. Indirect tests are used to a greater extent than direct assessments because they are practical, safe and inexpensive. Furthermore, the indirect tests have been found to provide valid estimates of maximal aerobic capacity (Burke, 1976; Cooper, 1968). The problem is that the components of human physique, especially body composition, influence individual performance on tests of aerobic capacity. Thus, physical characteristics may deter or enhance the estimation of aerobic capacity (Baubach, Hollering and Goulding, 1971). Therefore, it is essential to identify the influencing physical characteristics in order to select an appropriate test for estimating max VO_2.

This study was designed to investigate the degree to which three basic fitness tests, used to estimate maximal aerobic capacity, are affected by differences in somatotype. The specific objective was to determine if the predictive results of the Queens College step test, 1.5-mile run and YMCA bicycle ergometer test, differed significantly between three general groups of somatotype (somatogroups): endotype, mesotype and ectotype. Each somatogroup was composed of subject exhibiting a dominance of the first component, endomorphy, the second component, mesomorphy, or the third component, ectomorphy, in a Heath-Carter anthropometric somatotype rating. The scope of this study was considered to be an attempt to provide information relating to the problem: Can established tests used to estimate max VO_2 prove to be valid when administered to a general population, without first considering the influence of physical characteristics innate to each subject?

Research Question and Hypotheses

The question of importance to this research was: Are there significant differences between the performance of individuals, classified and grouped according to similar Heath-Carter anthropometric somatotype ratings, on selected indirect tests of aerobic capacity: the Queens College step test, 1.5-mile run, and YMCA bicycle ergometer test? Statements of the substantive hypotheses (null form) for this research were: (1) There is no significant difference between the endotype, mesotype and ectotype somatogroup grand means for estimated max VO_2, across all three indirect tests of aerobic capacity: Queens

College step test, 1.5-mile run and YMCA bicycle ergometer test.
(2) There is no significant difference between the Queens College step test, 1.5-mile run and YMCA bicycle ergometer test grand means for estimated max VO_2, across all somatogroups: endotype, mesotype and ectotype.

Significance of the Study

The purpose of this study was to relate somatotype to aerobic capacity assessment. Do individuals with different somatotypes perform at different levels on indirect tests of aerobic capacity? If so, then somatotyping might prove to be a valuable diagnositc tool for use in selecting an appropriate indirect test for assessment of cardiovascular fitness. Considering the physical characteristics of each subject would help to individualize testing procedures. This might require adjustments or changes in the testing methodology to be made based on individual differences in somatotype in order for the tests to be considered valid for all populations. Furthermore, by understanding how different somatotypes affect indirect tests of aerobic capacity, the interpretation of an individual's performance might be more clearly understood. The research results, at a minimum, provided additional information about the relationship between somatotype and selected indirect measures of aerobic capacity, thus possibly serving as a basis for related research in the future.

Chapter 2

Review of Related Literature

For several decades psychologists, anthropologists and social scientists have attempted to enhance understanding of such human characteristics as intelligence, temperament and general conduct by making detailed measurements of the physical aspects of human structure. Those measurements often included some determination of body type. Body type is often used today as a factor in the prediction of physical performance. However, neither in the past was there, nor is there yet, agreement as to how individual body types should be classified, nor how valid such ratings are over a period of years. Much study remains in regard to measurement of body type and determination of its relationship to the basic qualities of physical fitness and performance.

Many elements contribute to physical fitness: muscular strength and endurance, flexibility, cardiovascular endurance, body composition and body type. A great deal of research has been conducted on the contribution some of these elements make to total fitness. However, studies showing the relationship between body type and muscular strength and endurance, flexibility and cardiovascular endurance are limited.

It is the purpose of this research to determine if and how individuals, grouped according to body type classification, perform differently on indirect measures of aerobic capacity. This chapter includes a summary of the factors supporting the theoretical formulation that differences in body type might influence the indirect assessment of aerobic capacity. These factors include somatotype, body composition, aerobic capacity, anthropometry, physical performance and selected indirect tests used to estimate aerobic capacity. The specific relationships discussed include: the relationship of somatotype to body composition, the relationship of body composition to aerobic capacity, the relationship of body measurements to physical performance, anthropometry and somatotype in relation to measures of cardiovascular fitness, the relationship between direct and indirect measures of aerobic capacity, and the validity and reliability of bicycle ergometer tests, step tests and endurance runs. The first section of this chapter is concerned with the development and description of anthropometric somatotyping.

Anthropometric Somatotype: Development and Description

The morphological classification of man has been of both scientific and general interest dating back as far as the time of Hippocrates, around 400 B.C. (Sheldon, Stevens and Tucker, 1940). The majority of the classification systems were unsatisfactory due to the fact that each system attempted to divide the total population into only one of two to five categories without any attempt to differentiate among individuals in any category, or to attribute to any one individual characteristics of another category. The major problem was that few people fell clearly into a single category; the majority displayed characteristics of two or more categories. In 1940, Sheldon, Stevens and Tucker made a major contribution to morphological classification technique when they introduced their classic somatotype system which allowed each individual to be rated in each of three different categories (components) of physique. The three components identified were body fatness (endomorphy), muscularity (mesomorphy) and linearity (ectomorphy). A 7-point scale was used to rate the relative degree to which an individual possessed each of these three components. A rating of "1.0" in any of the three components represented a low degree of that particular component in an individual's overall body type. The higher the rating, with a theoretical limit of "7.0", the more that particular component was considered to contribute to the individual's body type. Somatotype ratings were reported as a series of numerical values, always in the same order: endomorphy, mesomorphy and ectomorphy. Sheldon determined standards of somatotype dominance on the basis of the visual interpretation of photographs taken of the subject in the nude. The rating of each component was then based on a series of 17 photographic measurements. Therefore, a population could be classifed on the basis of somatotype dominance and the relative values of the component ratings. This system provided the foundation from which advanced somatotype techniques have evolved.

In the past four decades somatotyping has been used in various fields of study. The most famous use of Sheldon's somatotype method was the attempt by psychologists to relate morphology and physiology of the body to the study of psychological aspects of human behavior. Specifically, patterns of somatotype were correlated with the components of temperament in an individual's personality traits. The basic three-component pattern of a somatotype was found to be reflected at various levels of personality structure: at the morphological level in the somatotype itself, at the motivational level in the Index of Temperament, and at a level of behavioral or psychiatric pathology in the Psychiatric Index (Sheldon, Dupertuis and McDermott, 1954). This original use of somatotyping, as a link to psychological insights, is no longer considered sound. In addition to criticism of the use of Sheldon's somatotype, the method itself was criticized as being too subjective and having limited reproducibility (Carter, 1972).

Because somatotyping was originally a photographic-dependent method, all resulting validity was dependent on a criterion rater. Agreement between somatotypists depended to a great extent on the personal visual interpretations of the photographs. In order to overcome the inadequacies of the original method, several modifications were developed.

Parnell (1954 and 1958) introduced the application of several anthropometric measures to be used in conjunction with somatotype photographs in an attempt to make somatotype ratings more objective. He chose three sets of measurements which included bone diameters, muscle girths and skinfolds (subcutaneous fat). The problems identified by Parnell were that standards of somatotype dominance were subjectively determined, that subject's objection to being photographed in the nude rendered the somatotype sample unrepresentative to a population chosen for study, and accomodation for the 10-meter camera distance, the cost of photographic equipment and the development and standard enlargement of photographs were considered impractical for many research and educational purposes. Furthermore, even when the long photoscopic method was correctly completed, including the labor of making 17 photographic measurements, the result might still be wrong if the original choice of dominance was incorrect. He agreed with Sheldon that the photographic records provide information in more assimable form than any large number of bare anthropometric measurements, and, therefore, concluded that somatotyping cannot end with "millimeters", but it may reasonably begin with measurement (Parnell, 1954).

In summary, Parnell's modifications were an attempt to show that anthropometry could provide a useful degree of scientific objectivity as a preliminary guide to somatotypists and could provide accurate estimates of the Sheldonian somatotype. When compared against Sheldon's long form photoscopic method, Parnell's method was in agreement within ± 0.5 rating units for 90% of the cases (Parnell, 1954). This accuracy was perceived by Heath and Carter (1966) to be achieved because Parnell retained Sheldon's arbitraty, closed 7-point scale for rating somatotype components. Parnell also rated the third component so that it corresponded closely to the median range for each component given in Sheldon's tables, and made the ratings of the first and third components conform with age-scaled interpretations of skinfolds and height/weight ratios.

In 1962, Damon, Bleibtreau, Elliot and Giles found selected anthropometric measurements to be feasible and valid for estimating somatotype ratings when compared to Sheldon's method. It was concluded that it is possible to use anthropometric measurements to somatotype within ± 0.5 rating units in 80% of the ratings and within ± 1.0 rating units in 97% of the ratings when compared to Sheldon's standard photoscopic rating in young men. The major reason Damon et al. (1962) used anthropometry was to increase reproducibility and limit the subjective element present when determining somatotypes from photographs alone. Although valuable in theory, the first few attempts to modify somatotyping by use of anthropometric measurement failed to correct the basic weaknesses in Sheldon's original somatotype method (Heath and Carter, 1966).

In 1963, the transformation of somatotyping from a photographic-dependent method to an anthropometric technique began. Heath (1963) proposed four basic changes in somatotyping methodology: (1) replacement of the closed rating scale by an open scale, beginning theoretically at zero (in practice at 0.5) and having no arbitrary endpoint, (2) elimination of an arbitrary range of total sums of component rating points, (3) construction of a table of somatotype and height/cube root of weight ratios (Ponderal Index) which preserved a linear relationship between the two, and (4) elimination of extrapolation for age. These changes introduced the concept of a longitudinal series of somatotypes for each individual, replacing the original concept of somatotype permanency. Heath also pointed out that under special circumstances it is not feasible to obtain somatotype photographs, although it is convenient to make anthropometric measures.

In 1967, Heath and Carter introduced a new and improved somatotype method with universal applications to both sexes, for all ages, and which is reproducible, justifiable and validated. This method combines Heath's (1963) modifications and adaptations from Parnell's (1958) M.4 deviation scale.

The extension of the somatotype component rating scales was justified from the study of 844 male and female somatotype ratings (Heath and Carter, 1967). Extremes of somatotype component ratings for endomorphy, mesomorphy and ectomorphy were found to be higher than Sheldon's scale rating of "7.0" would allow. It was also reported that high extremes in endomorphy and low extremes in ectomorphy were found in the same individuals, thus emphasizing the need for a method that could describe all human variation. In a separate study by Edwards (1950) the sum of the subscapular, suprailiac and triceps skinfolds were correlated with the sum of 53 separate skinfold sites on the same subjects and an extremely high correlation coefficient (r = +.99) was determined. Heath and Carter (1967) applied this information and determined that the skinfold values and the Ponderal Index values indicate ratings greater than a "7.0" for the first and second components. This analysis suggested that it was desirable to readjust the Ponderal Index distribution by widening the component rating scales at the low end to zero; that it was feasible to extend the rating scales upward for the first and second components; and that total skinfold values are an acceptable reference for rating the first component. It became evident that anthropometric measurements, such as the sum of specific skinfold values, could be used to increase the objectivity and reliability of somatotype ratings.

For 501 subjects, the product moment correlation coefficient between skinfold values and Heath's method of determining first component ratings was reported to be r = +.95 (Heath and Carter, 1967). This relationship indicated that Heath's first component ratings and specific skinfold scores were so similar that a skinfold score substituted for a Heath rating would sacrifice little or no accuracy, especially in group studies. The test-retest reliability for Heath's ratings was approximately r = +.92, and the test-retest reliability of the skinfold measures was r = +.90 to r = +.96 (Heath and Carter, 1967).

The use of skinfold measurements to determine the first component by anthropometry was referred to as the F-scale. In order to validate the F-scale, Heath rated 414 subjects by Heath's method and Carter re-rated the same subjects using the F-scale. The data indicated that the mean differences were small and the reliability and percentage agreement were high (r = +.90 to r = +.96). It was concluded that the F-scale was an excellent tool for estimating the Heath rating for first component values ranging from 1.0 to 7.5 (Heath and Carter, 1967).

The modifications made by Heath and Carter (1967) in determining the second component were based on the general principle that given amounts of mesomorphy will be proportional to height, since somatotype is a measure of shape not size. Thus, the taller the person the larger the musculoskeletal dimensions must be to maintain the same levels of the second component. It was found that the best simple indication of mesomorphy (apart from photographs) was a combination of height, humerus and femur bi-epicondyle diameters, flexed arm and calf girths and application of a modified version of Parnell's M.4 deviation scale. This method of determining the second component, mesomorphy, was referred to by Heath-Carter as the M-scale. Parnell's M.4 deviation scale was modified by moving the height column to the left, and by making direct correction of skinfolds to the limb circumferences, thus eliminating the need for age correction.

Heath and Carter (1967) noted that fat contributes to girth measurements, a problem not addressed in Parnell's M.4 deviation scale. In ectomorphs there is generally less than average fat to contribute to muscle girth; consequently, the smaller girth measurements may lead to underestimates of mesomorphy. Among endomorphs and many endomorphic-mesomorphs there is more than average fat, thus mesomorphy is apt to be overestimated (Wilmore, 1970). In 369 white male soldiers, Damon, Bleibtreau, Elliot and Giles (1962) found Sheldon's mesomorphy could not be predicted as closely using a combination of anthropometric measures. Only 44% of the variance was accounted for in mesomorphy as compared to 61% and 81% of the variance accounted for in endomorphy and ectomorphy respectively. In the process of developing the new M-scale, Heath and Carter made the assumption that direct correction of skinfolds to limb circumferences accounts for the contribution of fat to girth measurements.

Validity of the M-scale was established by comparison with Heath's rating method. Data indicated that mean differences were small and the reliability ($r = +.94$) and percent agreement (90%) were high. It was concluded that Parnell's M.4 deviation scale was not a satisfactory estimate of the Heath rating, but the new M-scale was (Heath and Carter, 1967).

The anthropometric scale used for determining the third component, ectomorphy, was referred to by Heath-Carter as the L-scale. In order to develop the L-scale, third component values associated with given height/cube root of weight ratios ranging from 12:00 to 15.00 were plotted. For 121 somatotypes the correlation was $r = +.97$. Therefore, it was determined that the third component L-scale could be identified with the use of the following regression equation: $Y = 2.42X - 28.58$, where Y = the third component value and X = height/cube root of weight ratio (Heath and Carter, 1967).

Validity of the L-scale was determined by correlating Heath's ratings and L-scale estimations determined by Carter for 397 subjects. Heath ratings were found to be slightly lower than estimations of the third component using the L-scale. Even so, the reliability ($r = +.98$) and the percentage agreement (91%) between Heath ratings and L-scale estimations were high for the range of 0.5 to 6.0 on the third component. It was concluded that the L-scale was an objective and valid method for estimating Heath's third component (Heath and Carter, 1967).

The anthropometric scales developed by Heath and Carter (1967) were determined to be highly satisfactory for estimating the first and third components, and satisfactory for estimating the second component. The scales are less reliable for subjects very high in the first component (8.0 to 12.0) and very low in the third component. Overall, the Heath-Carter anthropometric somatotype method, when validated against standard somatotyping techniques, was found to be a highly successful and accurate method. In the absence of a photograph this method is considered to provide the best estimate of a certain somatotype rating and also provides an objective starting point for a combined anthropometric plus photoscopic rating by different observers when a photograph is available (Carter, 1972).

The Heath-Carter anthropometric somatotype method is unique in comparison to previous somatotype rating methods, in that it is based entirely on anthropometric measurements. Even though the basic terminology used in the Heath-Carter anthropometric method is the same as that introduced by Sheldon, Stevens and Tucker (1940), the two methods of rating somatotype are distinctly different. By redefining the basic components and rating scales, Heath and Carter provided an objective, valid and simple method for classifying individuals representing a wide range of populations, thereby increasing the practicality and usefulness of somatotyping as a research instrument.

Somatotype In Relation To Body Composition

Since the introduction of the Heath-Carter anthropometric somatotype method, many investigations have been made concerning its validity in relation to body composition as determined by several criterion methods. In general, Heath-Carter's first component has been found to be closely associated with body fatness (Slaughter and Lohman, 1976; Wilmore, 1970; Damon, Bleibtreau, Elliot and Giles, 1962; Hunt and Barton, 1959). In the same studies, mesomorphy, the second component, defined by Heath-Carter as the relative musculoskeletal development per unit of height, has not been closely associated with lean body mass. Ninety percent of the variation in Heath-Carter's third component, ectomorphy, has been accounted for by height and weight; thus, its validity is not questioned (Slaughter and Lohman, 1976).

The main criticism of the Heath-Carter anthropometric somatotype method has been its assumption that lean body mass (LBM) for a given height is closely associated with the sum of standard scores of four anthropometric sites and that skinfold thickness corrects for variation in limb fatness (Lohman, Slaughter, Selinger and Boileau, 1978). Slaugher and Lohman (1976) used 31 white female college students as subjects for the purpose of determining the relationship between somatotype and body composition, comparing both Sheldon's (1969) and Heath-Carter's (1967) somatotype procedures with whole body potassium (^{40}K) counting. It was concluded that Sheldon's endomorphy is closely associated with height and weight, and that Heath-Carter's first component is significantly related to weight ($r = +.65$) and body fatness as determined by ^{40}K ($r = +.74$). Lean body mass as an absolute weight or as a percent relative to the total body weight, was not closely associated with either Sheldon's mesomorphy or Heath-Carter's second component. However, when LBM and height were used as independent variables to estimate somatotype, both variables were found to be related significantly to Heath-Carter's second component, accounting for 61% of the variance. Therefore, "Heath-Carter's second component is significantly associated with LBM for a determined height" (Slaughter and Lohman, 1976, p. 237). Sheldon's somatotype for all three components is not as closely associated to body composition as are Heath-Carter's three components.

In further analysis, Slaughter and Lohman (1977) used 45 young boys ages 7-12, for the purpose of studying the relationship of body composition to somatotype in a population other than young adults. It was reported that Heath-Carter's first component accurately reflected body fatness to a considerable extent. In fact, percent body fat was significantly associated with endomorphy ($r = +.79$), mesomorphy ($r = +.56$) and ectomorphy ($r = -.65$). Again, LBM accounted for only 23% of the variation in Heath-Carter's second component. However, when weight in addition to height and LBM was used to estimate somatotype, coefficients of determination increased to 72% ($r = +.848$) for Heath-Carter's second component. Furthermore, the anthropometric variables used in determining Heath-Carter's second component, when used together in multiple regression analysis, accounted for 88% of the variation for Heath-Carter's second component and 88% for LBM (^{40}K). "The regression coefficients for all independent variables used to determine the second component were statistically significant when estimating Heath-Carter's second component" (Slaughter and Lohman, 1977, p. 754). But when estimating LBM by ^{40}K, only height and corrected calf circumference were found to be significant. From this information it appears that corrected circumferences still reflect some fatness as well as lean body mass. Slaughter and Lohman

(1977) concluded that the correction for skinfolds needs to be multiplied by π before it is subtracted from the respective circumference. It was found that this modification reduced the limb circumference measurement in obese children, thus decreasing the possibility of overestimating mesomorphy. In doing so, the variance accounted for in LBM increased by 4%, and both the corrected biceps and the calf circumference variables significantly accounted for variation in LBM, while skeletal diameter measurements were not significant (Slaughter and Lohman, 1977).

Lohman, Slaughter, Selinger and Boileau (1978) designed a study to determine the relation of somatotype to body composition in college age men and to test the assumptions of the Heath-Carter approach to the estimation of the second component as lean body mass relative to height. Lohman et al. (1978) found that LBM/height accounted for less than one third of the variation in the Heath-Carter second component, mesomorphy. However, when LBM and height were used together in multiple regression analysis as separate predictors instead of a ratio, 66% of the variance in the second component was accounted for. The muscle circumferences and height, but not skeletal widths, used in Heath-Carter's method, were significant predictors in regression analysis, accounting for 84.5% of the variance in LBM. It was proposed from this study that even though there is a significant relation between Heath-Carter's anthropometric approach to estimating the second component and LBM relative to height, a more valid approach to prediction of the second component from anthropometry is the use of skinfolds and body weight, rather than body circumferences and widths (Lohman et. al., 1978).

It should be pointed out that these theoretical attempts to validate and modify the anthropometric estimation of the second component, as defined by Heath-Carter (1967), were formulated on a basic assumption that incorrectly interpreted the mesomorphy component to be representative of the LBM component in body composition (M.H. Slaughter, Personal Communication, January 27, 1985). An earlier attempt to validate the Heath-Carter second component by use of the absolute weight of LBM (Wilmore, 1970), is evidence of the misinterpretation of Heath-Carter's definition of mesomorphy (Slaughter and Lohman, 1976). Slaughter and Lohman (1976) pointed out that Carter (1972, p. 1) stated, "the second component refers to relative musculoskeletal development per unit of height." Therefore, because the Heath-Carter anthropometric somatotype describes body morphology as well as body composition, not all of the variation in somatotype can possibly be expected to be accounted for by measures of body composition. Nevertheless, body composition remains an important factor in accounting for variations in Heath-Carter's first and second component.

Body Composition in Relation to Oxygen Uptake

Body composition has been shown to be significantly related to the first and second components of the Heath-Carter anthropometric somatotype. Because the variation in anthropometric somatotyping can be accounted for in part by body composition, it is necessary to review the effect that weight, body fatness and lean body mass have on cardiorespiratory function.

Buskirk and Taylor (1957) determined max VO_2 along with weight of body fat in 46 male students and 13 soldiers. Correlation coefficients were calculated between max VO_2 and fat-free weight ($r = +.85$), active tissue ($r = +.91$) and body weight ($r = +.63$). Sedentary students within the study population were divided into three groups: (1) 25% or greater body fat; (2) 10-25% body fat; and (3) less than 10% body fat. It was shown that there was no difference in max VO_2 per kilogram of fat-free weight in these three groups. It was concluded that when max VO_2 is used to examine the capacity to perform exhausting work, the values should be expressed as VO_2 per kilogram of body weight per minute (ml/kg/min). However, it was stressed that when a test is used to examine the performance of the respiratory-cardiovascular system, the values should be expressed as VO_2 per kilogram of fat-free weight, which is the weight of the muscles actually performing the work. Buskirk and Taylor (1957) emphasized that if one considers the max VO_2 technique as a procedure to be used to determine the fitness of an individual for tasks requiring exhaustive running or the lifting of one's own body weight, the proper unit of reference is max VO_2 (ml/kg of body weight/min). The ratio of max VO_2 to kilogram of body weight provides a measure of the immediately available oxidative energy which can be supplied to move a kilogram of body weight from one point to another (Buskirk and Taylor, 1957). Buskirk and Taylor (1957) also reported that the presence of excess fat per se does not have any important influence on the capacity of the cardiovascular system to deliver oxygen to the working muscles under maximal performance conditions. However, the obese man is under a substantial handicap in the physical performance requiring exhaustive work because of the load of fat (which does not contribute to his performance) which he must carry with him. This load of fat does not produce extreme stress on the cardiovascular system during exhaustive work but makes the accomplishment of a specific work task very difficult (Buskirk and Taylor, 1957).

Other studies (Katch, McArdle, Czula and Pechar, 1973; Taylor, Buskirk and Henschel, 1955) investigated the relationship of body composition to max VO_2 in both male and female college students, estimated from distance running and treadmill running respectively. It was concluded that an important determinant of max VO_2 is the mass of the muscle employed in performing the task used to elicit the max VO_2. The correlation coefficient reported between LBM and max VO_2 was $r = +.76$ (Katch, McArdle, Czula and Pechar, 1973).

In 1955, Miller and Blyth used 30 male college students to investigate the factors affecting the metabolic cost of grade running on a treadmill. It was concluded that the metabolic cost of lifting the body is directly proportional to gross body weight and that the cost of work per unit of body weight is only slightly influenced by height and fat content. Thus, the best metabolic reference unit for expressing the cost of work involving lifting the body weight is gross body weight. It was also determined that as body fat content increases, the exercise oxygen requirement per unit of lean body mass also increases because fat is lifted as an inert weight. There is a direct relationship between fat content and max VO_2 per unit of LBM during work, suggesting that the cardiovascular burden imposed by obesity is minimal at rest and is clearly manifested during physical exertion (Miller and Blyth, 1955).

Welch, Reindeau, Crisp and Isenstein (1958) further studied the relationship of max VO_2 with various components of body composition in 28 young men at a United States Naval base. It was found that oxygen consumption expressed as milliliters of oxygen per kilogram of body weight per minute is significantly affected by the percentage of body fat. Also, body weight was found to affect the oxygen consumption during a submaximal as well as maximal work bout, since an increase in weight makes the body work harder in any activity which involves lifting the body. In contrast to previous studies, Welch et. al. (1958) found the oxygen consumption to be less of a function of LBM at rest or while performing submaximal work. It was evident that as the intensity increased, oxygen consumption became a more accurate index of the circulatory capacity and was less affected by the body mass (muscles) using it. Therefore, percent fat was shown to have a significant influence on max VO_2 when reported in ml/kg of body weight/minute.

The study by Welch et. al. (1958) suggests that while fat may not have an effect on the absolute ability of the tissues to extract oxygen, it does have a significant effect on the relative circulatory capacity of the individual. This fact is obvious when one observes the limited capacity of obese individuals for prolonged strenuous work which involves lifting or transporting their bodies. This is because fat increases weight and, therefore, the energy requirement, without a corresponding increase in max VO_2 (Welch et al., 1958).

In an attempt to clear up the discrepancy that existed in the literature regarding the measurement of max VO_2 based on LBM as a meaningful measure of physical fitness, Gitin, Olerud and Carroll (1974) studied the relationship of body composition to aerobic capacity in 18 marine corps non-commissiond officers. The results indicated that large men are heavier as a result of both increased frame and muscle, and increased amounts of fat tissue. Large men also tend to consume more oxygen at the point of maximal exertion than small men regardless of other characteristics and parameters of physical fitness. In theory, it was argued that ". . . the subject with a larger percentage of his cardiac output going directly to skeletal muscle should possess an advantage in ability to do strenuous work when compared to a subject with the increased vascular circuitry and 'ergonomic dead space' created by excess adipose tissue" (Gitin et al., 1974), p. 759). In vitro studies have shown oxygen consumption of adipose tissue to be increased 50 to 100% in response to increases in epinephrine levels and as high as 40% for increased glucagon levels (Orth, O'Dell and Williams, 1960). Since both hormones are known to be elevated with strenuous work or exercise, it is reasonable to expect that oxygen consumption as a result of adipose tissue metabolism is also increased during exercise. Therefore, it was concluded that ". . . adipose tissue is more than just an inert weight jacket, and that to consider it so, in work physiology, is likely to lead to erroneous conclusions." (Gitin et al., 1974, p. 759). As a result it is considered meaningless and misleading to express max VO_2 in terms of LBM when assessing the ability to do strenuous work in a population of heterogenous somatotypes (Gitin et al., 1974). It is clear that if one wishes to examine the capacity of a man to perform endurance type work involving running or lifting of his body, then the max VO_2 in terms of ml/kg of body weight/minute is the most meaningful value since it describes the maximum quantity of aerobic energy available for moving the body.

Body Measurements in Relation to Physical Performance

Since the introduction of Sheldon's (1940) somatotype method there have been many studies of the relationship between specific anthropometric measures and physical performance. The criterion measure of performance emphasized in these studies has been motor skill tasks or a battery of motor skills assessments.

Bookwalter (1952) studied body build and physical performance in 1,977 elementary school boys using the Wetzel Grid as a means of classification. He found a fairly systematic relationship between physique channels and developmental levels according to the Wetzel Grid and physical fitness scores. He concluded that body size and shape seems to have an influence on physical performance. The very obese boys were the poorest performers, suggesting that maximum size and shape does not produce maximal performance. In a study of physique factors and certain measures of motor performance in 95 boys, it was discovered that the relationship of the endurance factor to morphological variables suggested that boys with high endurance tend to be linear and have long forelegs and arms (Barry and Cureton, 1961).

Grouping subjects by classification indices are done as a basis for establishing achievement standards in various fitness tests or sports skills. In almost every test within a battery of motor skills tests, the addition of height, or height and weight in determining percentile norms increases the percent of accountable variance (Montoye, Frantz and Kozar, 1972).

Research on boys has shown a relationship between body composition and performance and between somatotype and physical performance (Hebbelinck and Postma 1963). The best indices of physical performance were found to be measures of body fatness and linearity (Slaughter and Lohman, 1977).

Selected anthropometric measures and somatotype ratings of physical education majors were studied in relation to the performance of certain motor fitness tests (Hebbelinck and Postma, 1963). The mesomorphic trait was found to be the most distinctive feature of the subject's somatotype. The mesomorphs were superior in all motor fitness tests except the 60-yard dash, and the ecto-mesomorphs excelled the endo-mesomorphs in all tests except the shot-put. Sills and Mitchem (1957) also studied college students' anthropometric measures in relation to performance on motor skills tests. It was stated that even with college men it must be recognized that there is superiority of certain stature groups over others. Multiple correlation coefficients between body build measurements and sit-ups, pull-ups and the 300-yard shuttle run, showed substantial relationships between body build and motor skills tests. It was hoped that such information would serve as a basis for future classification of male college students into homogenous groups (Sills and Mitchem, 1957).

Various body measurements and indices in relation to motor performance have been studied extensively. Most studies concluded that significant correlations exist between measures of body build and motor capacity. It has been shown that during youth and early adulthood, body weight, height and the Ponderal Index play an important role in the determination of motor capacity. Anthropometry in application to the field of physical education is an important aspect in the process of testing and measuring. However, within the general framework of body types there are many detailed aspects to be tested and studied for separate interpretation, but all too frequently when the investigator's focus is on some particular part of the body, the whole person is overlooked (Cureton, 1941). Emphasis should be placed on the total physique and less on its individual parts. In studying one's overall capacity for physical fitness, the description of the total physique through the method of somatotyping presents considerable practical advantages (Seltzer, 1946). After 17 years of age, the body build in terms of somatotype is of greater importance than factors such as age, weight or other single direct measurements (Cureton, 1941).

Bicycle ergometer tests are widely used in the assessment of cardiovascular function and fitness. Davies, Barnes and Godfrey (1972) studied 92 teenage boys and girls in an attempt to determine the relationship of maximum oxygen uptake on a bicycle ergometer to anthropometric and body composition measurements. The results indicated that the max VO_2 is related to the amount of muscle which can be brought into use, essentially the leg muscles in cycling. Similarly, it has been stated that an important determination of max VO_2 is the mass of the muscle employed in performing this task (Astrand and Rodahl, 1977). It is suggested that in comparative studies of power output on a bicycle ergometer, there is a need to relate max VO_2 to leg size and composition and to standardize for these before determining the finer details of cardiovascular performance (Davies et al., 1972).

Wilmore (1969) studied the endurance performance of 30 male college students using a bicycle ergometer. It was concluded that there is a substantial relationship between endurance capacity and max VO_2 on the bicycle ergometer. However, when using the bicycle ergometer one must take into consideration the positive influence of body stature on performance because the larger individual has the potential to perform a greater amount of work than the smaller individual simply because of the greater quantity of absolute muscle mass inherent to the individual with the larger body.

The effect of anthropometric measures and body type in relation to their influence on physical work capacity, as measured by step tests, has been extensively studied. There is considerable discrepancy in the literature pertaining to the specific relationship between cardiovascular fitness, as determined by step tests, and body measurements.

Seltzer (1943) used a step test as a measure of cardiovascular endurance to inquire as to the possible factors which exert influence in controlling and limiting the degree of physical fitness in 1,173 male college students. The step test was a maximum effort assessment. Comparisons were made between subjects on the basis of the degree to which they possessed the mesomorphy component of physique. It was concluded that the mesomorphy component was related to physical fitness for hard muscular work. The higher the physical fitness, the more frequently the body type was high in the mesomorphy component.

Seltzer (1946) used 300 cadets at a military training center and found that no relation existed between absolute stature or leg length and the fitness index obtained by a step test. Additonal data indicated a virtual absence of relation between weight and chest circumference. It was only with the general index of body build, the Ponderal Index, that a moderate relation was found to exist with physical fitness. It was concluded that total body build or type is related to degrees of physical efficiency insofar as was indicated by the Harvard Step Test. Specifically, individuals with height/cube root of weight indices below 12.00, reflecting endomorphic or endo-mesomorphic body type, displayed lower physical fitness indices than both mesomorphs and ectomorphs. Similarly, Keen and Sloan (1958) found that individual anthropometric measures did not correlate significantly with scores obtained from the Harvard Step Test, but concluded that overall stature and limb length should be considered as factors which could possibly influence step test scores.

In 1978, Shahnawaz investigated the influence of limb length on stepping exercise. Limb length was defined as the vertical distance between the top of the greater trochanter and the floor. The mean oxygen consumption was found to be significantly related to the limb length in the step test exercise. He concluded that optimum oxygen consumption for a given work load during stepping exercise may in fact be a compromise between low stepping rate and a high bench where energy is wasted adjusting body posture and maintaining balance. As a result of this study it was recommended that the validity of any form of step test is enhanced if step height is related to the subject's limb length, rather than using a fixed height for all subjects.

Elbel, Reid and Ormond (1958) in agreement with Shanhawaz, found height, weight and limb length to be significant factors affecting the index scores of the Harvard Step Test. They concluded that the results suggest that a distinction between subjects on the basis of bodily size may be appropriate for college students and recommended that further investigation of the relation between step tests and anthropometric somatotype measures is warranted.

In contrast to the previously mentioned studies, Laubach, Hollering and Goulding (1971) found that weight, all four skinfolds from the Heath-Carter anthropometric somatotype method, endomorphy, ectomorphy, body density, percent body fat and body surface area significantly correlated with scores obtained from the Harvard Step Test. Non-significant correlations were reported for stature, mesomorphy, sitting height and lower extremity limb length. In conclusion it was stressed that when assessing cardiovascular endurance, physical educators should be aware of the fact that performance on the Harvard Step Test is limited by measures of body bulk, especially indicators of body fat.

Jette, Ashton and Sharnatt (1984) determined the major individual physical contributions associated with max VO_2 when determined from a three stage submaximal step test. Weight and the fat score (sum of the triceps, biceps, suprailiac and subscapular skinfolds) were found to be negatively correlated to max VO_2. It was stated that if a subject can hardly complete the second stage of the step test and possesses a low degree of lean body mass and a high fat score, then that subject's aerobic power, irrespective of his physical activity pattern, will be demonstrated by that individual.

It is a well established fact that the measures of body composition, specifically LBM and percent body fat are negatively correlated with performance of both sprinting and distance running (Cureton, Hensley and Tiburzi, 1979; Katch, McArdle, Czula and Pechar, 1973; Kireilis and Cureton, 1947). The influence of somatotype on endurance has also been investigated.

Sills and Everett (1953) analyzed the relationship between dominant body types and performance in the mile run. It was found that none of the 13 extreme endomorphs tested were able to complete the run, and the mesomorphs performed better than the ectomorphs but the mean difference was found to be insignificant. They concluded that structural differences in the body types influenced the results. Excess body weight was considered to handicap the endomorph in performance of endurance testing. The recommendation from this study was that consideration should be given to body types in formulating standards for achievement and interpretation of endurance run test data.

In 1980, Slaughter, Lohman and Misner studied the association of somatotype to physical performance in 7-12 year old girls. Results showed body size variables (height, weight and LBM) and somatotype components, determined by the Heath-Carter anthropometric somatotype method, to correlate moderately high with running performance. Correlation coefficients were higher for the one-mile and 600-yard runs than sprints of 100 yards or less. As subject body size increased, the running times decreased. The first and third components of the Heath-Carter anthropometric somatotype method were more closely related to physical performance than was the second component.

Slaughter, Lohman and Misner (1977) reported a similar study using 7-12 year old boys as subjects. In a comparison between Sheldon's (1969) trunk index and Heath-Carter's anthropometric method of measuring somatotype, Heath-Carter's somatotype was found to correlate more closely to running performance, particularly in the second and third components. In general, children with larger somatotype measures ran slower.

The components of physique such as size, body composition, structure and measures of anthropometry have been shown to influence or affect physical performance tests, specifically tests of cardiovascular fitness. Because factors other than physique, such as training, skill, subject motivation and environmental conditions can affect physical performance measures, physique will at best only account for a portion of the total variance. Therefore, "Empirical studies are needed to assess the extent to which physique influences physical performance measures in various human populations." (Slaughter, Lohman and Misner, 1980, p. 189).

Relationship Between Direct and Indirect Measures of Aerobic Capacity

Cardiovascular fitness is unquestionably one of the most important components of physical fitness. It is the single most indicative measure of a person's physical condition. The most used physiological criteria for assessing cardiovascular fitness are oxygen intake, heart rate, blood lactate concentration, cardiac output, stroke volume and pulmonary ventilation. The max VO_2 is considered the single most valid measure of cardiovascular efficiency (deVries, 1980; Astrand and Rodahl, 1977; Hebblinck, 1969). The max VO_2 measurement is considered superior because it indirectly assesses the functional status of the variety of physiological parameters mentioned above (deVries, 1980).

Although aerobic power in terms of max VO_2 can be determined with a minimal degree of error through direct measurement, the method is time consuming, expensive, rigorous for the subject and requires expert knowledge of sophisticated equipment (Astrand and Rodahl, 1977). In order to overcome the disadvantages of the direct measurement of max VO_2 there have been a number of tests developed to indirectly measure cardiovascular function or capacity. Some of these tests require the subject to perform a task that calls for sustained total body movement. Usually these tests involve running a prescribed distance or for a prescribed time, and the subject's cardiovascular endurance is measured by the elapsed time or distance traveled (i.e., 1.5-mile run or 12-minute run, respectively). Other tests have sought to determine cardiovascular fitness by indirectly estimating max VO_2 through measures of pulse rate and blood pressure under various degrees of submaximal work (Johnson and Nelson, 1979).

Tests are submaximal or maximal based on the physiologic response they induce in the subject. Submaximal criteria suggest the intensity and duration of the exercise should not exceed the capacities of the poorest subjects. A maximal exercise test, on the other hand, must bring all subjects to a comparable degree of exhaustion (Taylor, 1944). It is the constancy of energy requirement in well standardized tasks that makes the measurement of pulse and blood pressure during or at the end of the performance of a fixed standardized task a practical measure. Taylor, Wang, Rowell and Blomquist (1963) stated that if a continuously increasing work load is used with the intention of pushing a subject to a specific pulse, and the subject stops before the endpoint is reached, then the test becomes a measure of motivation of the individual and his willingness to endure the discomfort of the physical activity. Such a test may well be related to the capacity of the individual to perform aerobic work since there are very real psychological limitations to work capacity during maximal testing. The problem is that it will not be known for sure whether the limiting factor was psychological or physiological.

The simplest and most often applied way of testing aerobic capacity indirectly is to determine heart rate (HR) during or after exercise (bicycle ergometer and bench stepping respectively). Many studies have indicated a linear relationship between HR and max VO_2 and between HR and work rate over a relatively wide range, approximately 125-170 beats per minute (bpm) (Baumgartner and Jackson, 1982; Astrand and Rodahl, 1977; Johnson and Nelson, 1979; Clark, 1975; Metz and Alexander, 1971; Astrand and Rhyming, 1954; Truett, Benson and Blake, 1966). Linearity means the relationship between work rate and HR can be described with just two parameters, slope and a fixed coordinate such as time to 180 bpm, or an early working HR (Truett et al., 1966). Submaximal work capacity tests are based in theory on the fact that because heart rates between 125-170 bpm are generally linear with increasing work loads, working heart rates can be plotted against respective work loads and a straight line drawn through them that will intersect at a line representing maximum HR (predicted as 220 - age of the subject). It is generally accepted that the fit individual will have a lower heart rate elicited by a given work load than an unfit individual.

Within the limits of 125-170 bpm, heart rate is also linearly related to oxygen consumption. Therefore, it is possible to estimate a max VO_2 value for individuals from a single stage work test approximately 5 to 6 minutes in duration and of such a severity that the heart rate reaches a steady state between 125-170 bpm (Astrand and Rhyming, 1954).

Heart rate will also return to normal more readily after exercise in a trained individual as compared to an untrained individual (Cotton and Dill, 1935). Therefore, step tests have been used to indirectly determine cardiovascular fitness on the basis of the subject's recovery heart rate.

The heart rate of an individual provides a great deal of information about the physiological reaction of the individual's body to different degrees of exercise stress. From a practical standpoint it is a measure that is quickly and easily obtained. Therefore, heart rate can serve as a valuable tool for indicating an individual's cardiovascular condition.

Indirect measures of determining max VO_2 are cost efficient, require minimal equipment and expertise, require moderate work efforts for subjects, are formulated from easily obtained physiological data and can more easily accomodate large group testing. However, it has been argued that the advantages of these methods have sacrificed precise measurement for practicality.

There have been differences of opinion expressed concerning the significance of pulse rate measurements before, during and after exercise. Tuttle (1931) contended that it was necessary to obtain a ratio of resting pulse rate to the pulse rate after exercise. Brouha (1943) in developing the Harvard Step Test reported that pre-exercise pulse rate was relatively unimportant and thus concluded that only recovery heart rate needs to be measured. Metz and Alexander (1971) found heart rate during submaximal exercise to be significantly related to max VO_2 in 12-15 year old boys.

The standard error of predicting oxygen uptake from indirect methods on the basis of heart rate or other parameters tends to be approximately ± 10% (Baumgartner and Jackson, 1982). Davies (1968) used a random sample of college aged males to investigate the accuracy of nomograms developed to predict max VO_2 from heart rate. The predicted max VO_2 was reported to underestimate the observed max VO_2 by from 600-900 ml/min when using the Astrand-Rhyming nomogram, by 500 ml/min when the Margaria nomogram was used, and from 400-900 ml/min when using the Maritz-Wyndham extrapolation procedure. Similarly, Rowell, Taylor and Wang (1964) reported that submaximal tests based on the Astrand-Rhyming nomogram underestimated max VO_2 by 14 ± 7% (500-900 ml/min) for a group of sedentary male subjects. Both studies concluded that if an accuracy greater than ± 15% is required, then there is no alternative but to measure max VO_2 directly.

McArdle, Zwiren and Magel (1969) investigated the validity of the post-exercise heart rate as a means of estimating the heart rate during work. It was reported that the HR obtained during a 15 second recovery period from strenuous work (greater than 150 bpm) averaged

5% below the exercise level heart rate. Heart rates obtained during a 15-second recovery period from moderate work (approximately 140 bpm) resulted in a 10.5% error in estimating the exercise heart rate. The percentage error in estimating the actual exercise heart rate from post-exercise heart rate increased significantly as the length of the recovery period increased from 15 seconds to 30 seconds. Cotton and Dill (1935) reported that predicting heart rate during exercise from that obtained in the ten-second period following its cessation is reasonably accurate (mean error approximately 3%). The correlation coefficient between the measured max VO_2 and the max VO_2 predicted from submaximal heart rate has been reported to be $r = +.72$ (Metz and Alexander, 1971; Glassford, Baycroft, Sedgwick and MacNab, 1965; deVries and Klafs, 1965; Astrand and Rhyming, 1954).

The estimation of max VO_2 can be made with relative accuracy from HR response at submaximal workloads and from performance time or distance run on a standardized protocol. When deciding whether to use direct or indirect tests for measurement of max VO_2, the purpose of the test should be considered, as well as the impact the error may have on the interpretation of the test. In general, max VO_2 is used for identifying the state of fitness or showing serial results (Pollock, Wilmore and Fox, 1984). Therefore, a consistent (under or over prediction) 5-10% error may not be crucial. If the procedures are standardized, errors have been shown to remain consistent on repeated tests. The results from serial testing should not be greatly affected.

Validity and Reliability of Selected Indirect Tests of Aerobic Capacity

Maximal oxygen uptake can be predicted with relative accuracy from performance time and standard submaximal work load tests. It has been reported that maximum performance tests usually yield higher predictive scores, $r = +.70$ to $r = +.95$ with a $Sy{\cdot}x = 2.5 - 4.0$ ml/kg/min, than do submaximal tests, $r \cong +.75$ with a $Sy{\cdot}x = 4.0 - 5.0$ ml/kg/min (Baumgartner and Jackson, 1982). Burke (1976) used 44 male college studnets to determine the validity of selected laboratory and field tests of physical working capacity. Using Stepwise Multiple Regression, with max VO_2 as the criterion measure, the following multiple correlation coefficients were determined: maximal tests ($R = .91$), submaximal tests ($R = .78$), and field tests ($R = .91$). He concluded that among all the indirect tests, the 12-minute run was the most valid predictor of aerobic capacity ($r = +.90$).

Distance runs have become the most common means of evaluating aerobic capacity within the field of physical education because they are feasible for mass testing. Previously, the 600-yard run/walk was used as a tool to determine cardiovascular fitness. Studies have revealed that 600 yards is not long enough in duration nor distance to measure aerobic working capacity. Balke (1963) suggested that the distance covered during 15 minutes of running or walking is a more valid indicator of max VO_2. Cooper (1968) reported a correlation of $r = +.90$ between max VO_2 and the distance covered during a 12-minute run/walk. The 12-minute and 1.5-mile distance runs are valid field tests of cardiovascular function and performance because they are related to maximum oxygen intake along with other physiological parameters of cardiorespiratory endurance and provide an index of the participant's ability to run distances (AAHPERD, 1980).

Factor analysis studies (Burke, 1976; Jackson and Coleman, 1976; Disch, Frankiewicz and Jackson, 1975) have shown that running tests normally measure two factors: speed, which is represented in short distances, less than 440 yards, and endurance, which is represented in longer distances (i.e., one mile) or duration (9 minutes or longer). Distances of 600-800 yards and timed runs of 6 minutes were found to measure both of the factors, speed and endurance.

Ribisl and Kachadorian (1969) tested 24 middle-age men in the 2-mile run and 11 male college students in the 60-yard, 100-yard, 220-yard and 440-yard dashes, and the 880-yard, 1-mile, and 2-mile runs. They reported a high degree of association between max VO_2 and the 2-mile run in both young (r = +.85) and middle-aged men (r = +.86). The advantage of a run of this distance for evaluating aerobic capacity is that the distance is long enough to require that the subject supply the greater proportion of the energy through aerobic processes, and short enough in duration to allow a maximal effort before motivation becomes a limiting factor of performance. As the distance of the run increases, the max VO_2 assumes greater importance (Ribisl and Kachadorian, 1969). The correlations reported by several different researchers for the 12-minute run vary considerably (r = +.64 to r = +.90). This is most likely due to differences in the testing procedures and the subjects who comprised the sample. In studies where the correlation a certain distance in a specified time (9-12 minutes) has been correlated with laboratory determined max VO_2, and found to range from $|r| = .50$ to $|r| = .91$ (an average $|r| = .75$ to $|r| = .85$) (Baumgartner and Jackson, 1982).

Validity coefficients of submaximal bicycle ergometer tests tend to be moderate to moderately high ($r = +.58$ to $r = +.75$). It is important to note that these correlations were made against a direct laboratory method using the treadmill. Astrand and Rodahl (1977) have stated that even when max VO_2 is determined directly by use of a bicycle ergometer, the values obtained are consistently 7% lower than treadmill elicited max VO_2 values in the same subjects. Despite the 7% difference, the maximal pulmonary ventilation, heart rate, and blood lactate concentration were not found to be significantly different (Hermansen and Sertin, 1968). It is suggested that the total muscle mass involved in treadmill running and in pedaling a bicycle ergometer is not equivalent. The bicycle ergometer causes extreme fatigue in the legs with only moderate stress in the upper body. This discomfort may cause the work effort to be interrupted before the oxygen-transporting system has been fully taxed. Therefore, this extreme fatigue in a limited muscle area may be indirectly related to the inability of bicycle ergometer tests to elicit higher values of max VO_2. Motivation of the subject also plays an important role in the established difference between max VO_2 determined directly by a bicycle ergometer and treadmill tests. A treadmill run is a matter of an all or nothing effort as the subject must maintain the pace of the belt or remove himself from the treadmill. On the bicycle ergometer, it is possible for the subject to continue work at a reduced intensity. Therefore, the pedaling rate must be kept constant in any type of bicycle ergometer test (Astrand and Rodahl, 1977).

In comparison to a direct bicycle ergometer test, the Astrand-Rhyming indirect method, also employing a bicycle ergometer, did result in a higher correlation coefficient ($r = +.78$) than did the Astrand-Rhyming test compared to two different direct treadmill tests ($r = +.63$) (Glassford, Baycroft, Sedgwick and MacNab, 1965). It was concluded that the indirect bicycle test was as highly correlated with standard fitness test measures as were the three direct tests.

The Sjostrand bicycle ergometer test has been found to correlate somewhat higher ($r = +.877$) with actual max VO_2 values than does the Astrand-Rhyming bicycle ergometer test (deVries and Klafs, 1965). The YMCA's of the U.S. have modified the Sjostrand test by using two or three 3-minute continuous stages (Golding, Myers and Sinning, 1982). Pollock, Wilmore and Fox (1984) recommend the YMCA bicycle ergometer test because it provides both explicit, standardized instructions and appropriate norms.

Submaximal step tests are based on the theory that given an equal amount of work to accomplish, in this case bench stepping at the same rate and total time, the subject with the lower HR will be in better condition and therefore will have a higher max VO_2 (Pollock, Wilmore and Fox, 1984). Bench stepping at a predetermined bench height and frequency is a simple method of standardizing workloads. However, The major obstacle to the effectiveness of step tests is the difficulty of accurately measuring pulse rate. If the measurements are not accurate, the test will lose validity. Kurucz, Fox and Mathews (1969) investigated the reliability of a subject's ability to count his own pulse by comparing EKG readings during the last 10 seconds of exercise with the subject's palpated pulse in the 10 seconds following exercise. The results found the subject's palpation count to be consistent if only the QRS complex is counted on the EKG. A test-retest reliability coefficient of $r = +.94$ was obtained. It is suggested that in research, use of a stethoscope to listen directly to the heart rate is more accurate than palpation count (Baumgartner and Jackson, 1982).

Kasch, Phillips, Ross, Carter and Boyer (1966) reported a coefficient correlation between maximal treadmill and step test procedures for determining max VO_2 as $r = +.95$. In general, attainable max VO_2 from step tests tend to be about 5% lower than those elicited from treadmill methods. This difference is largely accounted for by the fact that the cost of negative stepping in a step test has been reported to be approximately one-third of the positive stepping work (Nagle, Balke and Naughton, 1965).

Correlation coefficients between laboratory determined max VO_2 and submaximal step tests have been reported to vary from $r = +.55$ to $r = +.77$ (Burke, 1976; McArdle, Katch, Pechar, Jacobson and Ruck, 1972; deVries and Klafs, 1965). The Queens College Step Test is a secondary modification of the original Harvard Step Test, which was deemed too strenuous for a large percentage of the population. It was found that unfit or sedentary subjects in general, had a hard time completing the original 5-minute test. The Queens College Step Test consists of continuous bench stepping (16-17 inch height) for three minutes. The rate is 24 steps per minute for men. After exercise the recovery pulse rate is counted for 15 seconds, beginning 5 seconds after exercise has ended. This value is multiplied by four to obtain the number of beats per minute. This recovery heart rate was reported as being reliable ($r = +.89$) and fairly valid as an indicator of the subject's aerobic capacity. The validity correlation coefficient between the first heart rate recovery score (5-20 seconds after exercise) and actual max VO_2 (ml/kg/min) was $r = -.72$ (McArdle, Katch, Pechar, Jacobson and Ruck, 1972). McArdle et al. (1972) developed a regression equation used to estimate max VO_2 (ml/kg/min) from the heart rate recovery score; max $VO_2 = 111.33 - (0.42x)$, where x = step test pulse rate (bpm). The standard error of predicting max VO_2 from this regression equation was $S_{y \cdot x} = 3.2$ ml/kg/min. The validity coefficient reported in the original study of the Queens College Step Test was as good or better than those obtained from physical work capacity tests, scores obtained for the same subjects on the Balke walking test, or from previously reported regressions which have used AAHPERD test measures or the Astrand-Rhyming bicycle ergometer test (McArdle, Katch, Pechar, Jacobson and Ruck, 1972).

Summary

Heath and Carter (1967) developed a modified somatotype method based on selected anthropometric measurements. The Heath-Carter anthropometric scales are highly satisfactory for estimating the first and third components, and satisfactory for estimating the second component of a standard somatotype rating. When validated against standard somatotyping techniques, the Heath-Carter anthropometric somatotype method was found to be a highly successful and accurate method. In the absence of a photograph, this method is considered to provide the best estimate of a certain somatotype rating and also provides an objective starting point for a combined anthropometric plus photoscopic rating by different observers when a photograph is available (Carter, 1972). The Heath-Carter anthropometric somatotype method is unique in comparison to earlier somatotype rating methods in that it is based entirely on anthropometric measurements. Even though the terminology used in the Heath-Carter method is the same as that introduced by Sheldon, Stevens and Tucker (1940), the two methods of rating somatotypes are distinctly different. By redefining the basic components and rating scales, Heath and Carter provided an objective, valid and simple method for classifying individuals representing a wide range of populations, thereby increasing the practicality and usefulness of somatotyping as a research instrument.

Since the introduction of the Heath-Carter anthropometric somatotype method, many investigations have been made concerning its validity in relation to body composition. In general, Heath-Carter's first component, endomorphy, has been found to be closely associated with body fatness, height and weight (Slaughter and Lohman, 1976; Wilmore, 1970; Damon, Bleibtreau, Elliot and Giles, 1962; Hunt and Barton, 1959). In the same studies, the second component, mesomorphy, defined by Heath and Carter (1967) as the relative musculoskeletal development per unit of height, has not been closely associated with lean body mass expressed as an absolute weight or as a percentage of the total body weight. However, when LBM and height were used as independent variables to estimate somatotype, both variables were found to be significantly related to Heath-Carter's second component, accounting for 61% of the variance (Slaughter and Lohman, 1976). Furthermore, the anthropometric variables used in determining Heath-Carter's second component, when used in multiple regression analysis, have been shown to account for variation in Heath-Carter's second component and for LBM (^{40}K) (Slaughter and Lohman, 1977). Therefore, it appears that Heath-Carter's second component is associated with LBM for a determined height. Ninety percent of the variation in Heath-Carter's third component, ectomorphy, has been accounted for by height and weight; thus, its validity is not questioned (Slaughter and Lohman, 1976). Because the Heath-Carter somatotype describes body morphology as well as body composition, not all of the variation in somatotype can possibly be expected to be accounted for by measures of body composition. Nevertheless, body composition remains an important factor in accounting for variations in Heath-Carter's first and second components.

Because some variation in anthropometric somatotyping can be accounted for by body composition, it was necessary to determine the effect that weight, body fatness and lean body mass have on cardiovascular function. Correlation coefficients were calculated between max VO_2 and fat-free weight (r = +.85), active tissue (r = +.91) and body weight (r = +.63) (Buskirk and Taylor, 1957). Several studies indicated that if one considers the max VO_2 technique as a procedure to be used to determine the fitness of an individual for tasks requiring exhaustive running or the lifting of one's own body weight, the proper unit of reference is max VO_2 expressed as milliliters of oxygen per kilogram of body weight per minute (Welch, Reindeau, Crisp and Isenstein, 1958; Buskirk and Taylor, 1957; Miller and Blyth, 1955). Percent fat was shown to have significant influence on max VO_2 (ml/kg/min). Gitin, Olerud and Carroll (1974) indicated that subjects with a larger percentage of their cardiac output going directly to skeletal muscle possess an advantage in ability to do strenuous work when compared to individuals with increased vascular circuitry created by excess body fat. Gitin et al. (1974) concluded that adipose tissue is more than just an inert weight jacket and that to consider it so in work physiology is likely to lead to erroneous conclusions. When assessing the ability to do strenuous work in a population of heterogenous somatotypes, max VO_2 should be expressed relative to gross body weight (ml/kg/min).

Various body measurements and indices to physical performance have been studied extensively. Bookwalter (1952) concluded that body size and shape seem to influence physical performance. The best indices of physical performance were found to be measures of body fatness, linearity, height and weight (Slaughter and Lohman, 1977; Hebbelinck and Postma, 1963; Sills and Mitchem, 1957).

Anthropometry in application to the field of physical education is an important aspect in the process of testing and measuring. However, in studying one's overall capacity for physical fitness, emphasis should be placed on the total physique and less on its individual parts (Seltzer, 1946). Willgoose and Rogers (1949) reported that there are significant differences in fitness among various somatotypes. Jensen (1978) concluded that the ectomorph and mesomorph possess an advantage over the endomorph in terms of the biomechanical processes inherent to the performance of running and lifting one's own body weight.

Tests of endurance or cardiovascular function can be understood more clearly in terms of their physiological significances when viewed against the general background of body type. Davies, Barnes and Godfrey (1972) found that max VO_2 is related to the amount of muscle which can be brought into use, essentially the leg muscles in cycling. It was suggested that in comparative studies of power output on a bicycle ergometer there is a need to relate max VO_2 to leg size and composition. In an investigation of the influence of limb length on stepping exercise, Shahnawaz (1978) concluded that the validity of any form of step test is enhanced if step height is related to the subject's limb length, rather than using a fixed height for all subjects. In a submaximal step test, weight and the sum of selected skinfold measurements were found to be negatively correlated to max VO_2 (Jette, Ashton and Sharnatt, 1984). Lean body mass and percent body fat are negatively correlated with performance on distance running tests (Cureton, Hensley and Tibuszi, 1979, Katch, McArdle, Czula and Pechar, 1973; Kirielis and Cureton, 1947). Structural differences between various body types influence the performance of running. In general, individuals possessing high ratings for endomorphy were found to run slower (Slaughter, Lohman and Misner, 1980; Slaughter, Lohman and Misner, 1977; Sills and Everett, 1953).

Cardiovascular fitness is the single most indicative measure of a person's physical condition. Maximum oxygen uptake is considered the single most valid measure of cardiovascular efficiency (deVries, 1980; Astrand and Rodahl, 1977; Hebbelinck, 1969). The simplest and most often applied way of indirectly assessing aerobic capacity is to determine heart rate during or after exercise, or to require the subject to perform a task that calls for sustained total body movement, such as running. Many studies have indicated a linear relationship between HR and max VO_2 and between HR and work rate over a relatively wide range, approximately 125-170 beats per minute (Baumgartner and Jackson, 1982; Astrand and Rodahl, 1977). It is possible to estimate a max VO_2 value for individuals from a single stage work test approximately 5 to 6 minutes in duration and of such severity that the heart rate reaches a steady state between 125-170 bpm (Astrand and Rhyming, 1954). Maximum oxygen uptake can also be determined indirectly on the basis of a subject's recovery heart rate (Cotton and Dill, 1935). The standard error of predicting oxygen uptake from indirect methods on the basis of HR or other parameters tends to be approximately ± 10% (Baumgartner and Jackson, 1982). Despite the error introduced by indirect methods used to assess aerobic capacity, the standardized procedures involved have shown error to remain consistent on repeated tests (Pollock, Wilmore and Fox, 1984).

The indirect tests of aerobic capacity selected for use in this study have been shown to produce valid and reliable estimates of max VO_2 (ml/kg/min) (Baumgartner and Jackson, 1982; Burke, 1976). The error introduced by indirect methods can remain consistent if careful measurement and standardized procedures are employed. Therefore, indirect tests can be useful for determining changes in one's level of physical fitness, and for estimating one's present status of physical fitness.

Chapter 3

Methods and Procedures

This study investigated the relationship of body type to indirect assessment of aerobic capacity. It was the specific purpose to determine if and how individuals, grouped according to Heath-Carter anthropometric somatotype, perform differently on indirect tests of aerobic capacity: YMCA bicycle ergometer test, 1.5-mile endurance run, and the Queens College step test.

Population and Sampling

The subject pool used for this study consisted of all the male students enrolled in the PE 100 Lifetime Fitness course at Emporia State University, for the spring semester of 1985 (n=141). The age of these students ranged from 18-29 years. It is important to note that PE 100 Lifetime Fitness is a required general education course, for all students attending the university to pass, in order to graduate with a degree, regardless of academic concentraion. Thus, unlike other physical education courses offered by the university, the male students enrolled in PE 100 Lifetime Fitness were a representative sample of the general population of male undergraduate students attending ESU. It was an assumption of this study that the subject pool would include individuals who could be classified into all of the three somatogroups: endotype, mesotype or ectotype. Members of the subject pool were also assumed to possess varying degrees of maximal aerobic capacity, due to the type and intensity of physical activity in which they had previously participated.

For each member of the subject pool a somatotype was determined using the Heath-Carter anthropometric somatotype method. After somatotype ratings had been determined, all subjects were classified according to similar somatotype. Similarity of somatotype was determined from the dominance of one of the three primary components of physique. For example, a somatotype rating of: 6.0 - 3.5 - 1.0, reflects a domination of the first component, endomorphy; 2.0 - 5.0 - 2.5, reflects a domination of the second component, mesomorphy; 2.5 - 3.0 - 5.0, reflects a domination of the third component, ectomorphy. Subjects who exhibited a dominance of endomorphy, mesomorphy or ectomorphy were grouped and referred to as endotype, mesotype or ectotype respectively. These three groups were collectively referred to as somatogroups. The scope of this research did not encompass the interpretation of the influence that mixed dominant somatotypes have on aerobic capacity measurement. Mixed dominance refers to a somatotype in which two or all three of the components share equal dominance (i.e., 6.0 - 6.0 - 1.5 or 3.0 - 3.0 - 3.0). Subjects who exhibited an equal dominance of two or all three components in a somatotype rating were not used for the aerobic capacity phase of testing in this study.

In order to obtain a sample for the aerobic capacity measurement phase of testing, the original sample plan called for the random selection of an equal number of subjects (n=25) from each somatogroup of the subject pool. Because there was a discrepancy in the frequency of subjects within each somatogroup of the subject pool, a proportional sample (n=60) was randomly selected. All sampling procedures were completed prior to any treatment of the subjects or collection of data pertaining to the aerobic capacity phase of testing. For further description and rationale of the sampling procedures used in this study, refer to Chapter 4.

Variables

The two factors studied were aerobic capacity measurement and somatotype. Both factors describe a physical fitness characteristic of each subject. For purposes of this research, each factor was investigated on three levels. Aerobic capacity measurement was obtained by use of three different indirect testing methods: the YMCA bicycle ergometer test, 1.5-mile endurance run and the Queens College step test. The Heath-Carter anthropometric somatotype method was used to classify the subject pool into three different somatogroups, endotype, mesotype and ectotype.

Validity of Instrumentation

The testing involved in this study was conducted in the human physiology laboratory and at Welch Stadium on the campus of Emporia State University. The Heath-Carter anthropometric somatotype method, YMCA bicycle ergometer test and Queens College step test were administered in the human physiology laboratory. The 1.5-mile endurance run was administered on the stadium ¼-mile all-weather track.

The Heath-Carter anthropometric somatotype method was the instrument used to determine somatotype ratings for all subjects. As indicated in the review of related literature, the validity of the Heath-Carter anthropometric somatotype technique has been established through comprehensive research. Current practice in the field of physical fitness testifies to its applied validity and reliability as a practical research tool for describing variation in human physique.

Three indirect tests were used to estimate maximal aerobic capacity for subjects in the proportional sample. These tests included the YMCA bicycle ergometer test, 1.5-mile endurance run and the Queens College step test. When compared to various direct measurement techniques, the values of max VO_2 estimated from indirect methods such as distance runs, step tests and submaxixmal bicycle ergometer tests have been proven valid and reliable. As denoted in Chapter 2, indirect tests introduce a greater error in determining max VO_2 values than do direct techniques, but adherence to standardized procedures and measurements permits the use of indirect tests for the purpose of evaluating cardiovascular fitness in a practical and efficient manner.

The use of specific equipment was necessary in order to carry out evaluation of somatotype and measurement of aerobic capacity. The equipment used for the collection of data in each phase of testing is listed in Appendix C.

Procedures and Methodology of Data Collection

Prior to data collection a signed informed consent form (Appendix A-1) and PE 100 Lifetime Fitness course contract (Appendix A-2) were obtained from each subject. Once the subjects had consented to participate in the study, the following procedures were used to obtain a Heath-Carter anthropometric somatotype rating for each subject. The first step in collecting data was to record the subjects' ages, code numbers and dates of assessment on the Heath-Carter anthropometric somatotype rating forms (Appendix B-1).

All raw data necessary to obtain a somatotype rating for each member of the subject pool were collected through various anthropometric measurements. For consistency, all anthropometric measurements were made according to the procedures, specifications and definitions as described by the Heath-Carter anthropometric somatotype method (Appendix B-3).

Skinfold measurements were taken with a Lange skinfold caliper and recorded to the nearest 0.5 millimeter. The first somatotype component, endomorphy, was determined by calculating the sum of the triceps, subscapular and suprailiac skinfold measurements. For measurement efficiency, all three of these skinfolds plus the calf skinfold, which was used in determining the second component, mesomorphy, were measured and recorded at the same time.

The second component of the somatotype rating, mesomorphy, was determined from height, humeral and femoral bone diameters, and biceps and calf girths. An anthropometric sliding caliper was used to measure bone diameters and an anthropometric flexible tape was used to measure limb girths. Before the biceps and calf girths were recorded, a correction for skinfolds was made. In order to do this, the triceps and calf skinfolds were converted to centimeters. To complete the correction, the triceps skinfold was subtracted from the biceps girth and the calf skinfold was subtracted from the calf girth. The largest values for each measurement were recorded.

In order to determine the third component of the anthropometric somatotype rating, ectomorphy, only one additional measurement, body weight, was necessary. Body weight was measured to the nearest 0.5 pounds on a standard balance scale, and then converted to kilograms. A height/weight ratio (H.W.R.) was determined by dividing the height by the cube root of the weight for each subject. Cube root of weight was determined by using the cube root table for specific weights (Appendix B-4). The H.W.R. value was recorded in the appropriate box of the somatotype rating form.

The value for each component of the somatotype rating was determined using the recording form (Appendix B-1), and the instructions for calculating endomorphy, mesomorphy and ectomorphy as described by Carter (1972) (Appendix B-2). In addition, regression equations developed by Heath and Carter were used for the purpose of double checking somatotype ratings and also producing specific values for each component (Appendix B-6) (M.H. Slaughter, personal communication, January 27, 1985).

After the somatotype phase of evaluation was completed, all subjects were somatogrouped as endotype, mesotype or ectotype. Table 1 shows the frequencies and number of subjects in each somatogroup of the subject pool and sample. From each somatogroup of the subject pool, a proportional number of subjects was randomly selected to participate in the assessment of aerobic capacity. The distribution of the somatotype ratings for subjects in the sample were plotted on a somatochart (Appendix B-5). The aerobic capacity phase of testing consisted of three indirect tests used to estimate max VO_2 which were the YMCA bicycle ergometer test, 1-5-mile endurance run and the Queens College step test. These tests were administered over a 16 day period. All tests were administered in the same order for each subject, a minimum of 48 hours apart. All subjects were tested in private on the YMCA bicycle ergometer test. Because the Queens College step test and the 1.5-mile endurance run are used for large scale testing, subjects were evaluated in groups. The groups for these tests were composed of a proportional number of subjects from each somatogroup.

Table 1

Number of Subjects and Frequencies for the Subject Pool and Sample

Statistic	Endotype	Mesotype	Ectotype	Mixed Dominance
Subject pool number of subjects (n)	32	79	24	6
Frequency (% of total n)	22.7	56.0	17.0	4.3
Total n=141				
Sample number of subjects (n)	15	30	15	---
Frequency (% of total n)	25.0	50.0	25.0	---
Total n=60				

The first test that was administered to each somatogroup of the sample was the YMCA bicycle ergometer test (Golding, Myers and Sinning, 1982). Prior to each testing session, the bicycle ergometer was calbrated (Appendix D-1). A brief explanation of the test procedures and purpose was given to each subject prior to administration of the test. Information was recorded on a testing form (Appendix D-2). Before the actual test was started, the seat height was adjusted so that the subject's knee would be straight with the ball of the foot on the pedal and the leg stretched.

In order for the subject to maintain the proper pedaling rate of 50 revolutions per minute, a metronome, which was calibrated against a stopwatch prior to each testing session, was set at 100 bpm so that at each "click" a foot (left or right) was on the downstroke. As an alternative, the subject was allowed to use the speedometer in order to maintain a constant speed of 18 kilometers per hour. This rate was equal to 50 revolutions of the bicycle wheel per minute. The subject was allowed to learn this pace by freewheeling (no resistance on the wheel) for one minute.

The initial workload was set at 300 kilogram-meters per minute for all subjects. The participant worked at the first workload for three minutes. Using a stethoscope and stopwatch, the subject's heart rate was determined by measuring the time required for his heart to beat 30 times. The time obtained was converted to beats per minute using a heart rate conversion sheet (Appendix D-3). The heart rate was taken at the second and third minutes of the workload. The heart rates recorded at the second and third minutes should not have differed by more than five beats. If they did the test was continued at this workload for an additional minute or until a stable heart rate value was obtained. The heart rates at the end of the second, third and fourth (if needed) minutes were recorded. Once a stable value had been reached, the workload was changed in accordance to the workload setting guideline chart for males (Appendix D-4). The new workload was then recorded.

For all workloads the heart rates were measured beginning at the 45-second mark of the second and third minutes in order to achieve consistency. The workload setting was periodically monitored throughout the test, because as the friction belt on the bicycle ergometer heats up it has a tendency to slip, thus producing a decreased resistance. Adjustment of the workload back to the designated point ensured that the proper workload was provided.

The procedures for the second and third workloads were the same as those used in the initial workload. Unless the first workload produced a heart rate of 110 bpm or above, a third workload was determined and the test was continued as previously. If the first workload elicited a heart rate of 110 bpm or greater there was no need for the third workload. When the heart rates at the end of the second and third minute of the third workload had been recorded (assuming a stable heart rate) the test was completed. The subject was required to freewheel on the bicycle ergometer until his heart rate returned below 110 bpm. This ensured a proper cooling down time for each subject.

The final heart rate for the second and third workloads was plotted against the respective workload on the maximum physical working capacity graph (Appendix D-6) in order to determine an estimated max VO_2 value for each subject (Appendix D-7). In order to convert the maximum oxygen uptake (liters/min) to milliliters per kilogram of body weight per minute (ml/kg/min) a conversion chart was used (Appendix D-8). Including body weight as a factor of the measurement allowed for relative comparisons to be made through statistical analysis.

The second aerobic capacity assessment that was administered was the Queens College step test (McArdle, Katch and Katch, 1981). Subjects were given a demonstration and explanation of the step test, followed by a short practice period prior to testing. For three minutes the subject performed a stepping cycle. Each stepping cycle was performed to a four-step cadence consisting of: (1) right foot up; (2) left foot up; (3) right foot down; and (4) left foot down. A 16¼" stepping bench was used for this test. A metronome, which was calibrated against a stopwatch prior to each testing session, was set at 96 bpm (each foot stepping at the "click") so that the subject worked at a rate of 24 steps per minute.

After the 3-minute work bout was completed the subject remained standing while the heart rate was counted for a 15 second interval, beginning 5 seconds after termination of stepping procedure. All subjects' recovery heart rates were determined by the primary investigator with the use of a stethoscope and stopwatch. The recovery heart rate was then converted to beats per minute by multiplying the value obtained from the 15-second count by four. All scores were recorded.

In order to convert the raw data to estimated max VO_2 (ml/kg/min), the following regression equation was used: Max $VO_2 = 111.33 - 0.42X$, where x = step test recovery pulse rate (bpm). The standard error of estimating max VO_2 values from this equation is $s_{y \cdot x} = 3.2$ ml/kg/min (Appendix F-1).

The 1.5-mile run was administered last to all subjects. Subjects ran in groups composed of a proportional number of subjects from each somatogroup. All subjects were tested within a two day period. Since the test was administered outdoors, weather conditions were monitored. The temprature on both days ranged from $30^{\circ}F$ to $48^{\circ}F$. The wind conditions were similar for both days. The major difference between the two days in terms of weather condition was that light snowfall occurred on the second day, producing wet but not detrimental track surface conditions. Prior to testing, all subjects were given a description of the test and expectations of them as subjects in the study. Information about pacing and practice sessions for pacing were administered to all subjects prior to the actual test through PE 100 Lifetime Fitness course content and activities. These precautions were repeated prior to each testing session.

The time that was required to run 1.5-miles was measured in minutes and seconds to the nearest 1.0 second, using a hand held stopwatch. If a subject was unable to run the entire 1.5 miles, he was allowed to walk until able to resume running. In this case verbal encouragement from the primary investigator was administered. It was assumed that all subjects put forth their maximum effort. All raw scores were recorded. Raw scores obtained from the 1.5-mile run were then converted to an estimated max VO_2 (ml/kg/min) value by using a conversion chart (Pollock, Wilmore and Fox, 1984) (Appendix E-1).

Statistical Design and Hypotheses

In order for the variables of this experiment to be satistically analyzed and the hypotheses to be simultaneously tested, a factoral design was utilized. The specific factoral design of this study was a 3 x 3, 2-way factoral design as diagrammed in figure 1.

	YMCA bicycle ergometer test	1.5-mile run	Queens College step test	Marginal means
Endotype	A_1B_1	A_1B_2	A_1B_3	A_1B
Mesotype	A_2B_1	A_2B_2	A_2B_3	A_2B
Ectotype	A_3B_1	A_3B_2	A_3B_3	A_3B
Marginal means	AB_1	AB_2	AB_3	

Figure 1. Diagram of the statistical design, A 3 x 3, 2-way factoral design. Factor A = somatotype, Factor B = aerobic capacity measurement.

Statements of the Hypotheses (Null Form)

(1) There is no significant difference between the grand mean values of the YMCA bicycle ergometer test, 1.5-mile endurance run and the Queens College step test, in terms of max VO_2 (ml/kg/min), across all somatogroups.

(2) There is no significant difference between endotype, mesotype and ectotype somatogroup grand mean values for estimated max VO_2 (ml/kg/min), across all indirect tests of aerobic capacity.

Statistical Hypotheses (Null Form)

(1) $H_o: \mu_{AB_1} = \mu_{AB_2} = \mu_{AB_3}$

$H_A: \mu_{AB_1} \neq \mu_{AB_2} \neq \mu_{AB_3}$

(2) $H_o: \mu_{A_1B} = \mu_{A_2B} = \mu_{A_3B}$

$H_A: \mu_{A_1B} \neq \mu_{A_2B} \neq \mu_{A_3B}$

The basic descriptive statistics, means, ranges and standard deviations were used to report the data collected in statistical summary. Further data analysis was performed using a fixed effects model of the analysis of variance (ANOVA) technique. The basic reason for using ANOVA to analyze the data was to produce information about the main effects of the variables in isolation, and about the interactions between the variables (Isaac and Michael, 1981). Using ANOVA for statistical analysis only indicated if there was a significant difference in the data base. For further statistical analysis the Tukey test was used to make comparisons of the marginal means to determine where significance existed in the data base, while adjusting for experimental error (L. Tompkins, personal communication, January 15, 1985).

Limitations of the Study

The main objective of research and the statistical analysis of data is to attempt to answer questions of importance in a controlled study while minimizing error. This research design was classified as quasi-experimental. The purpose of quasi-experimental research is to approximate the conditions of true experimental research in a setting which does not allow for the control of all extraneous variables (Isaac and Michael, 1983). Thus, an understanding of the internal and external validity inherent to this design was considered and research proceeded within these limitations. Because this study entailed the use of human subjects, it was recognized that the control of every source of "noise" in the design could not be maintained.

An extraneous variable inherent to the proposed research design was the difficulty in the establishment and development of the motivational level of each subject being tested. This factor was of particular concern in the 1.5-mile run, in which there was no objective means of determining levels of motivation, or the degree of effort put forth by each subject.

Chapter 4

Analysis of Data

The purpose of this study was to determine the difference in performance of individuals, classified according to body type, on selected indirect tests of aerobic capacity. The project investigated the performance of subjects from a sample population, classified and grouped according to similar Heath-Carter anthropometric somatotype ratings, on selected tests of aerobic capacity: 1.5-mile run; Queens College Step Test; and the YMCA bicycle ergometer test.

Sample Analysis

Heath-Carter anthropometric somatotype ratings were determined for 141 male college students, ranging in age from 18 to 29 years, with a mean age of 19.6. These students were enrolled in the PE 100 Lifetime Fitness course at Emporia State University, for the spring semester of 1985. It is important to note that the PE 100 Lifetime Fitness course, which is listed under the physical education curriculum of the College of Education at ESU, is a required course for all students attending the university to pass in order to graduate with a degree, regardless of academic concentration. Thus, unlike other physical education courses, the male students who composed the subject pool for this study were representative of the general population of male undergraduate students attending ESU.

The means, standard deviations and ranges for the somatotype component ratings of the subject pool are reported in Table 2. The mean somatotype rating of the subject pool was 4.5 - 5.2 - 2.8. A mean somatotype is expressed in a three-numeral rating, consisting of three sequential numerals, always recorded in the same order. Each numeral represents the mean rating or evaluation of one of the three primary components of physique; relative body fatness (endomorphy), musculoskeletal development per unit of height (mesomorphy) and relative linearity (ectomorphy), which describe variation in human morphology and composition for a given population. Each component scale consists of numerical values, theoretically ranging from 0.0 at the low end and having no arbitrary, upper limit. The larger the numerical value is for any given component in a somatotype rating, the more that particular component is considered to be expressed in the individual's body type. Conversely, the smaller the numerical value is for any given component in a somatotype rating, the less that component is considered to contribute to an individual's body type.

Table 2

Means, Standard Deviations and Ranges for Somatotype Component Ratings of the Subject Pool

Statistics	Endomorphy	Mesomorphy	Ectomorphy
Mean ($\overline{x}$)	4.5	5.2	2.8
Standard Deviation (s)	1.7	1.3	1.1
Range n = 141	2.1 - 10.7	2.6 - 9.9	0.1 - 5.2

Table 3 summarizes the relative frequencies of the different somatogroups within the subject pool. Each subject was classified into a particular somatogroup on the basis of component dominance exhibited in their anthropometric somatotype rating. A total of 79 subjects (56.0%) possessed a dominance of the second component, mesomorphy, and were classified as the mesotype somatogroup. Those subjects whose somatotype rating reflected a dominance of the first component, endomorphy, were classified as endotypes. The endotype somatogroup was composed of 32 subjects (22.7%). The ectotype somatogroup consisted of 24 subjects (17.0%) whose third componenet, ectomorphy, dominated their somatotype rating. Only 4.3% (n = 6) of the subject pool possessed somatotype ratings in which two or all three of the components shared equal dominance.

Table 3

Relative Frequencies of Subjects Within Somatogroups in the Subject Pool

	Endotypes	Mesotypes	Ectotypes	Shared Dominance
Number of subjects (n)	32	79	24	6
% of subject pool	22.7	56.0	17.0	4.3

The original design for drawing a sample from the subject pool called for the random selection of an equal number (n = 25) of subjects from each somatogroup. Because a discrepancy was found in the size of the somatogroups in the subject pool, the original sampling plan was not possible. Therefore, a proportional sample (n = 60) was drawn from the subject pool for purposes of analysis. In order to maintain a similar frequency of subjects per somatogroup as was indicated for the subject pool, the sample consisted of 15 randomly selected subjects from the endotype somatogroup, 30 randomly selected subjects from the mesotype somatogroup, and 15 randomly selected subjects from the ectotype somatogroup. The scope of this study did not include the analysis of subjects possessing shared dominance of somatotype rating components. The process of random selection was accomplished by assigning a numerical code to all to the subjects in each somatogroup of the subject pool. A total number of random digits equal to the number of subjects required for each somatogroup of the proportional sample was acquired by use of a random digits table. The random numbers were then matched with the same pre-assigned numerical code of particular subjects in order to select the sample.

A comparison of the means, standard deviations and ranges for somatotype ratings and basic anthropometric measurements in the subject pool and the sample are summarized in Table 4. The mean somatotype rating of the sample was 4.4 - 5.1 - 2.9. This mean somatotype rating was extremely close to the mean somatotype rating of the subject pool, which was 4.5 - 5.2 - 2.8. The physical characteristics of the sample population were very similar to the subject pool for measurements of height, weight and age. Because the mean differences were small, the sample was considered to be closely representative of the subject pool in terms of physical characteristics.

Table 4

Means, Standard Deviations and Ranges for Somatotype Ratings and Basic Anthropometric Measurements in the Subject Pool and Sample

Statistics		Somatotype Components			Anthropometric Measurements		
		First	Second	Third	Age	Height (cm)	Weight (kg)
(n = 141)	$\bar{x}$	4.5	5.2	2.8	19.6	179.4	77.8
Subject Pool	s	1.7	1.3	1.1	2.1	6.1	13.1
	Range	9.6	8.3	6.1	12.0	34.5	94.2
(n = 60)	$\bar{x}$	4.4	5.1	2.9	19.5	179.2	77.4
Sample	s	1.8	1.6	1.3	1.6	6.8	15.8
	Range	9.5	8.3	6.3	8.0	33.5	94.2

Table 5 summarizes the three basic somatotype component means, standard deviations and ranges for each somatogroup in the sample. The endotype somatogroup had a mean somatotype rating of 6.7 - 5.6 - 2.0. This mean somatotype reflects a high degree of the first component, endomorphy, as was expected and also reflects a relatively high degree of the second component, mesomorphy. This trend suggests that in the endotypes studied, a large value for the first component rating tended to be accompanied by a relatively high rating in the second component, mesomorphy, and a low rating in the third component, ectomorphy. The mean somatotype rating of the mesotype somatogroup was 3.8 - 5.6 - 2.6.

This mean somatotype rating is dominated by the second component, mesomorphy. The mesotypes that were studied, tended to have a higher degree of the first component than the third component expressed in their body types. The mean somatotype rating of the ectotype somatogroup was 3.4 - 3.4 - 4.4. This mean somatotype reflects what is referred to as balanced ectomorphy; the ectomorph component is dominant and the endomorph and mesomorph components are expressed to an equal degree in the mean somatotype rating.

Table 5

Means, Standard Deviations and Ranges for Somatotype Rating Components in the Endotype, Mesotype, and Ectotype Somatogroups

Statistics		Endomorphy	Mesomorphy	Endomorphy
(n=15)	$\bar{x}$	6.7	5.6	2.0
Endotype Somato-group	s	1.6	1.9	1.3
	Range	5.0 - 10.7	3.3 - 9.9	0.1 - 3.6
	$\bar{x}$	3.8	5.6	2.6
Mesotype Somato-group	s	1.1	1.1	0.9
	Range	2.3 - 6.9	3.9 - 8.5	0.7 - 4.0
	$\bar{x}$	3.4	3.4	4.4
Ectotype Somato-group	s	0.7	0.4	0.3
	Range	2.2 - 5.0	2.6 - 4.1	3.9 - 5.2

Table 6 summarizes the means, standard deviations and ranges for all of the anthropometric measurements used for determining somatotype ratings in the somatogroups of the sample. The sum of three skinfolds (suprailiac, triceps and subscapular) was used to determine the degree of the first component, endomorphy, in each subject's somatotype. The endomorphy component describes the relative fatness or leanness of each subject. As expected the endotype somatogroup had the highest mean value for the sum of three skinfolds ($\bar{x} = 74.6$ mm). The mesotype somatogroup had a lower mean value ($\bar{x} = 38.0$ mm) than the endotype somatogroup, but it was higher than the mean ($\bar{x} = 32.9$ mm) of the ectotype somatogroup, which was the lowest.

Height, corrected biceps and calf girths, and femoral and humeral bone diameters were used to determine the second component, mesomorphy. The second component rating reflects the relative musculoskeletal development for a given height in each subject. The endotype somatogroup had the highest mean value for height ($\bar{x} = 181.8$ cm), corrected calf girth ($\bar{x} = 38.3$ cm), humeral ($\bar{x} = 7.27$ cm) and femoral ($\bar{x} = 10.32$ cm) bone diameters, and the second highest mean value for correted biceps girth ($\bar{x} = 33.9$ cm). The determination of the second component is relative to the magnitude of these measurements, which in part may explain the high degree of mesomorphy exhibited by the mean somatotype rating of the endotype somatogroup. The mesotype somatogroup had the lowest mean value for height ($\bar{x} = 176.9$ cm), the highest mean value for corrected biceps girth ($\bar{x} = 34.2$ cm) and the second highest mean values for the corrected calf girth ($\bar{x} = 36.8$ cm), and humeral

($\bar{x}$ = 7.08 cm) and femoral ($\bar{x}$ = 9.78 cm) bone diameters. The lower value of height in combination with large corrected girth measurements accounted for the highest second component rating in the mean somatotype of the mesotype somatogroup, as was expected. The ectotype somatogroup had the second highest mean value for height ($\bar{x}$ = 181.2 cm) and the lowest values for corrected biceps ($\bar{x}$ = 29.2 cm) and calf ($\bar{x}$ = 34.2 cm) girths, and humeral ($\bar{x}$ = 6.92 cm) and femoral ($\bar{x}$ = 9.49 cm) bone diameters.

The third component, ectomorphy, was determined by the Ponderal Index (height/cube root of weight). As height values increase and weight values decrease for a given individual, the value of the Ponderal Index increases reflecting an increase in ectomorphy. The endotype somatogroup had the highest mean value for height, but also had the highest mean value for weight ($\bar{x}$ = 92.6 kg), resulting in the lowest mean value for the Ponderal Index ($\bar{x}$ = 12.26). The ectotype somatogroup had the second highest mean value for height, and had the lowest mean value for weight ($\bar{x}$ = 65.6 kg), thus resulting in the highest mean value for the Ponderal Index ($\bar{x}$ = 13.59). The mesotype somatogroup and the lowest mean value for height, and the second highest mean value for weight ($\bar{x}$ = 75.8 kg) which resulted in a Ponderal Index mean value of 12.69.

An analysis of the means for the anthropometric measurements used to determine somatotype ratings for all subjects reflects a trend for the endotypes to be larger than both the mesotypes and the ectotypes, and the mesotypes to be larger than the ectotypes, within the sample tested.

Table 6

Anthropometric Measurements Used For Determining Somatotype Ratings

Statistics		Age	Wt (kg)	Ht (cm)	Bone Diam. (cm)		Corr. Girths (cm)		S'fold Sum (mm)	Ponderal Index
					Hum.	Fem.	Bic.	Calf		
(n=60)	$\bar{x}$	19.5	77.4	179.2	7.09	9.84	32.9	36.5	45.9	12.81
Sample	s	1.6	15.8	6.8	0.39	0.63	3.7	2.8	23.9	0.74
	Range	8.0	94.2	33.5	2.00	4.20	17.2	15.2	136.5	3.48
(n=15)	$\bar{x}$	19.5	92.6	181.8	7.27	10.32	33.9	38.3	74.6	12.26
Endotype Somatogroup	s	1.6	20.4	6.7	0.48	0.83	3.9	3.4	29.3	0.87
	Range	7.0	72.4	22.5	1.90	3.10	15.9	14.2	107.0	2.95
(n=30)	$\bar{x}$	19.7	75.8	176.9	7.08	9.78	34.2	36.8	38.0	12.69
Mesotype Somatogroup	s	1.9	9.2	5.6	0.34	0.46	3.1	1.9	12.2	0.50
	Range	8.0	37.4	18.4	1.35	2.85	13.4	6.9	52.5	1.90
(n=15)	$\bar{x}$	18.8	65.6	181.2	6.92	9.49	29.2	34.2	32.9	13.59
Ectotype Somatogroup	s	0.8	7.9	8.2	0.34	0.40	1.8	2.1	6.6	0.12
	Range	4.0	26.9	29.2	1.45	1.70	6.6	6.9	28.5	0.58

Statistical Analysis

A fixed effects model of analysis of variance (ANOVA) was used to statistically analyze the 3 x 3, 2-way factoral design of this study. A fixed effects model refers to a design in which the selection of subjects is random, but the assignement of those subjects to groups is predetermined. The purpose of using ANOVA to analyze the data was to produce information about the main effects (Factor A = somatotype; Factor B = aerobic capacity tests) in isolation, and about the possible interaction between factors (interaction term = Factor A x Factor B).

F-ratios were determined for each factor separately and for the interaction term by ANOVA. An F-ratio is the ratio of treatment effect to error, and is used to indicate if a significant difference exists in the data base. Because F-ratios will only indicate whether or not a significant difference exists in the data base, a follow up statistical analysis was performed by use of the Tukey test. The Tukey test was used to make comparisons of the marginal means from the ANOVA to determine where significant differences existed in the data base, while adjusting for experimental error.

Table 7 shows the ANOVA results for the factors of somatotype and indirect tests used to determine aerobic capacity.

Table 7

Analysis of Variance of Differences
Between Somatogroup and Aerobic
Capacity Test Mean Values

Source	Sum of Squares (ss)	Degrees of Freedom (df)	Mean Squares (ms)	F-ratio	Level of Probability (p)
Tests	1724.751	2	862.376	16.082	.001
Somatotype	2303.402	2	1151.701	21.477	.001
Tests/Type	354.672	4	88.668	1.654	.162
Error	9169.734	171	53.642		

The F-ratio for the aerobic capacity tests factor was equal to 16.082, which was significant at the .05 level. The F-ratio for the somatotype factor was equal to 21.477, which also was significant at the .05 level. The F-ratio for the interaction term was equal to 1.654, and it was determined that because the main effects were significant, there was no interaction. Therefore, the main effects were interpreted.

There was an inequality in the grand means of the aerobic capacity tests across all somatogroups. Therefore, the null hypothesis (H_0): $\mu_{AB_1} = \mu_{AB_2} = \mu_{AB_3}$ was rejected, and the alternate hypothesis (H_A): $\mu_{AB_1} \neq \mu_{AB_2} \neq \mu_{AB_3}$ was accepted. There was also inequality in the somatogroup grand means across all indirect tests of aerobic capacity. Therefore, the second null hypothesis (H_0): $\mu_{A_1B} = \mu_{A_2B} = \mu_{A_3B}$ was rejected, and the alternate hypothesis (H_A): $\mu_{A_1B} \neq \mu_{A_2B} \neq \mu_{A_3B}$ was accepted.

In order to determine where the significant differences existed in the data base, the Tukey test was used as a follow up analysis. The Tukey test determines a quantity $(d_{\overline{T}})$ which indicates the least significnt differences, or how far the grand means $(\bar{x})$ must differ in order for the differences to be significant. If the grand mean difference is less than or equal to the value of $d_{\overline{T}}$ then the difference is significant.

Table 8 illustrates the results of the first Tukey test analysis. In this Tukey test, the difference between $\bar{\bar{x}}_{AB_3} - \bar{\bar{x}}_{AB_2} = 4.14$;

$\bar{\bar{x}}_{AB_2} - \bar{\bar{x}}_{AB_1} = 3.85$; and $\bar{\bar{x}}_{AB_3} - \bar{\bar{x}}_{AB_1} = 7.99$. Therefore, all grand mean differences were significant for aerobic capacity tests across all somatogroups. The meaning of the analysis is that the performance of subjects across all somatogroups differed between all three tests of aerobic capacity.

Table 8

Tukey Test Results for Grand Mean Values of Aerobic Capacity Tests Across All Somatogroups

	AB_1 YMCA bicycle ergometer test	AB_2 1.5-mile run	AB_3 Queens College step test
AB_1	---	3.85*	7.99*
AB_2		---	4.14*
AB_3			---

* significant at the .05 level. The value of $d_{\bar{T}}$ in this Tukey test was 3.13.

Figure 2 illustrates a graphic representation of the grand mean values for each of the aerobic capacity test performances of subjects across all somatogroups. There was a trend across all somatogroups for the Queens College Step Test to estimate the highest values of max VO_2 ($\bar{\bar{x}} = 49.17$ ml/kg/min). The next highest estimates were elicited by the 1.5-mile distance run ($\bar{\bar{x}} = 45.03$ ml/kg/min), and the lowest estimates were produced from the YMCA bicycle ergometer test ($\bar{\bar{x}} = 41.18$ ml/kg/min).

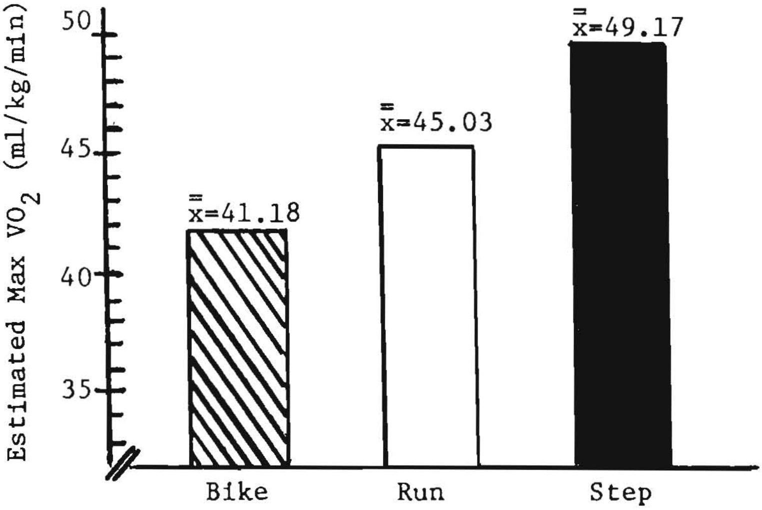

Fig. 2 - Aerobic Capacity Tests

Table 9 illustrates the result of the second Tukey test, which was used to analyze the significance of the difference between grand mean values of the endotype, mesotype and ectotype somatogroups across all indirect tests of aerobic capacity. In this Tukey test the difference between $\bar{\bar{x}}_{A_2B} - \bar{\bar{x}}_{A_1B} = 8.45$; $\bar{\bar{x}}_{A_3B} - \bar{\bar{x}}_{A_3B} = 7.31$; and $\bar{\bar{x}}_{A_3B} - \bar{\bar{x}}_{A_2B} = -1.23$. Significant differences were found to exist between grand mean values of the endotype and ectotype somatogroups, and between the endotype and mesotype somatogroups across all tests of aerobic capacity, at the .05 level. The difference between the grand mean values of the ectotype and mesotype somatogroups was not statistically significant.

Table 9

Tukey Test Results for Grand Mean Values of Somatogroups Across All Aerobic Capacity Tests

	A_1B Endotype Somatogroup	A_2B Mesotype Somatogroup	A_3B Ectotype Somatogroup
A_1B	---	8.45*	7.31*
A_2B		---	-1.23
A_3B			---

* significant at the .05 level. The value of $d_{\overline{T}}$ in this Tukey test was 3.13.

Figure 3 illustrates the graphic representation of the grand mean values for each somatogroup across all of the indirect tests of aerobic capacity. The mesotype somatogroup grand mean value across all three tests of aerobic capacity was the highest. The ectotype somatogroup grand mean value was slightly lower than the mesotype somatogroup grand mean value, but was not significantly different. Across all tests of aerobic capacity, both the mesotype and ectotype somatogroup grand mean values were greater than the endotype somatogroup grand mean value, which was consistently the lowest across all tests of aerobic capacity. The difference in performance, in terms of estimated max VO_2 (ml/kg/min), showed a consistent trend across all tests of aerobic capacity; the mesotype somatogroup ($\bar{\bar{x}}$ = 48.38 ml/kg/min) was superior to both the ectotype and endotype somatogroups; and ectotype somatogroup ($\bar{\bar{x}}$ = 47.15 ml/kg/min) was consistently superior to the endotype somatogroup ($\bar{\bar{x}}$ = 39.84 ml/kg/min).

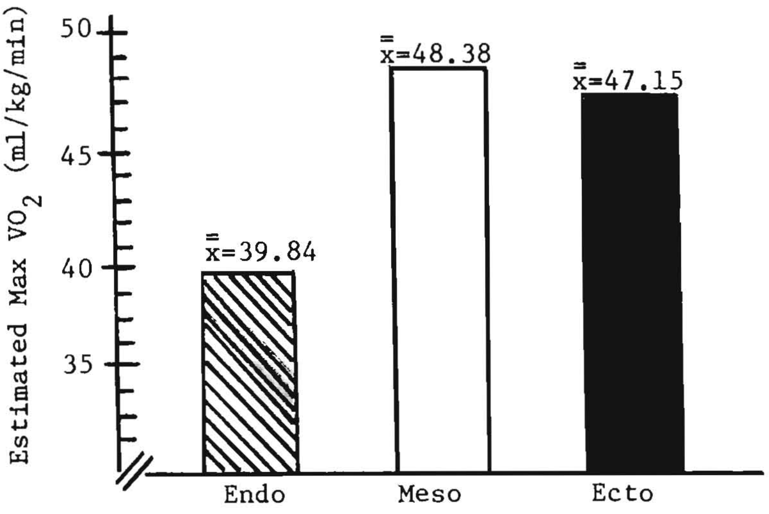

Fig. 3 - Somatogroups

Summary

A fixed effects model of ANOVA was used to statistically analyze the 3 x 3, 2-way factoral design used for this study. F-ratios were determined for each factor separately and for the interaction term by ANOVA. From the results of the ANOVA, it was determined that because the main effects were significant, there was no interaction. Therefore, the main effects were interpreted. Because there was an inequality in the grand means of the aerobic capacity tests across all somatogroups, and an inequality in the somatogroup grand means across all indirect tests of aerobic capacity, both of the null hypotheses of this study were rejected and each alternate hypothesis was accepted.

Since F-ratios could only indicate that a significant difference existed in the data base for the main effects, the Tukey test was used as a follow-up analysis to make comparisons of the marginal menas from ANOVA to determine where the significant differences existed in the data base, while adjusting for experimental error. All grand mean differences were significant for the aerobic capacity tests across all somatogroups. This analysis meant that the performance of subjects across all somatogroups differed between all three tests of aerobic capacity. Furthermore, significant differences were found to exist between grand mean values of the endotype and ectotype somatogroups, and between the endotype and mesotype somatogroups across all tests of aerobic capacity. The difference between the grand mean values of the ectotype and mesotype somatogroups was not statistically significant.

The differences in performance between somatogroups, in terms of estimated max VO_2 (ml/kg/min), suggests that mesotypes and ectotypes are physiologically better conditioned than endotypes. The consistent trend for all tests to differentiate between somatogroups in the same manner, suggests that there is not one test that is best for any particular somatogroup. However, across all somatogroups the Queens College Step Test elicited the highest estimates of max VO_2 (ml/kg/min). It was also indicated that the 1.5-mile run consistently estimated max VO_2 (ml/kg/min) values that were greater than those predicted from the YMCA bicycle ergometer test, across all somatogroups.

Chapter 5

Summary, Discussion, Conclusions and Recommendations

This study was designed to determine the difference in performance of individuals, classified according to Heath-Carter anthropometric somatotype ratings, on the YMCA bicycle ergometer test, 1.5-mile endurance run and Queens College step test. Heath-Carter anthropometric somatotypes were determined for 141 male college students who were enrolled in a required physical education course at Emporia State University. A sample (n=60) of 15 endotypes, 30 mesotypes and 15 ecototypes, representing the proportion of individuals classified in each somatogroup of the subject pool (n=141), was randomly selected. The sample was found to be highly representative of the subject pool in terms of physical characteristics. All subjects in the sample were evaluated in terms of their performance on the YMCA bicycle ergometer test, 1.5-mile endurance run and Queens College step test. These indirect tests of aerobic capacity were used to obtain estimates of max VO_2 (ml/kg/min) for each subject in the sample. A fixed effects model of ANOVA was used to determine if significant differences occurred in the data base. A Tukey post-hoc analysis was used to clarify ANOVA results.

Discussion

Results of the ANOVA showed significant differences to exist within the data base for the main effects of somatotype and aerobic capacity. The interaction term was found to be insiginficant. Therefore, the main effects were interpreted. A Tukey test was used to analyze the differences between the grand mean values of estimated max VO_2 for the endotype, mesotype and ectotype somatogroups, across all tests of aerobic capacity, and to analyze the differences between the grand mean values of estimated max VO_2 elicited by the YMCA bicycle ergometer test, 1.5-mile endurance run and the Queens College step test, across all somatogroups.

From the Tukey analysis it was determined that a significant difference existed between the grand mean values of estimated max VO_2 for the mesotype and endotype somatogroups, and between the grand mean values of estimated max VO_2 for the ectotype and endotype somatogroups, across all indirect tests of aerobic capacity. No significant difference was found to exist between the grand mean values of estimated max VO_2 for the mesotype and ectotype somatogroups, across all indirect tests of aerobic capacity.

It appears from the statistical analysis that individuals who possess a dominance of the second component, mesomorphy, or the third component, ectomorphy, tend to have a greater aerobic capacity than do those individuals whose somatotype is dominated by the first component, endomorphy. The mesotypes in this study had the highest grand mean value for estimated max VO_2 (ml/kg/min) across all indirect tests of aerobic capacity. The ectotype somatogroup grand mean value for estimated max VO_2 (ml/kg/min) was slightly lower than the grand mean value for mesotypes across all indirect aerobic capacity tests, but there was no siginficant difference found to exist between the two groups in terms of performance. The endotype somatogroup had the lowest grand mean value for estimated max VO_2 (ml/kg/min) across all indirect tests of aerobic capacity. These results suggest that, when aerobic capacity is expressed relative to gross body weight (ml/kg/min), mesotypes and ectotypes tend to possess similar levels of physical fitness, in terms of cardiovascular endurance, which are superior to those of the endotypes. Thus, it appears that a limiting factor in the performance of individuals on selected indirect tests of aerobic capacity is a high degree of the first component, endomorphy, in one's somatotype. This statement is in agreement with Willgoose and Rogers (1949) and Sills and Mitchem (1953) who found that individuals possessing a dominant first component in their somatotype scored low in physical fitness, and thus, that endomorphy was a limiting factor in fitness. In these same studies it was shown that mesomorphs performed better than ectomorphs, but the mean difference was not significant.

There is a high correlation between the first component, endomorphy, and body fatness (Slaughter and Lohman, 1976; Wilmore, 1970). Thus, it seems logical to further speculate that the percentage of body fat represented in the first component of a somatotype rating might partially determine one's performance on indirect tests of aerobic capacity. Referring to Table 6, Chapter 4, there appears to be a trend in the fat scores (sum of the suprailiac, subscapular and triceps skinfolds) that might well be related to the differences in performance indicated by this study. The mesotype and ectotype somatogroups performed at similar levels on all aerobic capacity tests and had similar mean values for fat scores ($\bar{x}$ = 38.0 mm and $\bar{x}$ = 32.9 mm respectively for each somatogroup). In contrast, the endotypes, who performed at the lowest level across all indirect tests of aerobic capacity, had a much greater mean value ($\bar{x}$ = 74.6 mm) for the fat score. Intuitively, it would seem reasonable to suggest that excess body fat is a limiting factor in the performance of aerobic capacity tests. This statement agrees in theory with Gitin, Olerud and Carroll (1974) who concluded from their study that even though oxygen consumption might increase as a result of adipose tissue metabolism, the subject with less fat has a larger percentage of his cardiac output going directly to skeletal muscles and thus possesses an advantage in ability to do strenuous work when compared to a subject whose cardiac output has to meet the needs of increased vascular circuitry created by excess adipose tissue.

Through subjective observation, the endotypes also appeared to be at a biomechanical disadvantage when performing the selected indirect tests of aerobic capacity. This was perceived to be caused not only by the excess fat inherent to the endotype, but also because of the greater dimensions in bone size, limb girths and gross body weight which the endotype tends to possess in comparison to the mesotype and ectotyoe (refer to Table 6, Chapter 4). This observation is in agreement with Jensen (1978) who found that in skills requiring high levels of linear velocity such as in running, or in lifting of one's own body weight such as in stepping, the motor skills of the endomorph were inferior to those of the mesomorph and ectomorph. Furthermore, he inferred that the differences between the somatotypes represent a serious potential constraint on the development of momentum and on the mechanical efficiency in tasks requiring the performance of motor skills by the endomorph. It appears that differences between individuals possessing a wide range of physical characteristics, in terms of performance on indirect tests of aerobic capacity, are partially the result of the degree of body fatness and the biomechanical efficiency which is inherent to each particular body type.

From the results of further Tukey analysis, it was determined that significant differences existed between all of the estimated max VO_2 (ml/kg/min) grand mean values elicited by the YMCA bicycle ergometer tests, 1.5-mile endurance run and Queens College step test, across all somatogroups. The grand mean value of estimated max VO_2 (ml/kg/min) elicited by the Queens College step test was the highest among all three indirect tests of aerobic capacity. The next highest grand mean value of max VO_2 (ml/kg/min) was produced by the 1.5-mile endurance run, and the lowest grand mean value for estimated max VO_2 (ml/kg/min) resulted from the YMCA bicycle ergometer test. This trend was consistent across all of the somatogroups.

Conclusions

(1) Although significant differences existed between the magnitude of the max VO_2 (ml/kg/min) estimates produced by the YMCA bicycle egrometer test, 1.5-mile endurance run and Queens College step test, across all somatogroups, the question of which test provides the most effective estimate of max VO_2 was not addressed. The study does suggest that the Queens College step test tends to produce the most liberal estimates of max VO_2 when compared to the estimates

of max VO_2 produced by the 1.5-mile endurance run and the YMCA bicycle ergometer test. The YMCA bicycle ergometer test tends to provide the most conservative estimates of max VO_2. The indirect aerobic capacity test of choice in a given research or practical application, then, is a function of the philosophy and purpose inherent in the evaluation.

(2) Significant differences existed between the grand mean values of estimated max VO_2 (ml/kg/min) for the endotype and mesotype somatogroups, and between the endotype and ectotype somatogroups, across all tests of aerobic capacity.

(3) No significant difference was found to exist between the grand mean values of max VO_2 (ml/kg/min) for the mesotype and ectotype somatogroups, across all tests of aerobic capacity.

(4) A high degree of the first component, endomorphy, in one's somatotype appears to be a limiting factor in the performance of selected indirect tests of aerobic capacity.

Recommendations

(1) Physical educators and fitness specialists should be aware that endotypes appear to possess physiological disadvantages in comparison to mesotypes and ectotypes that might inherently reduce their level of performance on indirect tests of aerobic capacity.

(2) It may be more practical to apply a two-group classification of body type when evaluating aerobic capacity with the use of the

indirect testing methods used in this study. This two-group classification system would include one group consisting of endotypes, and a second group consisting of a combination of ectotypes and mesotypes. Based on the results of this study, it appears that this would create two homogenous groups in terms of ability to perform on indirect tests of cardiovascular endurance.

(3) A similar study should be done with the addition of direct measurement of max VO_2, so that validity coefficients could be obtained for each indirect test in order to determine if there exists a single indirect testing method which produces the most accurate estimates of max VO_2 for each particular somatogroup.

(4) A study seems warranted for determining the variation in estimates of max VO_2 from indirect measures of aerobic capacity within each somatogroup. This might further help to determine and isolate the specific somatotypes that tend to enhance or deter performance on indirect tests of cardiovascular endurance.

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APPENDIX A

Informed Consent Form and P.E. - 100 Lifetime Fitness Course Contract

A-1

Informed Consent

I, Ben Leedle, am requesting your participation in a study designed to investigate the degree to which three basic fitness tests, used to assess aerobic capacity, are affected by individual differences in somatotype. The specific objective of this research is to determine if the predictive results of the bicycle ergometer test, endurance run, and step test, are sensitive to three general somatotypes.

As a subject in this study, you will be requested to participate in one of two groups. A somatotype will be determined for each subject in Group #1. A somatotype is a three-numeral rating, consisting of sequential numerals, always in the same order. Each numeral represents evaluation of one of the three primary components of physique which describe individual variation in body composition: endomorphy (fatness or relative leanness), mesomorphy (muscular development per unit of height), and ectomorphy (relative linearity). A somatotype rating is based on several simple body measurements including: height, weight, muscle girth, bone diameter, and skinfold measurements. This evaluation will require no physical exertion and will produce no physical discomfort to you as a participant. Subjects in Group #2 will be asked to participate in the exact same procedures as those requested of subjects in Group #1, and in addition will be asked to perform three basic fitness tests that measure aerobic capacity: bicycle ergometer test, endurance run, and step test. All three tests require physical work or exertion, and may produce temporary physical discomfort and possibly muscle soreness in the legs. These tests are standard methods for measurement in the field of physical fitness, are widely used, and are accepted as safe. These three tests of physical work have been carefully selected with concern to the risks presented to you as a participant. Close supervision, careful explanation, coaching and adherence to the safety measures built into each test, will make the chances of an emergency situation occurring very minimal.

This is not a training study. You will only be requested to participate in the testing procedures once. The sole purpose of your participation is to allow the primary investigator, Been Leedle, the opportunity to collect data on somatotype and aerobic capacity. Information from this research may prove that somatotype is an influencing factor on tests used to assess aerobic capacity in the general population. If so, physical educators and fitness specialists may be able to use somatotyping as a tool for selecting the most appropriate method for evaluating aerobic capacity.

Your permission to use the data collected is requested for use in conducting research for a thesis. All information will be kept confidential and results will be presented in a manner that will not allow a specific individual to be identified. A master list containing names matched with code numbers will be used and made accessible only to the primary investigator. If you have any further questions pertaining to this research study, please call Ben Leedle at 343-1200, ext. 354, or at home, 343-6506.

"I have read the above statement and have been fully advised of the procedures to be used in this project. I have been given sufficient opportunity to ask any questions I had concerning the procedures and possible risks involved. I understand the potential risks involved and I assume them voluntarily. I likewise understand that I can withdraw from the study at any time without being subjected to reproach."

P.E.-100 LIFETIME FITNESS
COURSE CONTRACT

A major objective of P.E.-100 Lifetime Fitness is to identify your individual strengths and weaknesses in the various aspects of health-related fitness. In order to determine this, you are required to attend one or more laboratory assessment sessions outside of regularly scheduled class time. The physical fitness evaluation will take place in the Human Performance Laboratory of the HPERA building. The health-related aspects of fitness that will be evaluated are: body composition, muscular strength, muscular endurance, flexibility and cardiovascular fitness.

For the 1985 Spring semester, all male students will be required to complete the following physical fitness assessments:

(1) Height
(2) Weight
(3) Anthropometric Somatotype (Body Composition)
(4) Grip Strength Test (Muscular Strength)
(5) Bench Press Test (Muscular Endurance)
(6) (a) Sit and Reach
    (b) Stick Raise (Flexibility)
    (c) Chin Raise
(7) (a) YMCA Bicycle Ergometer Test
    (b) Queens College Step Test (Cardiovascular Endurance)
    (c) 1.5-Mile Endurance Run

If there are individuals who cannot complete this physical fitness assessment for medical or other reasons, please contact Dr. McSwegin (phone number - 343-1200, ext. #354) to discuss alternative arrangements.

"I fully understand the requirements stated above and hereby agree to fulfill the obligations of this P.E.-100 Lifetime Fitness course contract."

______________________________ ____________________
(Name) (Date)

APPENDIX B

Heath-Carter Anthropometric Somatotype Rating Form, Procedures For Determining Anthropometric Measurements, Procedures for Calculating Somatotype Components From Raw Data, Table of the Cube Root of Weights, Somatochart Distribution of the Sample, and Regression Equations Used For Determining Somatotype Component Values

OCCUPATION .... ETHNIC GROUP .... DATE ....

PROJECT: .... MEASURED BY: ....

Skinfolds (mm):
Triceps =
Subcapular =
Supraliac =
TOTAL SKINFOLDS = ☐
Calf =

TOTAL SKINFOLDS (mm)

Upper Limit	10.9	14.9	18.9	22.9	26.9	31.2	35.8	40.7	46.2	52.2	58.7	65.7	73.2	81.2	89.7	98.9	108.9	119.7	131.2	143.7	157.2	171.9	187.9	204.0
Mid-point	9.0	13.0	17.0	21.0	25.0	29.0	33.5	38.0	43.5	49.0	55.5	62.0	69.5	77.0	85.5	94.0	104.0	114.0	125.5	137.0	150.5	164.0	180.0	196.0
Lower Limit	7.0	11.0	15.0	19.0	23.0	27.0	31.3	35.9	40.8	46.3	52.3	58.8	65.8	73.3	81.3	89.8	99.0	109.0	119.8	131.3	143.6	157.3	172.0	188.0
FIRST COMPONENT	½	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12

Height (in.) = ☐	55.0	56.5	58.0	59.5	61.0	62.5	64.0	65.5	67.0	68.5	70.0	71.5	73.0	74.5	76.0	77.5	79.0	80.5	82.0	83.5	85.0	86.5	88.0	89.5
Bone: Humerus (cm) = ☐	5.19	5.34	5.49	5.64	5.78	5.93	6.07	6.22	6.37	6.51	6.65	6.80	6.95	7.09	7.24	7.38	7.53	7.67	7.82	7.97	8.11	8.25	8.40	8.55
Femur = ☐	7.41	7.62	7.83	8.04	8.24	8.45	8.66	8.87	9.08	9.28	9.49	9.70	9.91	10.12	10.33	10.53	10.74	10.95	11.16	11.37	11.58	11.79	12.00	12.21
Muscle: Biceps (cm) - (triceps skinfold) = ☐	23.7	24.4	25.0	25.7	26.3	27.0	27.7	28.3	29.0	29.7	30.3	31.0	31.6	32.2	33.0	33.6	34.3	35.0	35.6	36.3	37.1	37.8	38.5	39.3
Calf - (calf skinfold) = ☐	27.7	28.5	29.3	30.1	30.8	31.6	32.4	33.2	33.9	34.7	35.5	36.3	37.1	37.8	38.6	39.4	40.2	41.0	41.8	42.6	43.4	44.2	45.0	45.8

SECOND COMPONENT ½ 1 1½ 2 2½ 3 3½ 4 4½ 5 5½ 6 6½ 7 7½ 8 8½ 9

Weight (lb.) =
Ht. / $\sqrt[3]{\text{Wt.}}$ = ☐

Upper limit	11.99	12.32	12.53	12.74	12.95	13.15	13.36	13.56	13.77	13.98	14.19	14.39	14.59	14.80	15.01	15.22	15.42	15.63
Mid-point	and	12.16	12.43	12.64	12.85	13.05	13.26	13.46	13.67	13.88	14.01	14.29	14.50	14.70	14.91	15.12	15.33	15.53
Lower limit	below	12.00	12.33	12.54	12.75	12.96	13.16	13.37	13.5[illegible]	13.78	13.99	14.20	14.40	14.60	14.81	15.02	15.23	15.43
THIRD COMPONENT	½	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9

	FIRST COMPONENT	SECOND COMPONENT	THIRD COMPONENT
Anthropometric Somatotype			
Anthropometric plus Photoscopic Somatotype			

BY: ....

RATER: ....

Calculation Of The First Component: Endomorphy

To calculate the endomorphy component, the triceps, subscapular, and suprailliac skinfold measurements were summed to obtain a total skinfold value (the calf skinfold measurement was used to aid in the determination of the second component, mesomorphy, but for ease and efficiency it was measured and recorded with the other skinfold measurements). Referring to the recording chart (Appendix B-1), the closest value in the TOTAL SKINFOLDS scale was circled. The component of endomorphy was then determined by circling the value in the row labeled, FIRST COMPONENT, which was directly under the column in which the total skinfold value was circled. All skinfold measurements were determined using a calibrated, Lange skinfold caliper.

Calculation Of The Second Component: Mesomorphy

Referring to the recording chart (Appendix B-1), the subject's height was marked in the row adjacent to the box used for recording the height measurement (the height row is to be considered a continuous scale). For each of the bone diameters and girth measurements, the value in each respective row, that is nearest to the value of the raw data that has been recorded, was circled. If the raw measurement value falls exactly between the midpoint of two values presented in the scale, the lower value was circled.

To determine the final rating for the second component, only the columns in which the values had been circled were dealt with (not the actual numerical values themselves). The column, or space between columns, that represents the average of the column deviations for the diameter and girths only (not including height), were figured. In order to do this, the following procedures were taken:

(1) The zero column was represented by the left-most column containing a circled figure.

(2) From the zero column, the number of columns (moving horizontally) that it takes to reach each of the other three circled values was summed.

(3) The total number of columns obtained was divided by four.

(4) The number obtained by division was used to locate a point (that will be marked by an asterisk), by counting the number of columns (which that number represents) to the right of the zero column. The point was marked at the exact point whether it be in the center of a column, or a fraction of the distance between columns.

(5) Still referring to the columns only, the number of columns representing the distance between the asterisk and the marked height was counted.

(6) From the number 4 in the row marked SECOND COMPONENT, the value obtained from step #5 above was used to move horizontally the specific number of columns it represents. If the asterisk was to the right of the height marker, the movement was that number of columns to the right of the number 4. If the asterisk is to the left of the height marker, the movement was that number of columns to the left of the number 4.

(7) The closest SECOND COMPONENT value, determined in step #6 above,

was circled. If the point is exactly mid-way between two rating points, the value closest to the number 4 on the scale was circled (this regression towards the number 4 in this case, was considered a conservative approach, but helped to control the production of invalid, extreme ratings).

To determine the third component of the anthropometric somatotype rating (ectomorphy), only one measurement, body weight, was necessary. Body weight was measured to the nearest 0.5 pounds on a calibrated, standard balance scale (Heath o meter by Continental Scale Corp.)

Calculation Of The Third Component: Ectomorphy

The closest value in the H.W.R. scale (located to the right of the H.W.R. box) was circled. The final rating was obtained by circling the THIRD COMPONENT value located below the column of the circled H.W.R. value.

To complete the somatotype rating form, the circled value for each of the three components was recorded in the row entitled Anthropometric Somatotype.

Heath-Carter Anthropometric Measuring Techniques

In order to remain consistent with the Heath-Carter anthropometric somatotype method (Carter, 1972), the following anthropometric measuring techniques were used:

(1) <u>Height</u>

- (a) Definition of Measurement: Erect body length from the soles of the subjects feet to the vertex.
- (b) Landmark: The vertex, which is defined as being the most superior part of the head when the head is held with the eyes fixed in the horizontal plane.
- (c) Posture: The subject stood erect with feet together and the heels, buttocks, upper back, and rear of the head against a wall.
- (d) Technique: The subject was instructed to take a deep breath as the measurement is made, thus allowing him to stretch to his full height (this was considered a maximal measuremen). The score was recorded to the nearest 1 millimeter, and then converted to inches.

(2) <u>Weight</u>

- (a) Technique: The subject stood in the center of the balance scale dressed in minimal clothing (shorts). The weight was recorded to the nearest 0.5 pounds, and converted to kilograms.

(3) <u>Skinfolds (subcutaneous fat)</u>

- (a) Definition of Measurement: The specific objective of the skinfold measurements is to measure the thickness of a complete double layer of skin and subcutaneous tissue (without including any muscle tissue in the process). The reading on the dial of the Lange caliper was taken after the full spring pressure of the instrument had been applied. Care was taken to ensure that sufficient time was allowed for the full pressure of the caliper to take effect, but was monitored so that the fat being measured was not over-compressed.

(b) Triceps

(1) Posture: The subject stood with his arms at his side, and the elbow extended, but relaxed. The muscle fibers were easily excluded by the subject performing elbow joint extension momentarily.

(2) Technique: The skinfold was raised with the thumb and the forefinger (of the left hand), over the triceps muscle on the back of the right arm, at the midpoint between the acromion process of the clavicle, and the elbow (thus the skinfold runs vertical).

(c) Subscapular

(1) Posture: The subject stood erect with arms at side, but remained relaxed.

(2) Technique: The skinfold was raised (in the same manner as above) over the inferior angle of the right scapula, with the skinfold running on a downward angel towards the rib cage.

(d) Suprailiac

(1) Posture: The subject stood in a normal position.

(2) Technique: The skinfold was raised as previously, approximately two inches above the right anterior superior iliac spline, in line with the medial axis of the body. The skinfold ran forward and slightly in a downward direction.

(e) Calf

(1) Posture: The subject sat in a chair with his foot on the floor.

(2) Technique: The skinfold was raised as previously, on the medial side of the right calf, slightly above the maximum girth, so that the skinfold ran vertically.

(4) Bone Diameters

(a) Definition of Measurement: Bi-epicondylar diameter of the distal extremity of the humerus (elbow) and femur (knee). The disc of the sliding claiper was applied against the epicondlyles so that it bisected the angle of the joint, and lay parallel to the plane of the limb. Measurements were taken on both limbs, applying firm pressure, and recording the largest of the two measurements taken, to the nearest 0.5 centimeters.

(b) Humerus

(1) Posture: The subject was seated, with the arm raised forward to approximately shoulder level. The forearm was flexed upward at an approximate right angle to the upper arm.

(2) Technique: Same as described in the definition of measurement.

(5) Muscle Girths

(a) Definition of Measurement: The maximum girth measurement of the muscle when the flexible tape is passed around the limb at right angles to the long axis of the muscle. Measurements were taken until the largest reading could be obtained. The tape only made light contact with the skin, and measurements were recorded to the nearest 0.1 centimeter. Measurements for the biceps and the calf were taken on both limbs, with the largest girth being recorded.

(b) Biceps

(1) Posture: The subject's arm was raised horizontally, with the forearm supinated, and the elbow fully flexed. The subject was then asked to clench his fist and contract his biceps as strongly as possible.

(2) Technique: Same as in the definition of measurements, and the tape was passed around the arm at the approximate midpoint between the acromion process and the elbow.

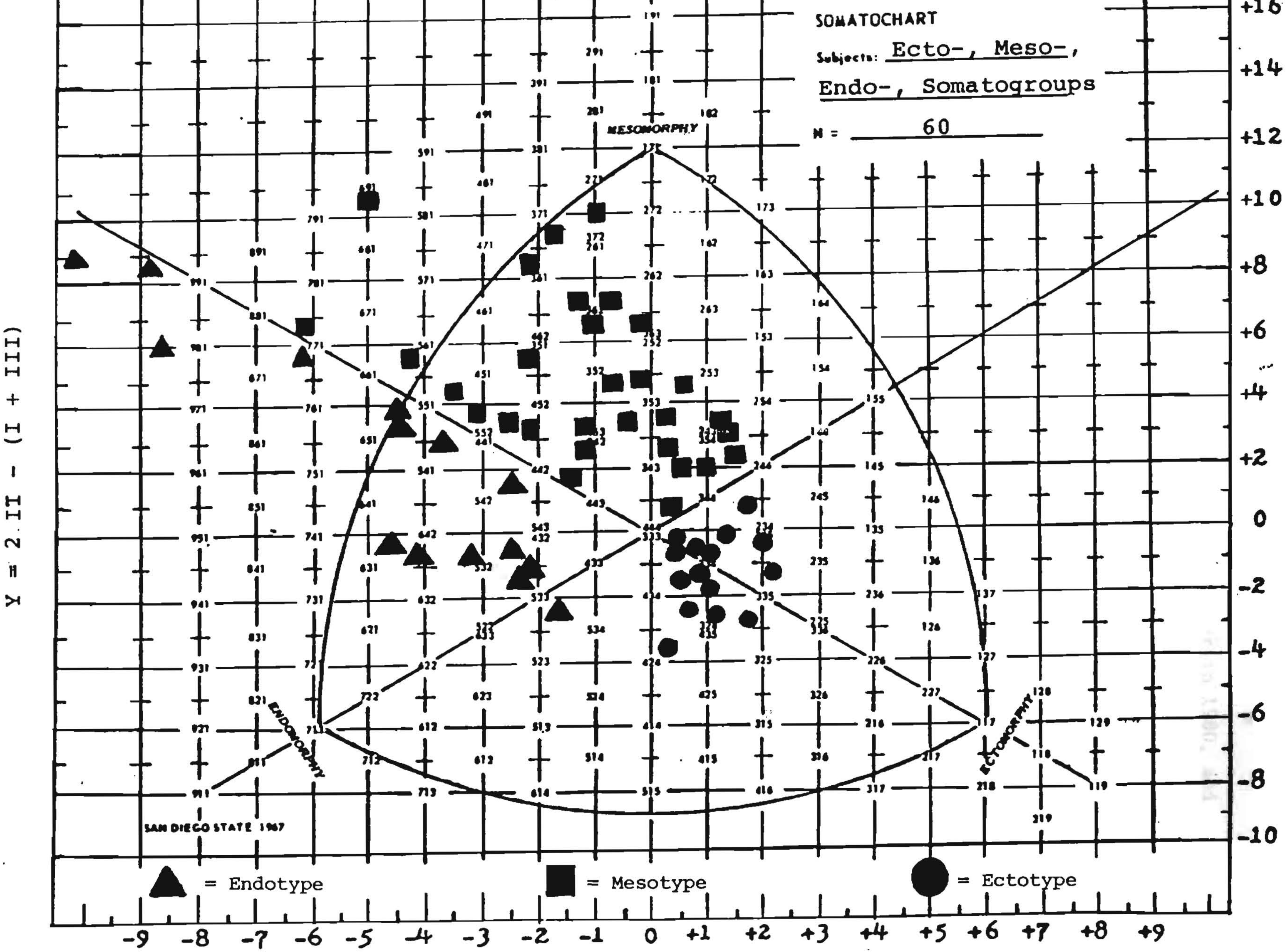
(c) Calf

(1) Posture: The subject stood on a table with his feet approximately six to nine inches apart, bearing his weight as equally as possible through both lower limbs.

(2) Technique: Same as in the definition of measurement above, and the flexible tape was passed around the upper calf muscle, and lowered until the largest girth was located.

TABLE OF THE CUBE ROOTS OF WEIGHT

Weight (lbs.)	$\sqrt[3]{Wt.}$	Weight (lbs.)	$\sqrt[3]{Wt.}$	Weight (lbs.)	$\sqrt[3]{Wt.}$	Weight (lbs.)	$\sqrt[3]{Wt.}$
40	3.42	94	4.55	148	5.29	202	5.87
41	3.45	95	4.56	149	5.30	203	5.88
42	3.48	96	4.58	150	5.31	204	5.89
43	3.51	97	4.59	151	5.32	205	5.90
44	3.53	98	4.61	152	5.34	206	5.92
45	3.56	99	4.63	153	5.35	207	5.92
46	3.58	100	4.64	154	5.36	208	5.92
47	3.61	101	4.66	155	5.37	209	5.93
48	3.64	102	4.67	156	5.38	210	5.94
49	3.66	103	4.69	157	5.39	211	5.95
50	3.68	104	4.71	158	5.41	212	5.95
51	3.71	105	4.72	159	5.42	213	5.97
52	3.73	106	4.73	160	5.43	214	5.98
53	3.76	107	4.75	161	5.44	215	5.99
54	3.78	108	4.76	162	5.45	216	6.00
55	3.80	109	4.78	163	5.46	217	6.01
56	3.83	110	4.79	164	5.47	218	6.02
57	3.85	111	4.81	165	5.48	219	6.03
58	3.87	112	4.82	166	5.50	220	6.04
59	3.90	113	4.83	167	5.51	221	6.04
60	3.92	114	4.85	168	5.52	222	6.06
61	3.94	115	4.86	169	5.53	223	6.07
62	3.96	116	4.87	170	5.54	224	6.07
63	3.98	117	4.89	171	5.55	225	6.08
64	4.00	118	4.91	172	5.56	226	6.09
65	4.02	119	4.92	173	5.57	227	6.10
66	4.04	120	4.93	174	5.58	228	6.11
67	4.06	121	4.95	175	5.59	229	6.12
68	4.08	122	4.96	176	5.60	230	6.13
69	4.10	123	4.97	177	5.62	231	6.14
70	4.12	124	4.98	178	5.63	232	6.14
71	4.14	125	5.00	179	5.64	233	6.15
72	4.16	126	5.01	180	5.65	234	6.16
73	4.18	127	5.03	181	5.66	235	6.17
74	4.20	128	5.04	182	5.67	236	6.18
75	4.22	129	5.05	183	5.68	237	6.19
76	4.24	130	5.07	184	5.69	238	6.20
77	4.25	131	5.08	185	5.70	239	6.20
78	4.27	132	5.09	186	5.71	240	6.22
79	4.29	133	5.10	187	5.72	241	6.22
80	4.31	134	5.12	188	5.73	242	6.23
81	4.33	135	5.13	189	5.74	243	6.24
82	4.35	136	5.14	190	5.75	244	6.25
83	4.36	137	5.15	191	5.76	245	6.26
84	4.38	138	5.16	192	5.77	246	6.26
85	4.40	139	5.18	193	5.78	247	6.27
86	4.41	140	5.19	194	5.79	248	6.28
87	4.43	141	5.20	195	5.80	249	6.29
88	4.45	142	5.22	196	5.81	250	6.30
89	4.46	143	5.23	197	5.82		
90	4.48	144	5.24	198	5.83		
91	4.50	145	5.25	199	5.84		
92	4.51	146	5.26	200	5.85		
93	4.53	147	5.28	201	5.86		



Somatochart Distribution of Proportional Sample

Somatotype Equations: Developed by Heath and Carter in 1980, and used to check estimated Heath-Carter somatotype values and to determine specific values for component ratings (M.H. Slaughter, personal communication, January 27, 1985).

First Component:

Endomorphy = -.7182 -.1451 (sum of triceps, subscapular and suprailiac skinfolds) + -.00068 (sum of triceps, subscapular and suprailiac skinfolds)^2 + .0000014 (sum of triceps, subcapular and sprailiac skinfolds)^3

Second Component:

Mesomorphy = .858 (humeral bone diameters) + .601 (femoral bone diameter) + .188 (corrected biceps girth) + .161 (corrected calf girth) - .131 (height-cm) + 4.5

Third Component:

Ectomorphy = .732 (H.W.R.-cm/cube root of weight - 28.58)

APPENDIX C

Equipment Used For Evaluation Methods

EQUIPMENT

Heath-Carter Anthropometric Somatotype Method

(1) one claibrated Lange skinfold caliper
(2) anthropometric sliding caliper
(3) flexible anthropometric measuring tape
(4) height scale
(5) Health o meter weight scale (Continental Scale Corp.)
(6) Anthropometric somatotype rating forms (total = 141)
(7) H.W.R. or cube root of weights table
(8) Anthropometric somatochart distribution form

McArdle Step Test

(1) 16¼" stepping bench
(2) Franz metronome (Lafayette Instrument Co., set at 96 bpm)
(3) stopwatch (single event timer)
(4) recording forms (60)
(5) conversion chart for determining VO_2 max
(6) Health o meter weight scale (Continental Scale Corp.)
(7) stethoscope

1.5 Mile Endurance Run

(1) ¼-mile track
(2) stopwatch (single event timer)
(3) recording forms (60)
(4) conversion chart for determining VO_2 max
(5) Health o meter weight scale (Continental Scale Corp.)

YMCA Bicycle Ergometer Test

(1) Monark Company Bicycle ergometer (constant torque) - must have a range of 0-2100 kg/m/min, with major graduation marks present every 300 kg/m/min., and minor graduation marks every 150 kg/m/min-calibrated to Monark Company specifications.
(2) stethoscope
(3) guideline chart for determining workloads for males and females for the YMCA bicycle test.
(4) heart rate conversion sheet
(5) Maximum physical working capacity/VO_2 max recording sheets (60)
(6) VO_2 max conversion sheet
(7) Health o meter weight scale (Continental Scale Corp.)

APPENDIX D

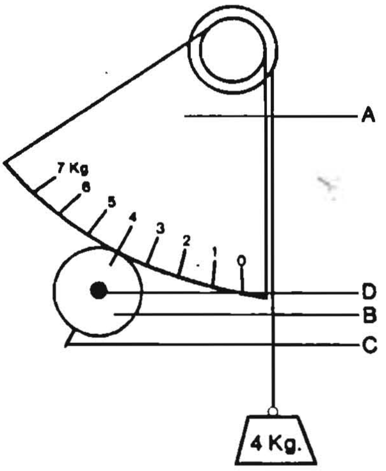
YMCA Bicycle Ergometer Test: Guidelines for Calibration of Bicycle Ergometer, Recording Form, Heart Rate Conversion Sheet, Guides to Setting Workloads, Maximum Capacity Graph, Conversion Sheet for Maximum Oxygen Uptake

D-1

BICYCLE ERGOMETER CALIBRATION

(Golding, Myers and Sinning, 1982, p. 92)

Workload Scale On Bicycle Ergometer And Calibration Procedures



2b. The calibration of the bike is done precisely at the factory and unless the adjusting screw (C) has been tampered with, seldom is there a need for recalibration. However, if you suspect incorrect calibration it can be checked as follows.

Set the mark on the pendulum weight (B) at "O". Attach a weight known to be very accurate as shown above. A 1 kg weight should correspond to a reading of 1 on the scale (A); a 2 kg weight should correspond to a reading of 2 on the scale A; and so on. The example above shown 4 kg corresponding to 4 on the scale.

If the numbers do not agree it can be corrected by changing the adjusting screw (C). This screw moves the center of gravity of the pendulum (this screw is locked with the screw D).

D-2

YMCA Bicycle Ergometer Test Recording Form:

Subject code ________ Date ______________________

Age __________

Weight ___________kg

Seat Height ________

Predicted Maximum Heart Rate (220 - age _______) ___________bpm

85% of Predicted Max Heart Rate ________bpm __________seconds for 30 beats

WORKLOADS	HEART RATE
1st Workload 150 kgm	__________ 2nd minute
	__________ 3rd minute
	__________ 4th minute (if needed)
2nd Workload ___ kgm	__________ 2nd minute
	__________ 3rd minute
	__________ 4th minute (if needed)
3rd Workload ___ kgm	__________ 2nd minute
	__________ 3rd minute
	__________ 4th minute (if needed)

Note: All above results were transferred to the PWC Graph

Y's Way to Physical Fitness

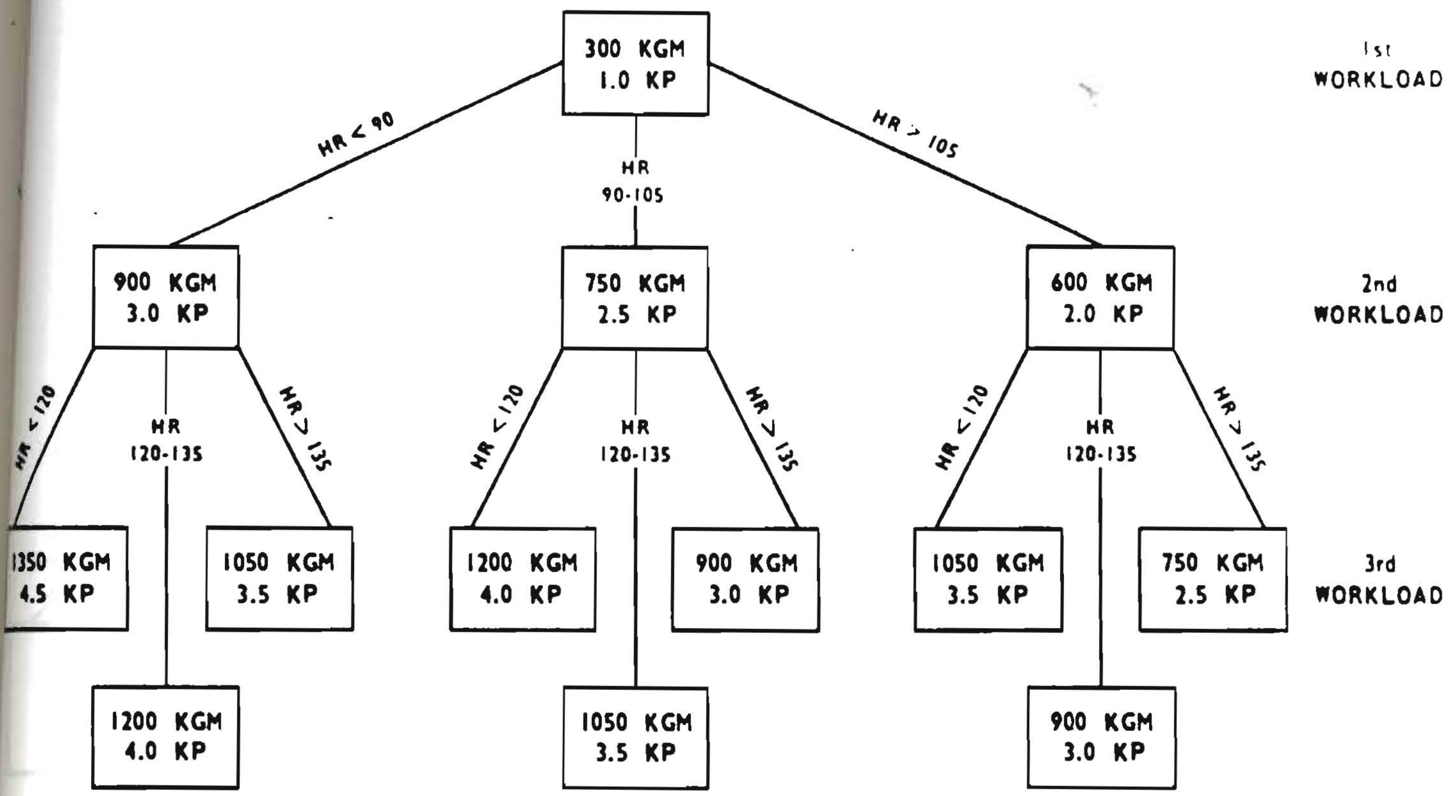
Table 4-9

Heart Rate Conversion Sheet (30 Beats to Rate/Min)

Sec.	/Min.	Sec.	/Min.	Sec.	/Min.
22.0	82	17.3	104	12.6	143
21.9	82	17.2	105	12.5	144
21.8	83	17.1	105	12.4	145
21.7	83	17.0	106	12.3	146
21.6	83	16.9	107	12.2	148
21.5	84	16.8	107	12.1	149
21.4	84	16.7	108	12.0	150
21.3	85	16.6	108	11.9	151
21.2	85	16.5	109	11.8	153
21.1	85	16.4	110	11.7	154
21.0	86	16.3	110	11.6	155
20.9	86	16.2	111	11.5	157
20.8	87	16.1	112	11.4	158
20.7	87	16.0	113	11.3	159
20.6	87	15.9	113	11.2	161
20.5	88	15.8	114	11.1	162
20.4	88	15.7	115	11.0	164
20.3	89	15.6	115	10.9	165
20.2	89	15.5	116	10.8	167
20.1	90	15.4	117	10.7	168
20.0	90	15.3	118	10.6	170
19.9	90	15.2	118	10.5	171
19.8	91	15.1	119	10.4	173
19.7	91	15.0	120	10.3	175
19.6	92	14.9	121	10.2	176
19.5	92	14.8	122	10.1	178
19.4	93	14.7	122	10.0	180
19.3	93	14.6	123	9.9	182
19.2	94	14.5	124	9.8	184
19.1	94	14.4	125	9.7	186
19.0	95	14.3	126	9.6	188
18.9	95	14.2	127	9.5	189
18.8	96	14.1	128	9.4	191
18.7	96	14.0	129	9.3	194
18.6	97	13.9	129	9.2	196
18.5	97	13.8	130	9.1	198
18.4	98	13.7	131	9.0	200
18.3	98	13.6	132	8.9	202
18.2	99	13.5	133	8.8	205
18.1	99	13.4	134	8.7	207
16.0	100	13.3	135	8.6	209
17.9	101	13.2	136	8.5	212
17.8	101	13.1	137	8.4	214
17.7	102	13.0	138	8.3	217
17.6	102	12.9	140	8.2	220
17.5	103	12.8	141	8.1	222
17.4	103	12.7	142	8.0	225

Y's Way to Physical Fitness

GUIDE TO SETTING WORKLOADS FOR MALES ON THE BICYCLE ERGOMETER

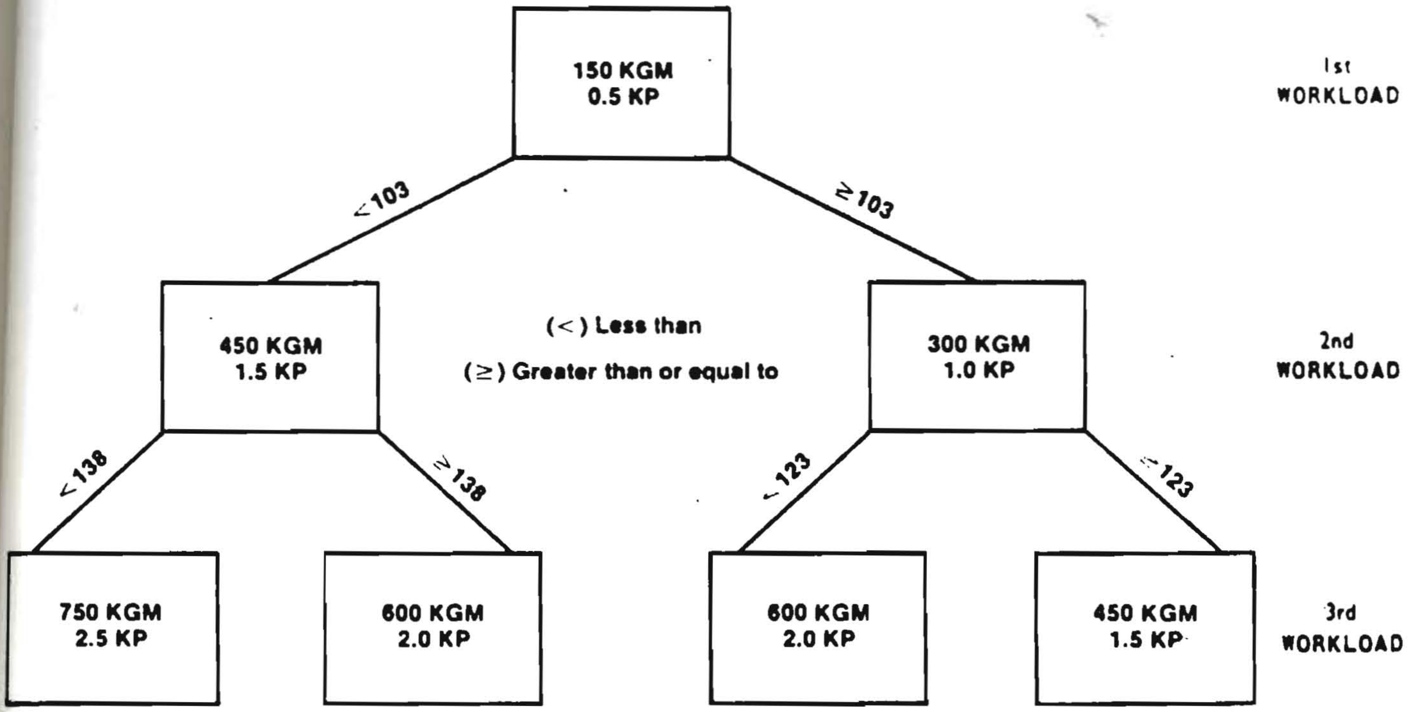


DIRECTIONS

1. **Set the 1st workload at 300 kgm/min (1.0 KP)**
2. **If HR in 3rd min is: Less than (<) 90, set 2nd load at 900 kgm (3 KP)**
   Between 90 and 105, set 2nd load at 750 kgm (2.5 KP)
   Greater than (>) 105, set 2nd load at 600 kgm (2.0 KP)
3. **Follow the same pattern for setting 3rd and final load.**

Y's Way to Physical Fitness

GUIDE TO SETTING WORKLOADS FOR FEMALES ON THE BICYCLE ERGOMETER



DIRECTIONS

1. Set the first workload to 150 kgm/min (.5 KP).
2. If steady-state heart rate is < 103, set 2nd load at 450 kgm/min (1.5 KP).
   If steady-state heart rate is ≥ 103, set 2nd load at 300 kgm/min (1.0 KP).
3. Follow this same pattern for setting the third and final load.
4. NOTE: If the 1st workload elicits a HR of 110 or more, it is used on the

Graph 4-6

Y's WAY TO PHYSICAL FITNESS — TEST BATTERY

MAXIMUM PHYSICAL WORKING CAPACITY PREDICTION

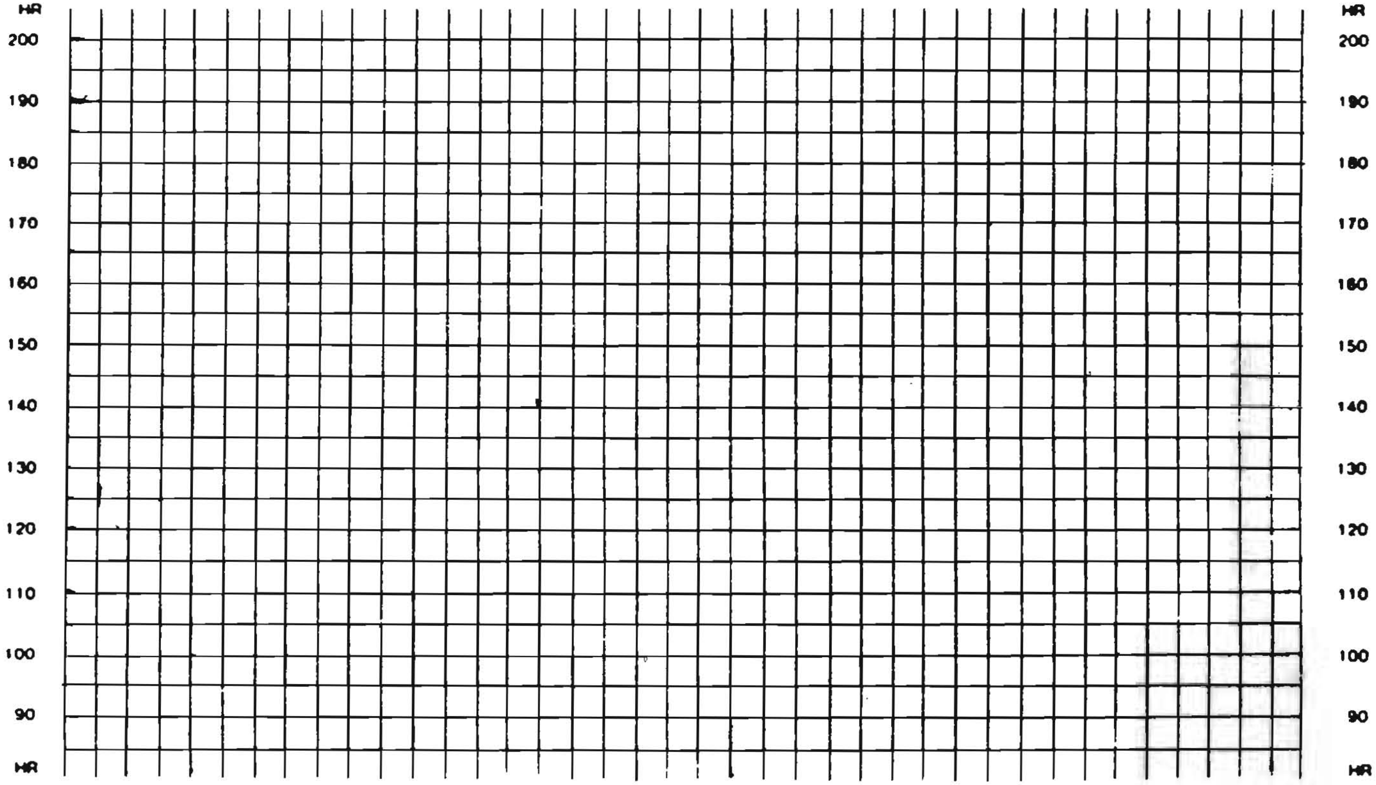
NAME ______________________ AGE ________ WEIGHT ________ LB. ________ KG SEAT HEIGHT ________

PREDICTED MAX. HR ________

	DATE	1st WORKLOAD HR USED	2nd WORKLOAD HR USED	MAX WORKLOAD	MAX O_2(L/min)	MAX O_2(ml/kg)
TEST 1						
TEST 2						
TEST 3						

DIRECTIONS

1. Plot the HR of the 2 workloads versus the work (kgm/min)
2. Determine the subject's max HR line by subtracting subject's age from 220 and draw a line across the graph at this value
3. Draw a line through both points and extend to the max HR line for age
4. Drop a line from this point to the baseline and read the predicted max workload and O_2 uptake



WORKLOAD (kgm/min)	150	300	450	600	750	900	1050	1200	1350	1500	1650	1800	1950	2100
MAX O_2 UPTAKE (L/m)	06	09	12	15	18	21	24	28	32	35	38	42	46	50
KCAL USED (Kcal/m)	30	45	60	75	90	105	120	140	160	175	190	210	230	250
APPROX MET LEVEL (for 132) lbs)	33	47	60	73	87	100	113	127	140	153	167	180	193	207
APPROX MET LEVEL (for 176 lbs)	30	40	50	60	70	80	90	100	110	120	130	140	150	160

EXPLANATION OF PLOTTING WORK LOADS

A straight line was drawn through the two points and extended to the subject's predicted maximum heart rate for his age group. From this point, a vertical line was dropped to the base line of the graph. The point where the two lines intersect represented the predicted maximum workload, and the predicted maximum oxygen uptake.

TABLE 4-10 CALCULATION OF MAXIMUM OXYGEN UPTAKE — ml/kg/min.

Body Weight		Maximum Oxygen Uptake — litres per minute																																											
pound	kg	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0
110	50	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120
112	51	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118
115	52	29	31	33	35	37	38	40	42	44	46	48	50	52	54	56	58	60	62	63	65	67	69	71	73	75	77	79	81	83	85	87	88	90	92	94	96	98	100	102	104	106	108	110	112	113	115
117	53	28	30	32	34	36	38	40	42	43	45	47	49	51	53	55	57	58	60	62	64	66	68	70	72	74	75	77	79	81	83	85	87	89	91	92	94	96	98	100	102	104	106	108	109	111	113
119	54	28	30	31	33	35	37	39	41	43	44	46	48	50	52	54	56	57	59	61	63	65	67	69	70	72	74	76	78	80	81	83	85	87	89	91	93	94	96	98	100	102	104	106	107	109	111
121	55	27	29	31	33	35	36	38	40	42	44	45	47	49	51	53	55	56	58	60	62	64	65	67	69	71	73	75	76	78	80	82	84	85	87	89	91	93	95	96	98	100	102	104	105	107	109
123	56	27	29	30	32	34	36	38	39	41	43	45	46	48	50	52	54	55	57	59	61	63	64	66	68	70	71	73	75	77	79	80	82	84	86	88	89	91	93	95	96	98	100	102	104	105	107
126	57	26	28	30	32	33	35	37	39	40	42	44	46	47	49	51	53	54	56	58	60	61	63	65	67	68	70	72	74	75	77	79	81	82	84	86	88	89	91	93	95	96	98	100	102	104	105
128	58	26	28	29	31	33	34	36	38	40	41	43	45	47	48	50	52	53	55	57	59	60	62	64	65	67	69	71	72	74	76	78	79	81	83	84	85	88	90	91	93	95	97	98	100	102	103
130	59	25	27	29	31	32	34	36	37	39	41	42	44	46	47	49	51	53	54	56	58	59	61	63	64	65	68	69	71	73	75	76	78	80	81	83	85	86	88	90	92	93	95	97	98	100	102
132	60	25	27	28	30	32	33	35	37	38	40	42	43	45	47	48	50	52	53	55	57	58	60	62	63	65	67	68	70	72	73	75	77	78	80	82	83	85	87	88	90	92	93	95	97	98	100
134	61	25	26	28	30	31	33	34	36	38	39	41	43	44	46	48	49	51	52	54	56	57	59	61	62	64	66	67	69	70	72	74	75	77	79	80	82	84	85	87	89	90	92	93	95	97	98
137	62	24	26	27	29	31	32	34	35	37	39	40	42	44	45	47	48	50	52	53	55	56	58	60	61	63	65	66	68	69	71	73	74	76	77	79	81	82	84	85	87	89	90	92	94	95	97
139	63	24	25	27	29	30	32	33	35	37	38	40	41	43	44	46	48	49	51	52	54	56	57	59	60	62	63	65	67	68	70	71	73	75	76	78	79	81	83	84	86	87	89	90	92	94	95
141	64	23	25	27	28	30	31	33	34	36	38	39	41	42	44	45	47	48	50	52	53	55	56	58	59	61	63	64	66	67	69	70	72	73	75	77	78	80	81	83	84	86	88	89	91	92	94
143	65	23	25	26	28	29	31	32	34	35	37	38	40	42	43	45	46	48	49	51	52	54	55	57	58	60	62	63	65	66	68	69	71	72	74	75	77	78	80	82	83	85	86	88	89	91	92
146	66	23	24	26	27	29	30	32	33	35	36	38	39	41	42	44	45	47	48	50	52	53	55	56	58	59	61	62	64	65	67	68	70	71	73	74	76	77	79	80	82	83	85	86	88	89	91
148	67	22	24	25	27	28	30	31	33	34	36	37	39	40	42	43	45	46	48	49	51	52	54	55	57	58	60	61	63	64	66	67	69	70	72	73	75	76	78	79	81	82	84	85	87	88	90
150	68	22	24	25	26	28	29	31	32	34	35	37	38	40	41	43	44	46	47	49	50	51	53	54	56	57	59	60	62	63	65	66	68	69	71	72	74	75	76	78	79	81	82	84	85	87	88
152	69	22	23	25	26	28	29	30	32	33	35	36	38	39	41	42	43	45	46	48	49	51	52	54	55	57	58	59	61	62	64	65	67	68	70	71	72	74	75	77	78	80	81	83	84	86	87
154	70	21	23	24	26	27	29	30	31	33	34	36	37	39	40	41	43	44	46	47	49	50	51	53	54	56	57	59	60	61	63	64	66	67	69	70	71	73	74	76	77	79	80	81	83	84	86
157	71	21	23	24	25	27	28	30	31	32	34	35	37	38	39	41	42	44	45	46	48	49	51	52	54	55	56	58	59	61	62	63	65	66	68	69	70	72	73	75	76	77	79	80	82	83	85
159	72	21	22	24	25	26	28	29	31	32	33	35	36	38	39	40	42	43	44	46	47	49	50	51	53	54	56	57	58	60	61	63	64	65	67	68	69	71	72	74	75	76	78	79	81	82	83
161	73	21	22	23	25	26	27	29	30	32	33	34	36	37	38	40	41	42	44	45	47	48	49	51	52	53	55	56	58	59	60	62	63	64	66	67	68	70	71	73	74	75	77	78	79	81	82
163	74	20	22	23	24	26	27	28	30	31	32	34	35	36	38	39	41	42	43	45	46	47	49	50	51	53	54	55	57	58	59	61	62	64	65	65	68	69	70	72	73	74	76	77	78	80	81
165	75	20	21	23	24	25	27	28	29	31	32	33	35	36	37	39	40	41	43	44	45	47	48	49	51	52	53	55	56	57	59	60	61	63	64	65	67	68	69	71	72	73	75	76	77	79	80
168	76	20	21	22	24	25	26	28	29	30	32	33	34	36	37	38	39	41	42	43	45	46	47	49	50	51	53	54	55	57	58	59	61	62	63	64	66	67	68	70	71	72	74	75	76	78	79
170	77	19	21	22	23	25	26	27	29	30	31	32	34	35	36	38	39	40	42	43	44	45	47	48	49	51	52	53	55	56	57	58	60	61	62	64	65	66	68	69	70	71	73	74	75	77	78
172	78	19	21	22	23	24	26	27	28	29	31	32	33	35	36	37	38	40	41	42	44	45	46	47	49	50	51	53	54	55	56	58	59	60	62	63	64	65	67	68	69	71	72	73	74	76	77
174	79	19	20	22	23	24	25	27	28	29	30	32	33	34	35	37	38	39	41	42	43	44	46	47	48	49	51	52	53	54	56	57	58	59	61	62	63	65	66	67	68	70	71	72	73	75	76
176	80	19	20	21	23	24	25	26	28	29	30	31	33	34	35	36	38	39	40	41	43	44	45	46	48	49	50	51	53	54	55	56	58	59	60	61	63	64	65	66	68	69	70	71	72	74	75
179	81	19	20	21	22	23	25	26	27	28	30	31	32	33	35	36	37	38	40	41	42	43	44	46	47	48	49	51	52	53	54	56	57	58	59	60	62	63	64	65	67	68	69	70	72	73	74
181	82	18	20	21	22	23	24	26	27	28	29	30	32	33	34	35	37	38	39	40	41	43	44	45	46	48	49	50	51	52	54	55	56	57	59	60	61	62	63	65	66	67	68	70	71	72	73
183	83	18	19	20	22	23	24	25	27	28	29	30	31	33	34	35	36	37	39	40	41	42	43	45	46	47	48	49	51	52	53	54	55	57	58	59	60	61	63	64	65	66	67	69	70	71	72
185	84	18	19	20	21	23	24	25	26	27	29	30	31	32	33	35	36	37	38	39	40	42	43	44	45	46	48	49	50	51	52	54	55	56	57	58	60	61	62	63	64	65	67	68	69	70	71
187	85	18	19	20	21	22	24	25	26	27	28	29	31	32	33	34	35	36	38	39	40	41	42	44	45	46	47	48	49	51	52	53	54	55	56	58	59	60	61	62	64	65	66	67	68	69	71
190	86	17	19	20	21	22	23	24	26	27	28	29	30	31	33	34	35	36	37	38	40	41	42	43	44	45	47	48	49	50	51	52	53	55	56	57	58	59	60	62	63	64	65	66	67	69	70
192	87	17	18	20	21	22	23	24	25	26	28	29	30	31	32	33	34	36	37	38	39	40	41	43	44	45	46	47	48	49	51	52	53	54	55	56	57	59	60	61	62	63	64	66	67	68	69
194	88	17	18	19	20	22	23	24	25	26	27	28	30	31	32	33	34	35	36	38	39	40	41	42	43	44	45	47	48	49	50	51	52	53	55	56	57	58	59	60	61	63	64	65	65	67	68
196	89	17	18	19	20	21	22	24	25	26	27	28	29	30	31	33	34	35	36	37	38	39	40	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	60	61	62	63	64	65	66	67
198	90	17	18	19	20	21	22	23	24	26	27	28	29	30	31	32	33	34	36	37	38	39	40	41	42	43	44	46	47	48	49	50	51	52	53	54	56	57	58	59	60	61	62	63	64	66	67
201	91	16	18	19	20	21	22	23	24	25	26	27	29	30	31	32	33	34	35	36	37	38	40	41	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	62	63	64	65	66
203	92	16	17	18	20	21	22	23	24	25	26	27	28	29	30	32	33	34	35	36	37	38	39	40	41	42	43	45	46	47	48	49	50	51	52	53	54	55	57	58	59	60	61	62	63	64	65
205	93	16	17	18	19	20	22	23	24	25	26	27	28	29	30	31	32	33	34	35	37	38	39	40	41	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	61	62	63	65
207	94	16	17	18	19	20	21	22	23	24	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	59	60	61	62	63	64
209	95	16	17	18	19	20	21	22	23	24	25	26	27	28	29	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	61	62	63
212	96	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	63
214	97	15	16	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	61	62
216	98	15	16	17	18	19	20	21	22	23	24	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
218	99	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	61
220	100	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60

APPENDIX E

Maximum Oxygen Uptake Conversion Chart For Recorded Times in the 1.5 Mile Endurance Run

E-1

1.5-Mile Recording Form:

Subject Code ____________

Date ____________

Time ____________

Age _______

Temperature _____ F

Weight ______kg

Wind ______ approximate mph

Track condition _________

Time____________ (to the nearest second)

Predicted Max VO_2 _____________ ml/kg/min

Maximum Oxygen Uptake Conversion Chart
For Recorded Times In The 1.5-Mile
Endurance Run

			TREADMILL PROTOCOLS						
NESS ICATION	**MAXIMUM O_2 UPTAKE** ml/kg·min^{-1}	**METs**	*Bruce*†	*Ellestad*†	*Balke*†,‡ *(3.3 mph)*	*Balke*†,§ *(3.0 mph)*	*Naughton*†,‖	*Åstrand* *(mph)*	**1.5-MILE RUN** (min:sec)
1	7	2	—	—	—	—	2:07	—	—
	10.5	3	—	—	1:00	3:00	4:17	—	—
	14	4	2:30	2:00	2:00	4:00	6:28	—	—
2	17.5	5	4:00	3:00	3:00	7:30	8:38	—	—
	21.0	6	6:00	4:45	6:00	10:30	10:49	—	—
	24.5	7	7:20	5:00	8:00	13:30	12:59	—	—
3	28.0	8	8:20	5:45	9:45	17:00	15:10	5.00	18:45
	31.5	9	9:15	6:40	12:00	19:30	17:20	5.25	16:30
	35.0	10	10:10	7:30	14:30	22:00	19:30	5.50	15:00
4	38.5	11	11:00	8:20	17:00	24:00	21:40	5.75	13:00
	42.0	12	12:00	9:10	19:00	27:00	23:51	6.25	12:00
5	45.5	13	12:45	10:15	21:30	30:00	26:01	6.50	11:00
	49.0	14	13:40	11:15	24:15	33:00	28:12	7.00	10:00
6	52.5	15	14:30	—	26:15	36:00	30:22	7.50	9:30
	56.0	16	15:15	—	27:45	—	32:33	8.00	9:00
7	59.5	17	16:10	—	29:00	—	—	8.50	8:15
	63.0	18	17:00	—	30:00	—	—	9.00	7:45
	66.5	19	18:00	—	31:15	—	—	9.25	7:15
8	70.0	20	19:20	—	32:00	—	—	9.75	6:52
	73.5	21	21:00	—	33:45	—	—	10.50	6:30
	77.0	22	22:30	—	35:45	—	—	11.00	6:10

Pollock, M.L., Wilmore, J.H. and Fox, S.M. (1984). Exercise in health and disease: Evaluation and prescription for prevention and rehabilitation. Philadelphia: W.B. Saunders Company.

APPENDIX F

Maximum Oxygen Uptake Conversion Chart And Prediction Equation for the Queens College Step Test

F-1

Maximum Oxygen Uptake Conversion Chart For The Queens College Step Test

PERCENTILE RANKING	RECOVERY HR, FEMALE	PREDICTED MAX $\dot{V}O_2$ $(ml \cdot kg^{-1} \cdot min^{-1})$	RECOVERY HR, MALE	PREDICTED MAX $\dot{V}O_2$ $(ml \cdot kg^{-1} \cdot min^{-1})$
100	128	42.2	120	60.9
95	140	40.0	124	59.3
90	148	38.5	128	57.6
85	152	37.7	136	54.2
80	156	37.0	140	52.5
75	158	36.6	144	50.9
70	160	36.3	148	49.2
65	162	35.9	149	48.8
60	163	35.7	152	47.5
55	164	35.5	154	46.7
50	166	35.1	156	45.8
45	168	34.8	160	44.1
40	170	34.4	162	43.3
35	171	34.2	164	42.5
30	172	34.0	166	41.6
25	176	33.3	168	40.8
20	180	32.6	172	39.1
15	182	32.2	176	37.4
10	184	31.8	178	36.6
5	196	29.6	184	34.1

McArdle, W.D., Katch, F.I. and Katch, V.L. (1981). Exercise physiology: Energy, nutrition and human performance. Philadelphia: Lea & Febiger.

Prediction equation for determining maximum oxygen uptake (ml/kg/min) from raw data obtained from the Queens College Step Test.

Men: max $Vo_2 = 111.33 - (0.42 \cdot X)$

where:

X = step test pulse rate in beats per minute

McArdle, W.D., Katch, F.I., Pechar, G.S., Jacobson, L. and Ruck, S. (1972). Reliability and interrelationships between maximal oxygen intake, physical work capacity and step-test scores in college women. Medicine and Science in Sports, 4 (4), 182-186.

Queens College Step Test Recording Form

Subject code ________ Date ____________________

Age ________

Weight _______kg

Recovery Heart Rates

A) Step test pulse rate ________# beats · 15 $\sec^{-1}$

B) Step test pulse rate ________# beats · $\min^{-1}$

Equation:

max VO_2 = 111.33 - (0.42X)

Where X = value in B above

= 111.33 - (0.42 · ________)

= 111.33 - __________

= __________________ ml/kg/min