THE O-SCALE SYSTEM FOR HUMAN PHYSIQUE ASSESSMENT

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ABSTRACT

In recent years, the assessment of individual physique status and in monitoring the change with growth, exercise and nutrition has become a focus for scientific and professional concern on a national scale. Contemporary methods based on group characteristics and assumptions of biological constancy of tissue densities and proportions have questionable validity for individual application. The purpose of this thesis was to construct, justify and evaluate the performance of a new system for the assessment of individual physique status. The new system, termed the O-SCALE system, provided microcomputer generated adiposity and proportional weight stanine ratings and 26 individual item profiles related to 24 size-adjusted norms for males and females aged 16 to 70 years old. The norms were generated from a data base of measurements on 19,647 Canadians from various comprehensive cross-sectional samples at Simon Fraser University and the large Y.M.C.A. Lifestyle Inventory and Fitness Evaluation Project developed at the University of Saskatchewan. The thesis contained descriptions of the construction of the system, the design and testing of new methods of estimation of normative distributions projected from instigator samples, comparison with a national sample and illustrations of the applicability of the system in assessing and monitoring physique in individuals with balanced, weight and adiposity dominant physiques. In addition, sport specificity was appraised in Olympic Rowers, Cyclists and Weightlifters. The applicability of the O-SCALE system in serial measurements was tested by assessment of individuals measured before and after a change in body weight. On the basis of the following criteria - efficiency in data resolution, reliability of measurement, ease of interpretation, ability to rationalise discrepant results among other assessment systems, and ability to explain changes in body composition associated with changes in body weight - it was concluded that the system was an effective method for the assessment of individual physique status.

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PART A

INTRODUCTION

CHAPTER I

INTRODUCTION

The methodology for the description of human form and body composition is concerned with either the assessment of physique status or the prediction of fractional masses. Both approaches may be used to quantify individual and group differences with respect to growth and aging, health and well-being, exercise and nutrition.

The approaches are not mutually exclusive. In his book "On Understanding Science", James B. Conant (1947), referred to ... "the Principle that a conceptual scheme is never abandoned by a few stubborn facts with which it cannot be reconciled: a concept is either modified or replaced by a better concept, never abandoned with nothing better to take its place". When there are many prevalent methods, it is obvious that no single one is best for all situations.

During World War II, the fallibility of the weight for height tables in assessment of physique status and the ascription of adipose tissue mass was noted in the practical problem of appraising susceptability to nitrogen narcosis in diving operations and in classification of obesity in rejection of military draftees (Behnke, 1942). In the wake of his critiques and propositions, a two compartment densitometric model based on underwater weighing became the dominant method. As Archimedes had demonstrated over 2,000 years ago, when one knows the mass and density of an object and the densities of its consituent parts are known, it is possible to ascribe the mass of each. (Dijksterhuis, 1938, 1987). The principle has been applied to estimate relative "fatness" in individuals often without tredpidation of the "stubborn facts" that the "non-fat" compartment consists of different tissues and these have varying densities.

Roche (1987) is explicit about the use of densitometry:

> "...although the two-compartment equations to estimate body composition variables from body density are probably adequate for young white men, different equations are needed for females, for other ethnic groups, for different age groups and for those who are active physically, because the groups differ in density of fat-free mass.

The use of skinfold calipers to predict density and then infer "percent fat" is doubly indirect, calling for additional assumptions to make the transformation from linear distances between pressure plates of a double layer of skin and entrapped adipose tissue to predict "percent fat".

Nevertheless, the advantages of quantification by densitometry and the formulae based on this criterion method often justify them for a variety of scientific and professional purposes summarized as follows, being adapted from that of Martin (1984).

Applications of Physique Assessment and Body Composition

Basic Science
- *Study of human variability
- *Study of human adaptability
- *Structural concomitants of metabolic events
- *Biomechanical correlates of movement
- *Food and nutrition effects on growth and aging

Medicine
- *Dietary, surgical and pharmacological intervention in obsity
- *Assessment and treatment of malnutrition and wasting disease
- *Longitudinal effects of nutritional and dietary intervention plans
- *Assessment and treatment of anorexia nervosa and bulimia
- *Prescription of drug dosage and anasthesis
- *Assessing fluid balance
- *Assessing composition and therapies for orthopedically disabled
- *Monitoring recovery and physical rehabilitation regimens

Public Health
- *Public awareness and information
- *Epidemiology
- *Prevention of obesity as cardioovascular and other disease risk factors
- *Early recognition and prevention of eating disorders
- *Assessment of "feeding" programs for indigent and third world peoples
- *New concepts of individually appropriate "ideal" physiques

Child Health
- *Normative data and morphometric atlases
- *Growth standards for normal and genetically aberrant children
- *Identification of atypical children
- *Assessment of physical activity

Sports Programs
- *Indentification of salient aspects in physique of elite performers
- *Monitoring growth and training
- *Optimization of body composition in weight restricted sports
- *Nutritional guidance and counselling

Occupational Health and Safety
- *Role of physique in hypo- and hyperthermia
- *Diving safety
- *Tissue specific posioning
- *Assessing energy costs

Fitness and Employee Wellness Programs
- *Recruitment of clients and particpants
- *Planning individual and group exercise and nutritional programmes
- *Promotion of active health and positive self image

This list of categories and specific applications is not exhaustive, nor does it imply that that the methods used are adequate, for the purposes intended.

Statement of Purpose

The purpose of this thesis was to design an anthropometric system for the assessment of human physique where a detailed indication of individual status was required. The proposed system was not intended to predict "fat" or other tissue masses, rather, it's purpose was to describe individual differences and explain conflicting results among methods which purport to do so.

The proposed system was predicated on the assumption that humans are sui generis. That is, no two human physiques are indentical in all aspects. This is consistent with the concepts of Alphonse Bertillion who devised a workable anthropometric system for the identification of criminals to replace the photographic and narrative methods used by the French Surete. As discussed by Ross et al. (1983), Bertillionage, as the system was called, was based on Quetelet's views on the uniqueness of the individual's physique in that the odds of having seven or more identical measures for any given individual were practically infinitesimal. Indeed, had it not been for the "ineradicable mark" of finger printing, anthropometry rather than dermatoglyphics may well have served as the universal identity system.

Assumptions

It was assumed that height, weight, eight skinfolds and ten girths would reflect individual physique characteristics. It was further assumed that ratings of adiposity and ponderosity would provide a general reference for the display of individually height scaled items which precisely defined physique status in relation to a size adjusted age and sex specific norm.

Limitations

The O-SCALE system as presented in this thesis has inherent limitations with regard to:

1) Age, 2) Reference Norms , 3) Scaling , 4) Technique and 5) Interpretation. 1) Age: While a primordial version of the system by Ross and Ward (1984) provided norms for children and youth, the present system was limited to age range 16-70 years. It was recognised that chronological age is only a general reference for developmental status, and not adequate for children and youths. This problem is outside of the scope of the present study.
2) Reference Norms: The ratings and profiles for the O-SCALE system in this thesis were largely based on data assembled in Y.M.C.A. operation Lifestyle in 50 Canadian cities. Presumably, this sampling frame would provide a bias in favour of an active lifestyle or "reasonably well-off" subjects as suggested by Tanner (1976) to be the most appropriate for health assessment.
3) Scaling: Apart from geometrical scaling of items to a standard stature, no other assumptions were made with respect to combinations of variables or ascription of biological

constants.

4) Technique: It was recognised that any system capable of assessing minute individual differences, would be susceptible to error of measurement. A basic limitation of the O-SCALE system is it's reliance on precision and accuracy of measurement. Consequently, it is a professional system requiring technical competence in anthropometry.

5) Interpretation: While the O-SCALE system describes physique status with respect to a group it does not presuppose to make value judgements about appropriateness for appearance or health risk. The system does not ascribe an ideal weight, it provides only quantitative description of physique. Decisions for counsel and guidance of the individual are complex professional decisions and should be made by users of the system in conjunction with other appraisals and particularly their own expertise. Although use of the system has been extensive even generalized interpretions about health risk of specific ratings would be premature and innappropriate at this time.

Designed primarily as a method for individual assessment, the O-SCALE system was compatible with the Heath-Carter Somatotype method (Carter, 1972) the Phantom stratagem for proportional growth assessment (Ross and Wilson 1974; revised by Ross and Ward 1981) and the standard measurement proforma used in the Montreal Olympic Games Anthropological Project (Carter, 1982) and a series of studies relating anthropometry to anatomical evidence in 34 human cadaver dissections (Martin, 1984; Drinkwater, 1984; and Marfell-Jones 1984), and in the recommended protocol for elite athletes (Ross and Marfell-Jones 1982).

Thesis Design

The thesis was divided into two parts, the first being devoted to the development of the system along with justification of all component parts, and the second being devoted to the testing of the system by application in individual assessments. Each part was organised into a format of introduction, methods and discussion, with a concluding discussion and a summary at the end of the thesis.

The Development of the O-SCALE System

The O-SCALE system was designed as an anthropometric normative based method for the individual assessment of human physique. Based on data assembled on 19,647 Canadians, it provided ratings for a geometrically stature adjusted sum of six skinfolds (**A-rating** - Adiposity) and a similarly scaled weight rating (**W-rating** - Proportional Weight). The ratings were based on percentile transformed standard nine (STANINE) scores for males and females, grouped by ages 16 and 17, 18 and 19, and in five year increments thereafter until age 70. Using microcomputer analysis raw score summaries of 22 directly measured items (stature, weight, eight skinfolds, ten girths and two bone widths) and 4 derived items (skinfold-corrected arm, chest, thigh and calf girths) were provided along with a proportionality profile. The profile consisted of stature adjusted values for the 25 anthropometric items plotted relative to similarly scaled norms for the same age and sex group. This analysis allowed for the description of the unique characteristics of the subjects physique.

Prior to the calculation of percentile values for all items it was necessary to compile a normative data base. This was hampered by missing values for many of the items in each of the three data bases used to compile the norms. It was therefore initially necessary to develop a procedure for the estimation of missing data based on relationships determined in smaller independent samples. This therefore comprised the first experimental endeavour in the development of the O-SCALE system. Having achieved this it was then possible to move on and derive the required percentiles for variabies included as part of the system. An IBM compatible GWBASIC microcomputer programme was written to provide on-line resolution of data into a four page printed report.

Application of the O-SCALE System

The basic premise of this thesis was that:

A comprehensive anthropometric battery and geometrically scaled ratings and items in comparison to appropriate age and sex norms could be used as an *effective* method for individual physique assessment.

Apart from extensive field testing and testimonial evidence of hundreds of analyses being carried out successfully by many practitioners, with no complaints of the O-SCALE system ever giving misleading information, the case for affirmation of the hypothesis was based on whether the system fulfilled five basic criteria of *effectiveness*:

1) **Efficiency of data resolution.**

2) **Reliability of techniques.**

3) **Ease of interpretation.**

4) **Rationalize discrepant results.**

5) **Explain changes in body composition**

Individual case studies were randomly and selectively sampled for demonstrtating effectiveness. As shown in Chapter BI, these cases were organised under three categories: 1) Subjects with balanced ratings of adiposity and ponderosity, 2) subjects where adiposity ratings were higher than ponderosity ratings and 3) Subjects where adiposity ratings were lower than ponderosity ratings.

In addition to the assessment of individual physique, comparative data with other methods was presented to demonstrate the ability of the O-SCALE system to rationalise discrepant results.

Definition of Terms

For the purpose of this thesis the technical terms were defined as follows:

Accuracy -- agreement between an obtained and true value, in anthropometry, this is usually assessed by comparison of obtained measures with those of a criterion anthropometrist, that is an experienced measurer who has demonstrable precision and presumedly does not to make systematic error from a prescribed technique.

Adipose Tissue -- the total amount of adipose tissue present in the body, that is. the subcutaneous adipose tissue, the internal adipose tissue surrounding the organs, visceral and skeletal muscle.

Adiposity -- the amount of adipose tissue present in a given individual relative to his or her own age and stature.

Adiposity Dominant Physique -- (A > W): a physique where O-SCALE Adiposity (A) rating is greater than the proportional weight (W) rating.

Adipose Tissue Free Mass -- the mass remaining after the removal of the dissectible adipose tissue. This includes the lipids of the non-dissectible adipose tissue, structural lipids, lipids of the nervous system, and bone lipids. his term is not equivalent to the "lipid free body mass" or "lean body mass" (Martin, 1984).

Adiposity Rating -- a stanine rating of the sum of six skinfolds at triceps, subscapular, suprailiac, abdominal, front thigh and medial calf sites adjusted geometrically to a standard stature and related to appropriate age and sex norms.

Anthropometry -- a system of human measurement used to assess gross structure.

A rating -- an O-Scale adiposity stanine rating from 1 to 9 with respect to stature adjusted norms for an individual's age and sex.

Balanced Physique -- (A = W): a physique where O-SCALE Adiposity (A) equals the proportional weight (W) rating.

Body Mass -- the mass of the body, a force with the acceleration of gravity, inferred from a weighing machine calibrated in mass units or kilograms, commonly termed "body weight".

Body Mass Index (BMI) or ratio of body mass (kg) and the square of the stature (m).

CANAD -- An expanded data set from that used as university male and female control groups for the Montreal Olympic Games Anthropological Project.

COGRO -- Coquitlam Growth Study, cross-sectional data on children and youth age 6 to 18 years (Ross, et al. 1980)

Contingency Coefficient -- mean square contingency, a coefficient of association based on the comparison of the number cases actually occurring in a given cell or box and the number which would occur according to an expected frequency.

Density -- the mass of a substance per unit volume, e.g. although subject to individual variation, typical value in gm ml-1 are as follows: lipid 0.90, adipose tissue 0.94, muscle 1.05, lean body mass 1.10, bone 1.23.

Densitometry -- a method of determining the density of an object, or human, most commonly by underwater weighing.

Essential lipid -- is distinguished from more metabolically active "depot" lipids such as the triglycerides and free fatty acids of the adipose tissue and muscles. The essential lipids are estimated to be between 3 and 7% of the body weight (Behnke and Wilmore, 1974).

Fat -- is defined biochemically as ether extractable lipid from the subcutaneous and omental adipose tissue, the structural phospholipids of the the cell membrane and nervous tissue, lipids of the bone marrow, and small amounts of other lipid based compounds. The term "fat" will not be used in this thesis except in discussion of the literature where authors have used terms such as "fatness" or "percent fat", or, it is used in a colloquial sense and is delineated by quotation marks.

Fat Free Body Mass -- the residual body mass when all the ether extractable lipid of the body has been removed. The contention that the density of this fraction is relatively constant at 1.10 gm/ml has been challenged (Martin et al. 1986).

Fractional Mass -- used as a descriptive term referring to a predicted amount of tissue from a fractionation method of body composition, e.g. skin, adipose, muscle, bone, and residual fractional masses.

Geometrical Scaling -- the use of geometrical similarity theory to ascribe dimensional exponents to scale all lengths, breadths, girths and skinfold thickness (L) to surface and cross sectional areas (L2) and masses and volumes (L3).

Girth -- the perimeter distance horizontal to the long axis of a bone or body part at designated or maximal levels obtained without distorting the outer conformation of the encompassed skin surface.

Height -- General term for stature.

Iconometrographics -- a method of displaying structural data as perceived departures from a model or "icon" (Boyd, 1980)

Ideal Body Weight -- A recommended body weight for optimal health which is often misleading even when adjusted for stature and frame size. While there may be individually appropriate body weight there is no single ideal for all people and all health risks.

IWGK -- International Working Group on Kinanthropometry, commissioned by the International Council for Sport Sciences and Physical Education, NGO, A-Level Committee of U.N.E.S.C.O. This working group was operative 1978 to 1986 sponsored certification programs for standardization of anthropometric technique. The function is currently handled by a Working Group on Techniques and Standards of the successor International Society for the Advancement of Kinanthropometry (ISAK).

Kinanthropometry -- an emerging scientific specialization concerned with the assessment of size, shape, proportion, composition, maturation and gross function related to concerns for normal and atypical growth and aging, exercise effects and the lack thereof, performance of *all kinds, and effects of various conditions of adequacy of nutrition.*

Lean body mass -- the remaining mass of the tissue of the body after removal of all lipid except the essential lipids of the bone marrow and small amounts of other lipid based compounds of the body.

LIFESTYLE -- YMCA LIFE, Young Men's Christian Association Lifestyle Inventory and Fitness Evaluation Project, a national project conducted in 50 Canadian cities in a program for health and fitness appraisal and guidance based on computer data assembly, resolution and report procedures by Drs. D.A. Bailey and R.L. Mirwald, University of Saskatchewan. This provided a large data base in excess of 20,000 Canadian adults with a presumed slightly better than average disposition to active health.

O-Scale System -- an age and sex normative scaling method for assessing physique status in terms of stature adjusted adiposity and proportional weight ratings and proportionality profiles for body weight, eight skinfolds, ten girths, two bone breadths and four skinfold corrected girths.

Phantom -- a unisex reference human based on an arbitrary human population used iconometrographically to compare size adjusted z-values.

Ponderal Index -- The ratio of weight and $height^3$.

Precision -- reliability or replicative measurements expressed in absolute terms as the technical error of measurement.

Predictor Sample -- a sample used to determine relationships for prediction of distributions in another sample where there are common regression items.

Reciprocal of Ponderal Index -- Stature divided by the cube root of weight, the height weight ratio commonly used in somatotyping.

Resolution -- reduction of data to meaningful terms, in graphic displays, the resolution is expressed in terms of the size of spatial scale increments relative to the technical error of measurement.

SPSSX -- a comprehensive computer program for statistics in psychology and the social sciences designed for mainframe and microcomputer operations.

Stature -- a measurement using specified techniques to obtain the vertical distance from the vertex to the floor when a subject is in a defined position with the head oriented in the Frankfort plane.

Skinfold -- a double thickness of skin and entrapped adipose tissue of a fold raised and encompassed with full tension on the pressure plates on a skinfold caliper applied to a specified site on the body.

Stanine -- a standard score scale providing nine categories. In normally distributed data the category divisions are set at the mean plus and minus 0.25 standard deviation distances for a central 20% encompassment and 5 rating, with four other rating categories set above and four below the 5 category at 0.5 standard deviation distance increments. In the O-Scale system, the stanine scale is determined by percentile transformation at P 4, 11, 23, 40, 60, 77, 89, and 96 providing theoretical percent expectancies of 4, 7, 12, 17, 20, 17. 12, 7, and 4.

Technical Error of Measurement -- *the square root of the quotient of the sum of the square of the differences of replicated measures and twice the number. This may be also expressed as a coefficient of variation, i.e. as 100(TEM/ mean of the first series).*

Weight -- *the force due to gravity exerted on a mass. If the variability due to gravity is neglected as conventionally done, weight can be expressed in the same units as mass, i.e. kilograms.*

Weight Dominant Physique -- *(A < W): a physique where O-SCALE Adiposity (A) rating is less than the proportional weight (W) rating.*

W-Rating -- *proportional body weight. In the O-Scale System, this is a geometrical adjustment of body weight for stature or height, i.e.* $W_p = w\ (170.18/h)^3$. *Mathematically this has the same dimensional relationship of stature and body mass as the ponderal index. The reciprocal of the ponderal index is used to obtain the somatotype ectomorphic component.*

Z-value -- *standard deviation distance from size-adjusted items compared to a unisex reference human or Phantom using given constants and defined dimensional relationships.*

The balance of the introductory section is devoted to an overview physique and body composition assessment techniques. This is followed by three parts, development of the system, application of the system and the conclusions and summary and four appendices for algorithms and data summaries.

CHAPTER II

THE ASSESSMENT OF HUMAN PHYSIQUE AND BODY COMPOSITION

HISTORICAL PERSPECTIVE

Comprehensive reviews of body composition assessment techniques have been made by Keys and Brozek (1953), Malina (1969), Lukaski (1987) and most recently by Brodie (1988a, 1988b). None of these, however, were written in historical perspective. For the purposes of this thesis the history of body composition and physique assessment can be regarded as being built around three major impulses. These might be labelled normative scaling, densitometric extrapolation and physical fractionation of body mass. The three major impulses used in the organization of this chapter are personified by three prime movers: Quetelet, Spivak and Matiegka. Latter day scientists such as Sheldon, Behnke and Brozek defy such categorizations, however, for organisational convenience they have been identified with one or more of the impulses.

NORMATIVE SCALING: THE QUETELET IMPULSE

Adolphe Quetelet (1796–1874), the Belgian astronomer, mathematician was the progenitor of modern physical anthropology. Quetelet discovered that the error distribution that worked so well in describing astronomical measures was also a reasonably good model for empirical distributions of anthropometric and other measures on humans.

By 1835 he had recorded chest girths of scottish soldiers, stature of french army draftees, and other measures, and found that they distributed themselves around the "average" in a random fashion. Later, he used the 1846 Belgian census for statistical analyses and showed the frequency of measures approximated the Gaussian or bell-shaped normal probability curve. His studies helped shape modern views on randomness and gave rise to the concept of the "average man" and "vital statistics".

Quetelet is still part of contemporary scientific discourse. Hogben (1957) decries what he identified as the "Normal Mystique" or the influence whereby investigators tend to regard the normal probability curve as the population archetype. The view that skewness is a simple by-product of sampling and could be made to disappear if a sufficiently large number of observations were made, has been replaced by the acceptance that some distributions are inherently not normal and may require transformations or the use of distribution free techniques in statistical analyses.

In 1833 Quetelet, highly influenced by the classical art and sculpture of the renaissance, also observed that the human architecture was not geometrical. That is, that body mass was not proportional to the stature raised to the third power. He demonstrated empirically an application of Galileo's cubed-square law. Tall individuals are not proportionally weaker than short individuals for their body mass since the human architecture for increased size is to become proportionally less ponderous. Thus, taller individuals are less ponderous or as a corollary mass is related to stature by some other dimensional exponent less than 3. As reported by Boyd (1980,p327) Quetelet stated:

> "In general, we do not err much when we assume that, during development the squares of the weight at different ages are as the fifth powers of the height; which naturally leads to this conclusion, in supposing the specific gravity constant, that the transverse growth of man is less than the vertical. However if we compare two individuals who are fully developed and well-formed with each other, to ascertain the relations existing between the weight and stature, we shall find that the weight of developed persons at different heights is nearly as the square of the stature. Whence it naturally follows, that a transverse section, giving both the breadth and thickness, is just proportional to the height of the individual. We furthermore conclude that proportion still being attended to width predominates in individuals of small stature."

Thus, tallness is associated with linearity whereas shortness is accompanied by squatness.

In Canada, a recent national campaign for a "Healthy Weight in 88" based on the Body Mass Index (Weight/Height^2) sponsored by the National Department of Health and

Welfare has made the use of the ratio the centre of controversy. The rational for it's use is that stature is minimally correlated with the Body Mass Index (BMI) and the variance of this ratio reflects the adiposity differences and therefore it is appropriate as an obesity index. Previous studies by Ross et al. (1987) have shown the Quetelet generalisation of body mass to stature to the power two was a gross generalisation and not supported by data on a large sample of Canadians aged 20 to 70 years. The actual exponents found in each age and sex group were less than 2. They also showed in the same paper that short men and women differed from their tall peers in being proportionally larger in transverse breadths and girths exactly as observed by Quetelet.

Although the BMI may have some use in epidemiological studies, Durnin et al. (1985) showed indicting evidence of its use in assessing individual obesity status, by showing vast differences in other criteria of fatness in samples of subjects of the same sex selected for having the same stature and body mass, hence, the same BMI. In a recent study by Ross et al. (1988) on over 18,000 men and women the correlation of BMI with the sum of skinfolds was ($r = 0.5$) was not appreciably different than that with the sum of humerus and femur breadths ($r = 0.51$) In fact, in this sample it was more a function of the skinfold-corrected girths ($r = 0.57$) than it was of the sum of five skinfold thicknesses as an indicator of fatness.

Quetelet's reputation 150 years after his death is perhaps sullied by the failure of modern day investigators with their application of the BMI to individual assessments. Nevertheless, his emphasis on large scale sampling, the uniqueness of the individual and his concern for the development of humans and all their faculties is a strong tradition.

Somatotype

The attempt by Sheldon et al. (1954) to devise a somatotype method as a taxonomy of the human species was in the Quetelet tradition. The original somatotype and the anthropometric based revision by Heath and Carter (1972) which has largely replaced it, provide for ratings of Endomorphy - relative fatness (sum of three skinfold thicknesses with or without a geometrical stature correction.); Mesomorphy - relative musculo-skeletal robustness (size-dissociated arm and calf girths corrected for skinfolds, and two bone breadths) and Ectomorphy relative linearity (from geometrically scaled weight/height ratio, being the inverse of the Ponderal Index (stature/cube root of weight)).

Both Quetelet and Sheldon were concerned with the variety of human physique and the need to provide the context for viewing individual differences. In this they used prototypical "averages" or "types" in their studies. Quetelet recognised that tall individuals differed systematically from short ones and made gross generalisations about the difference. Sheldon also recognised this and selected the reciprocal of the ponderal index, a purely geometrical index to quantify the photoscopic impression of the relative linearity of tall individuals.

The Behnke Somatogram

Behnke and Wilmore (1974) were critical of anthropometric surveys in that they generally measured too few variables to give more than a fragmentary picture of physique status. Their approach was to take a comprehensive set of girth and width measurements in an assessment of body build. Essentially, they showed that multiple girths and stature describing perimetric size could be used as a substitute for body weight. The cubic dimension of weight had therefore been converted to the linear dimension of the multiple girths. They also found that skeletal widths and stature were useful in defining frame size, which was used to extrapolate a reference weight or make a prediction of lean body mass. The estimates of lean body mass were not as accurate as those from densitometry, however, they were found to be useful. In characterizing physique Behnke believed that it was necessary to use a battery of trunk and extremity measures.

What is now referred to as the Behnke Somatogram was first proposed by Behnke, Guttentag and Brodsky (1959). The deviations of a single radius from the total body radius were given in terms of a percentage. This was later modified by Behnke such that the modern version of the Somatogram is produced by dividing each girth (c) by its respective k value to obtain the d value ($d={}^{c}/_{k}$). D, which is the sum of the circumferences divided by the sum of the k values (normally 100) is used as the reference value. The Somatogram profile is then produced by plotting the percentage deviation of each d quotient from D. All of these deviations lie in the same plane when the proportional girths of the individual conform to group symmetry.

This technique provides the examiner with a useful visualisation of a large amount of anthropometric data. It was primarily designed to allow comparisons to a given reference male or female, however, it can also be used to compare one group with another or one individual with another by making a straight forward height correction. Since the percentage deviations of each girth are calculated using the sum of the girths then if the size of any one girth changes then the percentage deviation of all girths will change also. Thus, the deviations are dependent on each other. This may lead to problems of interpretation when serial data on an individual undergoing some form of dietary or training programme is being considered. Another drawback of the technique is that it is limited to the use of girths. Thus one is only quantifying external shape and can make no firm pronouncements on relative muscularity or adiposity. Although Behnke did propose a technique to estimate excess muscularity based on these deviations, this approach assumed that any increases in girth were due only to muscularity and that the contribution of bone and adipose tissue to the girths was constant. In all of their assessment procedures Behnke and Wilmore conceded that any skewness in weight due to excess fat, caused problems of prediction. This was due to the inability of the girths to differentiate between component tissues.

Ross and Wilson and the Phantom Proportionality Profile

The scaling to height in an assessment of physique, was an approach advocated by Ross and Wilson (1974) and later revised by Ross and Ward (1982) in which a single, unisex reference human was used as a calculation device for quantifying proportional differences. Arbitrarily, they ascribed a standard stature of 170.18 cm (5 feet 7 inches) to their model and defined over 100 measures (P values) and their corresponding standard deviations (s values).

It should be recognised that anthropometric technique is not invariable but reflects systematic differences as well as inter- and intraobserver error. The defined landmarks and techniques for the Phantom have been reported by Ross and Marfell-Jones (1982). These specific techniques are similar to those reported by de Garay et al. (1974) and were advocated by the International Working Group on Kinanthropometry (IWGK) as taught in their sponsored certification courses. It should be appreciated however, that the Phantom does not require absolute adherence to those techniques if comparisons are made to a control where the anthropometric technique is consistent. The Phantom is technique independant for within-sample analyses, or whereever the anthropometric technique is common for all subjects. This has particular advantage in secular trend studies or in longitudinal growth analyses.

The general formula for the use of the Phantom geometrically scales all measures to the Phantom stature (170.18), obtains the difference from the given Phantom values (P) and expresses this as a deviation (s). In computational notation the formula is:

$$Z = ((\ v * ((\ 170.18/h\ )^{d}\ )) - P\ )\ /\ s$$

where:

Z is a proportionality value or z-value.
v is the size of any measured variable.

170.18 is the Phantom stature constant.
h is the subject's obtained stature.
d is a dimensional exponent. When scaled geometrically d=1 for all lengths, breadths, girths and skinfolds; d=2 for all areas and d=3 for all weights and masses.
P is the Phantom value for the measured variable v.
s is the Phantom standard deviation for variable v based on a hypothetical universal human population.

A z-value of 0.00 indicates that the subject for variable v is proportionally the same as the Phantom. A value greater than 0.00 means that the subject is proportionally greater than the Phantom for variable v, whereas a z-value of less than 0.00 shows that the subject is proportionally smaller than the Phantom for that item. The value of the Phantom is not as a normative data set however, but as a calculation technique for comparing individuals and groups. It does not obviate the need for normative data. On the contrary, it encourages such compilation, because any available data can be compared to any other by z-value differences.

Since it's proposal in 1974 the Phantom stratagem has found application to problems in the definition of perinatal events (Ross and Ward 1981) showing a three month proportionality deflection in body mass and other variables (Faulhaber 1978); describing differential growth rates (Ross 1976, Hebbelinck and Borms 1978, Ross 1978, Ross, Drinkwater, Wittingham and Faulkner 1980, Ross, Grand, Marshall and Martin 1982); serving as a basis for proportionality norms for children and youth (Hebbelinck and Borms 1978); helping to elucidate secular trends (Eiben 1978, Vajda and Hebbelinck 1978, Helmuth 1982); serving as a tool to study sexual dimorphism (Ross and Ward 1982) and the effects of sex chromosome aneuploidy and other genetic abberations (Miller, Ross, Rapp and Roede 1980, Eiben 1980, Bosze, Eiben, Gaal and Laszlo 1980, Ross, Ward, Sigmon and Leahy 1983, Pelz et al. 1982, Gueguen et al. 1983); identifying black and white athletes from skeletal structure and clearly showing persistence of ethnic proportionality patterns in Olympic events (Ross, Ward, Leahy,and Day 1982, Ross and Ward 1984); helping explain strength and maximal aerobic power phenomena associated with growth (Ross, Bailey, Mirwald amd Weese 1977, Ross and Ward 1980); studying athletes (Ross and Wilson 1974, Ross 1976, Eiben, Ross, Cristensen and Faulkner 1976, Eiben 1980, Skibinska 1979, Perez 1982, Hebbelinck, Ross, Carter and Borms 1980, Reilly and Townshed 1982, Ross, Ward, Leahy and Day 1982, Chovanova 1983, Ross and Ward 1984); and forming the basis for a body composition assessment tactic (Drinkwater and Ross 1980, Martin 1984, Drinkwater 1984).

An attractive feature of the Phantom is that it can be used to visualise vast amounts of anthropometric data, in the same way that somatotype reduces a large amount of anthropometric data to a three component descriptor of shape that is then plotted on a Rouleau triangle, thus giving a quick visually interpreted impression of the shape of the individual. When calculated Phantom z-values are plotted on a proportionality profile an immediate visual appraisal of the detailed proportionality characteristics of a group or individual can be made. This approach to data resolution is termed "Iconometrographic Analysis". The word iconometrography was used by Boyd (1980) to identify a methodological approach to the study of human growth. The neologism is derived from the greek "eikon" meaning an image or likeness, "metrikos" involving measurement, and "graphikos" belonging to painting or drawing. In using this approach the Phantom may be used as an imaging technique. Any of the ascribed Phantom variables may appear in the proportionality profile. However, by convention the items are listed from finger tip to toe in subsets of lengths, breadths, girths and skinfolds.

DENSITOMETRIC EXTRAPOLATION: THE SPIVAK IMPULSE

Archimedes (287-212 BC) was the progenitor of modern methods of scaling human structure and understanding of dimensionality with his elucidation of the principles of bouyancy. There is a story that Archimedes was asked by King Heiro of Syracuse to determine whether a sacred wreath was an alloy of gold and silver, rather than being all gold. Archimedes had discovered the laws of bouyancy and put this to use in solving the problem. Gold being more dense than silver, occupied a smaller volume. Thus he was able to measure the volume of the crown by knowing that the weight in air minus the weight in water was equal to the weight of water displaced. By determining the volume of the same weight of silver, and the same weight of gold, he was able to calculate the fraction of the crown that was gold. This was only possible if he could assume that the densities of gold and silver were different and constant.

According to Spivak (1915) the earliest recorded observations of specific gravity in terms of the amount of water displaced by humans were made by John Robertson in 1814, a librarian of the Royal Society. One of the practical reasons for his experiments was to determine how much timber would be required to keep a man afloat, thinking that men had a specific gravity heavier than fresh water. Apart from omission of the calculation of the entrapped air in the lungs, Spivak's own experimental procedures for water displacement and the reported results were entirely plausible with specific gravity values of 1.003 found for adults and 1.006 for young boys. His experimental observations on one subject, before and after a weight gain of 10 lbs with concomitant volume displacements of 79,380 and 84,000 ml, are pertinent to modern day analyses.

> "When the man weighed 176 lbs he was heavier than water. Now that he weighs 10 lbs more he is lighter than water. Since, the specific gravity of all tissues except fat is higher than water. If the increase had been due to the enlargement of the mucular or boney tissues, his specific gravity would have been the same or higher than before. But specific gravity has been found lower and therefore it is evident his bulk was primarily due to and increase in his fatty constituents. Such a procedure is of diagnostic value." (Spivak 1915)

Spivak's statements were also prophetic; his comments were in keeping with the modern day criticism of the two component model (which will be addressed later in this chapter):

> "I recognise the fact that with our present insufficient knowledge of the relative weight and specific gravity of the body, we can not yet construct a formula, which like Archimedes would give us the respective quantities of the human alloy". (Spivak 1915)

It is perhaps axiomatic that the genetic material of living organisms ascribes specific limits to mass and form. Two adults of the same weight may have entirely different proportions if their statures differed by 10 cm. The taller might be linear whereas the shorter would be relatively more ponderous. However, as recognised by Francis Galton (1822–1911) linear measurements cannot be compared directly with volumetric measurements such as body mass. His solution was to make the ratio of stature to body mass dimensionless as in the ponderal index (PI), which is the ratio of stature to the cubic root of body mass, multiplied by 100. Spivak (1915) demonstrated insight by pointing out the limitations of such a general descriptor:

> "this formula represents an index which is serviceable for predictive purposes in the absence of a better one. But since the body does not consist of homogeneous materials, I contend the weight represents the sum of the parts differing from one another, the difference in this instance is the specific gravity. For it makes a great difference whether a large proportion of the weight is adipose tissue, brain or striped muscle. Each of the organs has its special specific weight, it is evident therefore that neither the total weight of the body or its stature, either separately or relatively give us an idea of its volume, less so of its constituent parts."

A practical method was sought for the assessment of body fat in divers, since fat had been shown to be an important component of weight in relation to the solubility of gaseous nitrogen, and hence is related to propensity for the bends. Behnke, Feen and Welham (1942) reintroduced the notion of body volume as a third dimension for consideration along with weight and height, and described the specific gravity as a useful measure. With reference to Archimedes and his discoveries on bouyancy in relation to the problem with the gold/silver wreath, body volume was ascertained as the difference between the weight in air and the weight in water. The conceptual basis for the estimation of body composition were reviewed in the framework of human biology as practiced at the University of Minnesota by Keys and Brozek (1953). Their methodological contributions included technique improvements such as the direct measurement of "residual air" in the lungs in determining body vloume by underwater weighing, the concept of a "reference body" and the prediction of percent fat from skinfold calipers and radiographic techniques.

Modern densitometric techniques are based on the assumption that the body can be divided into two compartments, ie. fat and fat-free body mass. If one assumes constant densities of each compartment eg. fat as 0.9 gm/ml (at 36°C) as proposed by Fidanza (1953) and a value such as 1.1 gm/ml for the fat free mass proposed by Siri (1956) then estimations of percentage body fat may be made from the measured body density. The determination of body density could then be achieved by the division of body mass by body volume. Based on these assumptions Siri produced the following equation:

Siri (1956)

% body fat = ((4.95/Density) - 4.5) x 100

It is important to note that the density of fat is that of ether extractable lipid from adipose tissue and not the adipose tissue itself. The density of 0.9 gm/ml (at 36°C) for fat was obtained lipid extracted from human adipose tissue by Fidanza, Keys and Anderson (1953). Adipose tissue is a storage organ for lipid, and has considerable variation in its composition. The distinction between adipose tissue as opposed to "fat" has created errors in the scientific literature. For example Dauncey and colleagues (1977) determined the volume of the subcutaneous adipose tissue in infants, referring to this as the fat layer. In converting from volume to mass they used 0.9 gm/ml as the density of fat. This constant is only appropriate for the density of ether extractable lipid. A higher and more variable value would have been appropriate for the density of adipose tissue (0.92 to 0.96 gm/ml). Alternative constants were given by Rathbun and Pace (1945) and Brozek, Grande, Anderson and Keys (1963) such that body fat could be determined as:

Rathbun and Pace (1945)

% body fat = ((5.548/Specific Gravity) - 5.044) x 100

Brozek, Grande, Anderson and Keys (1963)

% body fat = ((4.57/Density) - 4.142) x 100

It should be noted in the Rathbun and Pace formula was based on guinea pig data and used specific gravity rather than water density to compute body volume. Consequently the volume could vary with the measurement conditions. The assumptions of constant densities of the fat-free body mass recently challenged by cadvre evidence by Ross et al. (1984) and Martin et al. (1986) are not original insights. They are consistent with those made over seventy years ago by Spivak (1915) and by Brozek and Keys (1951). Behnke and Wilmore (1974) reported communication with Siri reporting whole body densities as high as 1.11 gm/ml and Adams et al. (1982) showed even higher values for professional football players. Although discussed by Struinkamp (1977) and Wilmore (1983), the recent review of the criterion methods for the measurement of body composition by Roche (1987) concluded:

> "although the present two-compartment equations to estimate body composition variables from body density are probably adequate for young white men, different equations are needed for females, for other ethnic groups, for different age groups and for those who are very active physically, because the groups differ in the density of fat-free mass."

Anthropometric Prediction of Percentage Body Fat

Even if it did not have questionable assumptions and problems of validity, densitometry is not appropriate as a field technique for mass testing. Thus, estimation of percentage body fat from anthropometric measurements, primarily using skinfold measurements has found extensive use. Brozek and Keys (1951) were the first to develop equations for the prediction of specific gravity of the body from skinfold measurements. Abdominal, Chest, Back, Upper Arm and Thigh skinfolds were used in simple regression equations to predict specific gravity. Correlation coefficients varied from −0.749 to −0.857 for younger men, and −0.538 to −0.681 for older men. When several skinfolds were combined in a multiple regression equation, multiple correlation coefficients of −0.876 for younger and −0.744 for older men were obtained. The authors pointed out a need for more complete predictive equations covering the complete range of ages for both sexes. Brozek and Keys (1951) had selected skinfold sites for their techniques using the following criteria;

a) Representation of regions known to show large variations in subcutaneous fat thickness.

b) Representation of the extremities.

c) Ease of precise location.

The two compartment model with densitometry as its validation was the chosen course for anthropometric prediction after the work of Brozek and Keys. Numerous small sample studies appeared in the following decades, each expounding a predictive equation for body density or percentage body fat based on anthropometric measurements. There was general agreement among these studies that the correlation coefficient between body density and the specific anthropometric measures selected was in the region of 0.6 to 0.8 (Pascale et al. 1956, Parizkova 1961, Steinkamp et al. 1965, Durnin and Rahaman 1967, Haisman 1970, Adam et al. 1962, Best 1953, Chinn and Allen 1960, Edwards and Whyte 1962, Sloan 1967, Wilmore and Behnke 1969, Sloan et al. 1962, Katch and Michael 1968, Lohman et al. 1975, Durnin and Womersley 1969).

Damon and Goldman (1964) investigated the validity of ten of these anthropometric equations predicting percentage body fat. They found that the closest predictions of densitometrically determined fat were obtained from the equations of Pascale et al. (1956) and that of Brozek and Keys (1951). In both studies the two standard skinfold sites, triceps and subscapular were used. The difference between predicted and densitometric fat percentages averaged plus or minus 2% for the Pascale formula. Individuals whose fat was predicted poorly were at the extremes of age, height, and weight for the sample. At present the researcher is faced with the choice of a plethora of predictive equations for percentage body fat estimations.

Equations relating skinfold thicknesses to body density tend to be sample specific. Equations could only be valid as predictors of percentage body fat, if applied to a sample which was similar to the population from which they were derived (Wilmore and Behnke 1969, Damon and Goldman 1964, Haisman 1970). Large errors were obtained when equations were applied to samples diverse in age, sex, ethnic group and level of fitness (Durnin and Womersley 1969 and 1974). Due to sample specificity great caution must be used when applying predictive equations to samples different from those from which thay were derived.

The specificity of these equations is related to differences in both samnples and techniques employed, reflecting differences in:

- **Ratio of internal to external fat mass.**
- **Compressibility of skinfolds.**
- **Variation of densities of constituent tissues.**
- **Variations of skinfold patterning.**
- **Skinfold caliper design.**
- **Differences in anthropometric techniques.**

There are several equations available for the prediction of percentage body fat for college age males and females such as those of Sloan, Burt and Blyth (1962), Sloan (1967), Fletcher (1962), Katch and Michael (1968), Katch and McArdle (1973), Flint, Drinkwater, Wells and Horvath (1977), There are equations available for specific age groups such as children (Johnston, Pallone, Taylor and Schell 1982; Lohman, Boileau and Massey 1975) and middle aged adults (Durnin and Womersley 1969; Smith and Boyce 1977; Lewis, Haskell, Klein, Halpern and Wood 1979; Noppa, Andersson, Bengtsson, Bruce and Isaksson 1979) or restricted ethnic groups such as young Punjabi women (Satwanti, Bharadwaj and Singh 1977) or young Japanese males and females (Nagamine and Suziki 1964). The 'use and misuse' of such equations was pointed out by Sinning (1980). There are no universal formulae which control all potential for error. Lohman (1981) has provided a comprehensive critique of the problems associated with such prediction formulae and has provided cautionary guidelines for their use. These predictive equations carry with them not only the inherent problems of their densitometric criterion, but also those due to the assumptions required to make the transformation from one or more compressed double thicknesses of skin plus adipose tissue (skinfolds) to the mass of total body lipid. Some of the difficulties in using skinfold thicknesses to infer percent fat, even if the density criterion was perfect, arise from five additional assumptions which are generally not true as discussed by Martin et al. (1985).

1) Constant compressibility of skinfolds
2) Skin thickness is a negligible or constant fraction of skinfold
3) Fixed adipose tissue patterning
4) Constant fat fraction in adipose tissue
5) Fixed proportion of internal to external fat

In addition Katch and Katch (1980) pointed out six items of concern about the validity of prediction equations:

1) Bias due to lack of true random sampling

2) Prediction equations should accurately predict the mean of the criterion sample

3) Regression between the first prediction and the criterion should be linear

4) The standard error of estimate, the constant error and the total error (mean of the squared deviations) should be

considered

5) For bias introduced by including a large number of independent variables, r^2 should be corrected

6) Large sample sizes should be used (>75)

Lohman (1981), pointed out that the standard error of estimate of skinfold based prediction equations averaged around 3.7% of body fat. In approximately two out of three individuals the error of prediction would thus be plus or minus 3.7% body fat of the densitometric estimate. Lohman, however contended that as long as the equation used was appropriate to the individual being measured, standardised techniques were used and the measurer was well trained then these equations can be used satisfactorily. Presumably, he was referring to group comparisons or changing status for the same individual. Considering the vulnerability of the asumption of biological constancies of a "fat-free" compartment and the series of asumptions in the use of skinfold calipers, it appears that the conventional skinfold prediction formulae are inadequate for individual assessment. This conclusion was succinctly stated by Johnston (1982):

> "At present it seems that human biologists are better off to continúe to use anthropometry itself, rather than to attempt to make estimates of whole body composition from available equations. Even if such equations could provide usable estimates of mean parameters for samples, it seems clear that they are not sufficiently reliable for individual prediction."

Over and above the problems of the assumptions required to make predictions of percent body fat from anthropometric items, is the consideration that it requires considerable training to become proficient in the use of skinfold calipers. With good instruction and practice good intra-tester reliabilities can be obtained (Pollock and Jackson (1984). Persistent comparison between measurers is also required however, since significant variability has been shown between experienced measurers in many studies (Burkinshaw, Jones and Krupowicz 1973, Jackson, Pollock and Gettman 1978, Lohman et al. 1979, Lohman et al. 1984, Munro 1966).

PHYSICAL FRACTIONATION OF BODY MASS: THE MATIEGKA IMPULSE

In his now classical paper on the testing of physical efficiency, Matiegka (1921) proposed an original system for geometrically scaling anthropometric items to estimate Skeletal mass (O – Ossa); Skin and subcutaneous adipose tissue (D – Derma); Skeletal muscle mass (M); and the Remainder (R – the difference between body mass and the sum of O, D and M). Matiegka derived a series of coefficients based on limited cadavre evidence, to be used in the scaling of subsets of anthropometric items to estimate the fractional masses. This work went largely ignored until Drinkwater et al. (1985) validated the equations against cadavre findings. They concluded that Matiegka's original equations could make reasonable estimates of muscle and bone masses in adults, but that prediction of the other masses was less reliable. Brozek (1961) recognised Matiegka's contribution to body composition analysis:

> "While Matiegka was concerned with strengthening the practical usefulness of anthropological measurements, his ideas were of fundamental importance for quantitative human morphology in that he pointed to a new way for the synthesis of individual body measurements in a meaningful biological frame of reference and emphasized the fundamental role of body composition in describing man's physique."

Since Matiegka there have been several attempts to predict fractional masses from anthropometry. Behnke (1959) predicted body weight from the product of stature, a constant and the squared sum of certain girth measurements and bideltoid diameter. This assumed a geometrical analogue of the human body as a set of stacked cylinders. A model for the estimation of lean body mass from anthropometric breadths and girths was correlated with body density and total body water (Behnke 1959b). Von Dobeln (1964) predicted bone mass from stature and wrist and femur breadths. Drinkwater (1984) found that this equation overpredicted bone mass by about 25% on cadavre data. Drinwater's assessments of these systems was part of his investigations into a possible better system for fractionation of body mass along the lines of Matiegka original work. Drinkwater and Ross (1980) proposed a tactic which utilised a variation on the Ross-Wilson Phantom tactic for proportionality assessment. Masses for bone, fat, muscle and residual were independently predicted based on the deviations of a subset of predictor anthropometric items from the phantom model. Deviations of the masses were assumed to be equal to the deviations of their appropriate anthropometric subset from the phantom specifications. This differed from Matiegka's approach in that the masses were derived independently of body weight. In validation on cadavre data Drinkwater showed that the model was limited in it's application for two main reasons:

1) The method was dependent on the internal consistency of the Phantom model of Ross and Wilson (1974).
2) It did not account for differences in proportional lengths of various body parts.

He found the model particularly inadequate in children. He revised the tactic based on cadavre data, which resulted in an improvement of performance of the tactic, but still he concluded the revised model was not recommended for use in children or in individual assessments. Drinkwater then devised an approach were the body was divided into six regions; the head and neck, the trunk, the two upper and two lower limbs. The body was represented by a series of truncated cones composed on concentric shells of tissue. He accounted for deviations from these regular shapes by the inclusion of shape coefficients derived from data on five cadavres. This model was not fully validated in that the cadvre data was used to modify the shape coefficients thus could not be used as a validation source. The only validation available was in the prediction of total body weight in in vivo samples, where it performed well. Despite it's limitations it represents the most sophisticated attempt at the fractionation of body mass from anthropometric measurements.

Anthropometry in Comparison to Appropriate Standards

The simplest approach to the quantification of human physique is the expression of size via simple anthropometry. In obtaining any measurement on a subject, the "true" value is unknown, and at best, every measurement is an approximation. Standard techniques and protocols have been developed in order to keep "error" or the difference between obtained and true values to a minimum. The history of anthropometry is marked with attempts to arrive at consensus. Whatever techniques are used the investigator should be explicit: either cite the source or define the technique. Since the Geneva convention in 1912 (Stewart, 1952) a number of basal references have been used for this purpose (Stewart 1952, Borms, Hebbelinck, Carter, Ross and Lariviere 1979, Weiner and Lourie 1981, Ross and Marfell-Jones 1982, Lohman, Roche and Martorell 1987) When the investigator departs from cited specifications he or she is obliged to make explicit explanations within the text, ideally using recognized landmarks, anatomical nomenclature, and standard instrumentation.

It is also important in appraising the effort made to control intra-observer error, for investigators to report the technical error of measurement on replicated items. Some indication of the level of training should be alluded to; ideally comparative data with a "criterion" anthropometrist (one who presumably has technical skill and is both precise and accurate, that is, approaches the true measure for the specific technique) should be presented. Baumgartner and Jackson (1982) defined reliability as being the degree of consistency with which a test measures what it measures. Reliability has been expressed in several different statistics. A reliability correlation coefficient is a relative measure of precision but not extent of error. In the test-retest situation for determining the reliability of a measure an intraclass (univariate) correlation coefficient is used. This correlation coefficient is calculated from a one-way repeated measures analysis of variance.

For assessment of the extent of error as a measure of reliability, Johnston et al. (1972) proposed that the Technical Error of Measurement be used. The technical error is defined as:

Technical Error = (Sum d^2 / 2n)0.5**

where:

d = difference between repeated measures

n = number of pairs of measurements

Edwards et al. 1955 and Johnston et al. (1972) indicated that the error of measurement is directly proportional to the size of measurement. Thus the Coefficient of Variation was proposed:

Coefficient of Variation = (Technical Error x 100) / Mean of the variable

The technical error of measurement and the coefficient of variation were used in this thesis to assess the reliability of anthropometric measures in assessment of reliability rather than the intraclass correlation since the extent of error was required rather than merely a relative measure of precision.

The measurement techniques used in this thesis have been evolved during continuous operation of a kinanthropometric laboratory and have been specified in recent publications (Ross and Marfell-Jones, 1982. Those used in the advanced O-SCALE system are described with illustrations of techniques in Appendix 2.

Norms and Standards

Individual physique status can be assessed by reference to a normative data assembly (norm). Ideally, these should be based on a sampling frame which provides an estimation of the population. Practically all norms represent a compromise from a purely random sample to one stratified according to age, sex and demographic factors. A prototypical sample of a particular group, such as an elite athletic group may be an appropriate reference for assessment of physique status of a given individual. Tanner (1976), recommended that a norm would best serve if it reflected a healthy rather than an average population. National standards may not serve as a guide to assess health but as an indicator of present status which may not be optimal.

The types of measurements available in the form of national norms tend to be those found useful in the assessment of nutritional and growth status. The two most popular variables are height and weight. The U.S. National Center for Health Statistics (NCHS) publishes standards such as the growth curves for children - birth to 18 years (US Dept. Health, Education and Welfare, 1977) for weight and height. These were also reported by Hamill et al. (1979). In order to gain more insight into the composition of body weight skinfold and girth measurements are used. Anthropometry is increasingly becoming an indispensible method for assessment of growth in children. U.S. norms are available for triceps and subscapular skinfolds and relaxed arm girth for ages 1 to 75 years (Frisancho, 1981). These were later presented as standards by frame size (as determined by biepicondylar humerus width and height category) (Frisancho, 1984). Nutrition Canada norms and the Canada Fitness Survey have presented simliar norms for these variables. Triceps skinfold and relaxed arm girth are used extensively in nutritional assessments. It is assumed that the triceps skinfold indicates the calorie reserves stored in the form of fat (Frisancho 1974, Frisancho 1981, Jelliffe 1966) and that the muscle protein reserves are reflected in the arm muscle size (Frisancho 1974, Frisancho 1981, Jelliffe 1966). The arm muscle size is quantified by the skinfold-corrected girth (Gc):

$$Gc = G - (PI \times SF)$$

where G = Girth in cm
PI = 3.14 approx.
SF = Triceps Skinfold in cm

This may further be expressed as an arm muscle area (AMA) by:

$$AMA\ (mm^2) = (G - (PI \times SF))^2 / 4PI$$

The assumptions made for both calculations are that:

- the arm is circular at the level of the measured girth.

- the triceps skinfold is twice the average fat rim diameter.
- the arm muscle is circular at the level of the measured girth.
- the bone size is directly proportional to the muscle size.

Despite the apparent crudity of these assumptions, the corrected girth has found extensive use in nutritional assessments. Indeed Martin (1984), in a cadaver study found a high correlation between dissected muscle mass and skinfold–corrected arm girth (0.89). Other girths similarly corrected for adjacent skinfolds also showed high correlations (thigh 0.99, calf 0.91).

Availability of other measures as National standards are limited. Jette (1981) did provide a guide for anthropometric measurement of Canadian Adults based on the data from the 1970–72 Nutrition Canada National Survey. The measurements included were weight, height, weight for height, percent fat from the sum of triceps and subscapular skinfolds, relaxed arm girth, arm muscle girth, chest, waist, gluteal and thigh girths. At the time it was the most comprehensive assessment package available for the Canadian practitioner.

Occasionally, the norms required for a particular evaluation are not available. In this situation the creation of norms by prediction of anthropometric data is not without precedent. In the field of ergonometry, prediction of anthropometric variables has been seen as the only solution to a lack of normative data for use in workplace design (Barkla 1961, Pheasant 1982a, Pheasant 1982b). In the method used by Barkla and Pheasant, parameters (means and standard deviations) of unknown variables are scaled to those of stature. In the population where all variable values are known, two coefficients e_1 and e_2 were obtained:

$$e_1 = X / H$$

$$e_2 = Sx / Sh$$

where:

X was the mean value of the dimension in the population
H was the mean stature in the population

Sx was the standard deviation of the dimension in the population
Sh was the standard deviation of stature in the population

For each dimension in the target population (T) where the dimension had not been measured, any percentile value could be predicted using the following formula.

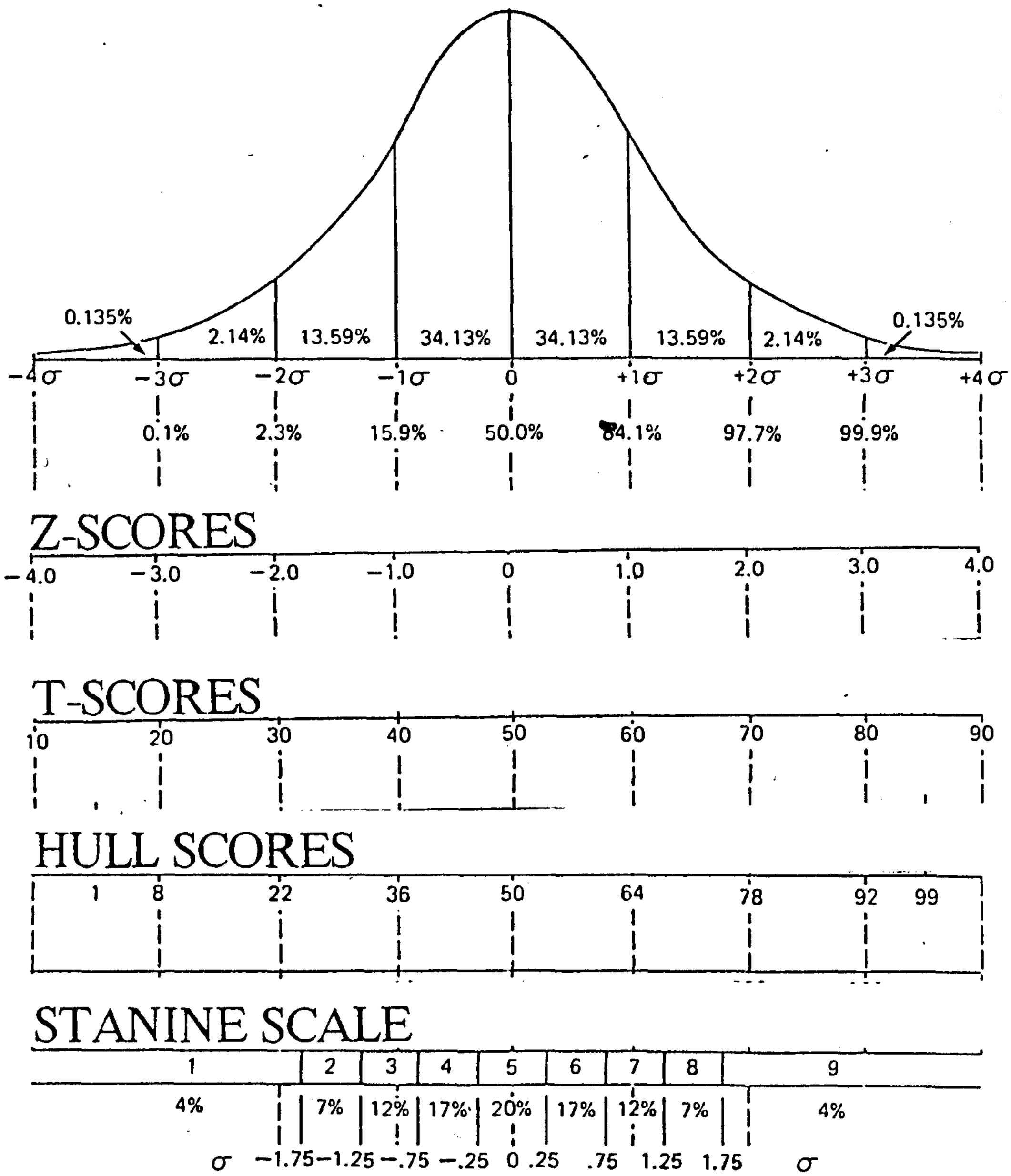
$$\text{Nth percentile} = e_1 Ht - SD\ e_2\ ShT$$

where:

Ht was the mean stature of the target population
Sht was the standard deviation of staure in the target population
SD was the number of standard deviations above or below the mean where the Nth percentile lies in comparison to the normal distribution

This technique was tested and shown to be valid in application to ergonometric variables such as limb lengths and body breadths which were well correlated with height and normally distributed (Pheasant 1982a). This process produces the norm in the form of a percentile scoring scale. The use of a scoring scale allows a subject's status in two or more dissimilar tests to be compared via the common scale. The percentile scale is based on the percentages of the sample at or below the particular percentile score. Thus 50 percent of subjects lie at or below the score represented by the 50th percentile. There are various scoring scales based on the properties of the normal probability distribution, that have commonly been used in the behavioural sciences Scott (1959). Figure AII.1 showed the relationship of some of these sigma scales to the normal distribution. The sigma scales use the standard deviation as a measure of variability. Those depicted were the z-score, T-score, Hull score and stanine scale. In the z-score, if a score lay one standard deviation above the mean it would be given a score of +1. Conversely, if the score lay one standard deviation below the mean it would be given a z-score of −1. In the T-scale the mean is arbitrarily assigned a value of 50 and the standard deviation a value of 10, and in the Hull score the mean is 50 but the standard deviation is 14. Thus a z-score of +1 would be equal to a T-score of 60 and a Hull score of 64. The stanine scale is different in that it divides the normal distribution into 9 categories (Ross and Ward 1986) based on the standard deviation. Each category is 0.5 standard deviations wide. This results in the 5th category encompassing the middle 20% of the sample, with the 1st and 9th categories being open ended containing the bottom and top 4% of the sample respectively. This is a valuable although seldom used scale, when categories rather than a continuous score is required.

Figure AII.1: Relationship of z-scores, T-scores, Hull scores and the stanine scale to the normal probability distribution



Despite the comprehensive nature of the physique assessments afforded by the Behnke and Wilmore or Ross and Wilson approaches the complexity of calculation and lack of normative data for comparison has meant that they find little application in the physique assessments carried out by health and fitness professionals. In contrast the prediction of percentage body fat from anthropometric assessments is commonplace, despite its limitations.

An approach that is gaining more proponents is to express the individuals measurements, or combinations thereof, as percentiles in comparison to an age and sex standard. Cronk and Roche (1982) described the use of weight/height^2 and subscapular skinfolds as indicators of body fat in children. They contended that if weight/height^2 or subscapular skinfolds were to be adopted as indicators of total body fat then they should be used by comparison to reference data for the independent variable and a percentile level determined.

The original intent of the Canada Fitness Survey was to use the age and sex specific equations of Durnin and Womersley (1974) to establish norms for percentage body fat. This system presumably had problems because it was later abandoned. Sinning et al. (1985) had reported that the Durnin and Womersley formula tended to overestimate percentage body fat by about 4%. In addition the Durnin and Womersley formula uses only upper body sites and may therefore give underestimations in individuals exhibiting lower body dysplasia of adiposity. The Canada Fitness Survey solution, which found application in the Canadian Standardised Test of Fitness, was to produce age and sex specific percentile distributions for four indices and display them as a profile. The four indices were:

1) Body Mass Index (Weight/Height^2): This has been shown to correlate fairly well with measures of "fatness" as discussed previously. But it also has been found to relate well to morbidity and mortality rates in epidemiological studies (Goldbourt and Medlie (1982).

2) Sum of Five Skinfolds (Triceps+Biceps+Subscapular+Iliac Crest+Medial Calf): As previously discussed skinfolds and their sums been highly correlated with body density and percent body fat.

3) Waist to Hip Girth Ratio (Waist/Hip girth): This has been shown to correlate well with measures of central obesity, but also is regarded as a index of upper segment obesity. Upper segment obesity has been correlated with abnormal glucose tolerance in adults (Evans, Hoffman, Kalkhoff and Kissebah, 1984; Krotkiewski, Bjorntorp, Sjostrom and Smith, 1983; Kissebah, Vydelingum, Murray, Evans, Hartz, Kalkhoff and Adams, 1982; Vague, 1956). Diabetic women have higher WHR than non-diabetic women (Hartz, Rupley, Kalkhoff and Rimm, 1983).

4) Sum of Trunk Skinfolds (Subscapular+Iliac Crest): This is aimed at quantifying trunk or central adiposity. A high ratio of trunk to limb adiposity has been related to increased mean arterial blood pressure (Weisner et al., 1985) and diabetes (Mueller and Stallones, 1981).

In practice, the individual subject is rated on each index, and interpretations are made from this differential comparison. One of the problems with this design is that the first three indices essentially, get their justification as measures of "fatness". WHR is intended as a measure of upper segment obesity, but has also been seen to relate to central obesity. The SOTS serves as a measure of central obesity, but there is no comparison to limb obesity as has been carried out in the literature. If a subject gets different ratings for each index, how should this be interpreted? The basic decision to move away from percent body fat prediction should be applauded, however the proferred alternate system often is more confusing than enlightening.

The following chapters will describe the design and implementation of the O-SCALE system, designed to provide a practical method for the assessment of individual physique status.

PART B

THE DEVELOPMENT OF THE O-SCALE SYSTEM FOR INDIVIDUAL PHYSIQUE ASSESSMENT

CHAPTER I

METHODS 1: DEVELOPMENT OF THE O-SCALE SYSTEM

In this part of the thesis, a series of experimental studies were carried out with the purpose of design and justification of the O-SCALE system. The studies were organised in the sequence of events that were required to justify the design of the system. Initially, a composite data assembly was required from which the normative percentiles could be derived. Having developed this normative data base, the system was designed and a microcomputer programme for data resolution was developed. Each aspect of the system required justification, and subsequently the reliability of the anthropometry was addressed in relation to the resolution of the proportionality profile which was an integral part of the system focussing on the detailed appraisal of physique.

SUBJECTS

The first task was to compile a data assembly from which the O-SCALE norms could be derived. Subjects used for compilation of this data were gathered from from three sources.

1) COGRO - Coquitlam Growth Study

The Coquitlam Growth Study was a project carried out in the Spring of 1978 by the Kinanthropometric Research Associates at Simon Fraser University under the direction of Dr. W.D. Ross. The protocol consisted of triple measurements on each of 41 items. The role of the author (R.W.) was to measure all of the skinfolds; approximately 6,000 individual measures in a three week period. The sample was described by Ross et al. (1979) as from:

> "Three schools judged to be middle class and having average or better than average physical activity programs were selected from the Coquitlam School District, a neighboring municipality of Vancouver, British Columbia. The project designated as the Coquitlam Growth Study quickly became known by it's computer acronym, COGRO. The sample used to construct the so-called COGRO prototypes consisted of 446 girls and 473 boys ranging in age from 5.57 - 18.22

years. Subjects with physical handicaps were measured but excluded from the analysis. Participation in the project was voluntary and five potential subjects chose not to be included".

Of the variables required for the O-SCALE norms, biceps and iliac crest skinfolds and gluteal girth were not measured as part of the COGRO anthropometric protocol.

2) LIFESTYLE - Y.M.C.A. Sample

LIFESTYLE was the acronym for the anthropometric data collected since 1976 during the YMCA-LIFE program. This data was kindly made available for use in this thesis by Dr. D. Bailey of the University of Saskatchewan. As described by Bailey, Carter and Mirwald (1982):

> "The YMCA-LIFE program (the initials standing for Lifestyle Inventory-Fitness Evaluation) is an ongoing nation-wide testing program to evaluate the physical fitness and lifestyle habits of Canadians that has been in operation since 1976.... ....The large sample covers a large geographical and socioeconomic spectrum and is probably representative of national status. If there is a bias, it is probably in the direction of a somewhat fitter sample than the general population, since it is unlikely that people in questionable health would sign up for a physical fitness test."

Data was available on all subjects for weight, free standing stature, triceps, subscapular, biceps, supraspinale and medial calf skinfolds, flexed arm and maximal calf girths, and humerus and femur width.

2) CANAD - University males and females

Initially, a sample of 152 males and 94 females from three British Columbia universities were measured according to a comprehensive anthropometric proforma by the same personnel that carried out the Montreal Olympic Games Anthropological Project (MOGAP) anthropometric measurements. This sample, termed CANREF, was composed of student volunteers from general education classes, a non-specialist teacher training class in physical education and a campus student residence. They were considered healthy and moderately active. The CANREF sample was also used as the non-athletic comparison group in the Montreal Olympic Games Anthropological Project (Carter, 1982).

The author (R.W.) was involved as a measurer in the augmentation of the CANREF sample to produce a larger data assembly known as CANAD. In total, measurements on 233 males and 199 females comprised the CANAD data set. The subjects added to the CANREF sample were students of Kinanthropometry classes at Simon Fraser University. The CANAD individuals were measured according to a 44 item basic anthropometric proforma. Although in the original CANREF sample was not measured at biceps and iliac crest skinfold sites or at the gluteal girth, which were all measures required for the O-SCALE norms.

From these data sets the data for the subjects aged 16 years or over and less than 70 years were selected for use in the O-SCALE norms in this thesis. This constituted a sample of 19,647 individuals. Table BI.1 showed the numbers in each age group for males and females. The O-SCALE norms were divided into 24 age and sex specific categories, with 16 and 17 years olds together, 18 and 19 year olds together and groups of five year increments in age thereafter to age 70 years.

TABLE BI.1: Numbers of subjects in the O-SCALE normative data set divided into 5 year age and sex specific categories.

Age Group (years)	Data Source	MALES	FEMALES
16-17.999	Cogro	89	73
	Canad	5	2
	Lifestyle	41	22
18-19.999	Cogro	10	5
	Canad	60	57
	Lifestyle	95	404
20-24.999	All Lifestyle	1030	1298
25-29.999	" "	1872	1366
30-34.999	" "	2356	1085
35-39.999	" "	1858	720
40-44.999	" "	1477	636
45-49.999	" "	1371	495
50-54.999	" "	1043	434
55-59.999	" "	716	305
60-64.999	" "	333	179
65-69.999	" "	148	62
TOTAL		12,504	7,143

ANTHROPOMETRIC TECHNIQUES

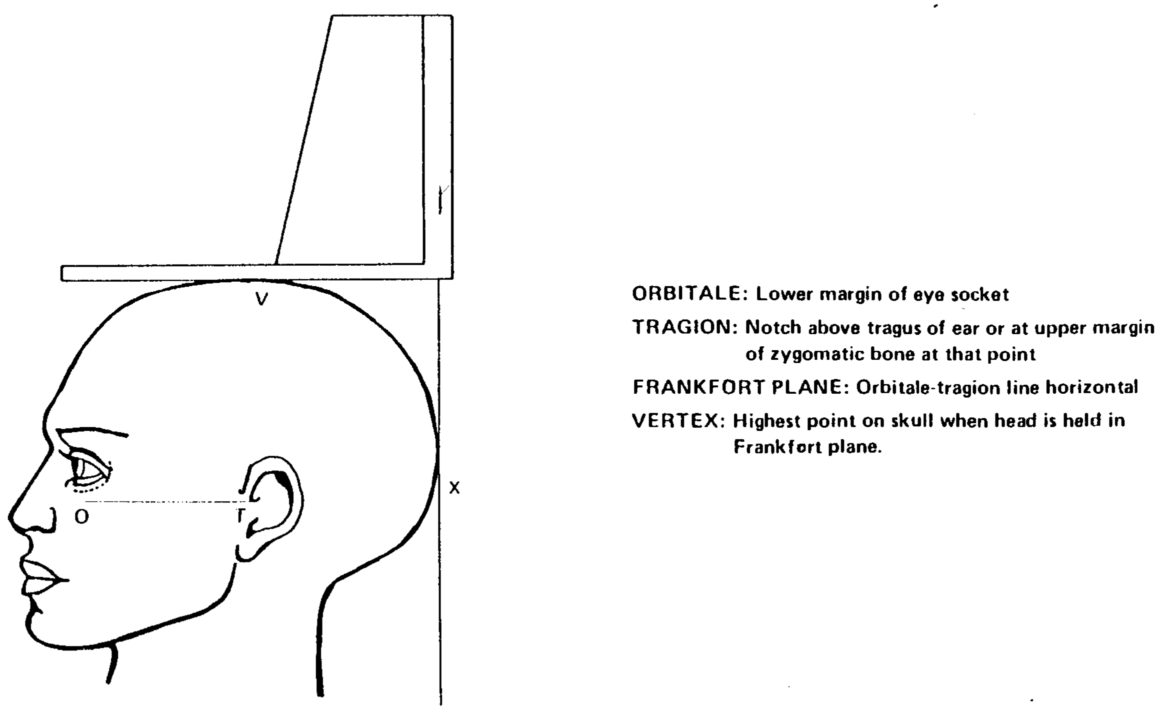
The anthropometric variables which were to be used as the basis of the O-SCALE system, and shown in the 22 item anthropometric proforma shown in figure BI.1, were stretch stature, body weight, eight skinfolds (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, medial calf), ten girths (relaxed arm, flexed arm, forearm, wrist, chest, waist, gluteal, thigh, calf, ankle) and two bone widths (Humerus and Femur). These techniques were routinely in use in our laboratory and were common to the data sets used for compilation of the O-SCALE norms. They were endorsed for use by the International Working Group on Kinanthropometry and were described by Ross and

Marfell-Jones (1983).

In carrying out an O-SCALE assessment each anthropometric item should be measured three times. The median of the three values then being used as the criterion value for that item. The standardised techniques for the measurements were as follows:

STRETCH STATURE: A device that is used, known as a stadiometer, can feature an elaborate ball-bearing, counter weighted headboard and digital readout or, it can be little more than two wooden planes set at right-angles. The critical aspect of the technique is obtaining the maximum distance from the floor to the subject's **vertex**. Technically, the **vertex** is the highest point on the skull when it is oriented in the **Frankfort Plane**. As shown in figure BI.1 the position is achieved when the line from the **Orbitale** to the **Tragion** is horizontal to the long axis of the body. The **Orbitale** is the lower or most inferior edge of the eye socket. The **Tragion** is the notch above or superior to the flap of the tragus of the ear.

Figure BI.1 : Frankfort Plane



When obtaining stretch stature the barefoot subject stands erect, heels together and arms hanging naturally by the sides. The heel, buttocks, upper part of the back, but not necessarily the back of head, are in contact with a vertical wall. The subject is instructed to "look straight ahead", "take a deep breath", and "stretch up as far as possible". During this time, one measurer assists in the stretch by cupping the subject's head in his hands an applying gentle traction to the mastoid processes, assuring the subject's head is maintained in the Frankfort Plane. The other measurer assures that the subject's heels are not elevated and then brings the headboard down, flattening the hair to make firm contact with the vertex. The scale is read to the nearest 0.1 cm.

WEIGHT: Body weight has daily variance. The most stable minimal values are obtained when the subject is weighed nude, in the morning, 12 hours post-absorptive and after voiding. Customarily, body weight is obtained at a convenient time of day with the subject wearing minimal clothing and a correction made for this clothing weight accordingly. All scales should be calibrated frequently; measurements are made to the nearest 0.1 kg.

SKINFOLDS: **(Figure BI.2)**

The intent is to encompass a double fold of skin and entrapped subcutaneous tissue. This is facilitated by a slight rolling and pulling action of the grasping fingers. The skinfolds are raised by the measurer's fingers at designated sites. The measurer grasps the folds with the index finger and thumb of the left hand; the grasp is maintained throughout the measurement. Calipers are always grasped in the right hand and applied at right angles to the raised fold. The back of the hand always faces the measurer. The pressure plates are applied 1 cm away from the near edge of the grasping fingers. Measurement is read after 2 seconds of applied pressure. Measurement is made to the nearest 0.1mm (Harpenden) or 0.5 mm (Slim Guide).

Triceps: A mark is made on the posterior midline of the arm at the level of the mid acromiale (most lateral superior point of the acromial process of the scapula) – radiale (upper lateral border of the radius) distance. The subject stands, arms hanging relaxed by the sides, palms against legs. A vertical fold is raised on the posterior surface of the arm with the measurer's thumb and index fingers at the marked site. The calipers are applied 1 cm below the fingers using the technique previously described.

Subscapular: The subject stands, shoulders erect and relaxed. The fold is raised by the measurer's left thumb and index finger just below and to the right of the inferior angle of the right scapula. The grasp encompasses the double layer of skin and subcutaneous tissue in the natural fold which runs obliquely downwards. The calipers are applied at right angles to the fold 1 cm lateral to the grasping fingers.

Biceps: The fold is raised at the marked mid-acromiale-radiale line on the midline of the anterior surface of the right arm. The caliper is applied one centimeter distally to the left thumb and index finger raising the vertical fold.

Iliac Crest: The fold is raised immediately superior to the iliac crest at the midaxillary line. The fold runs anteriorly downwards with the caliper being applied one centimeter anteriorlly from the left thumb and index finger.

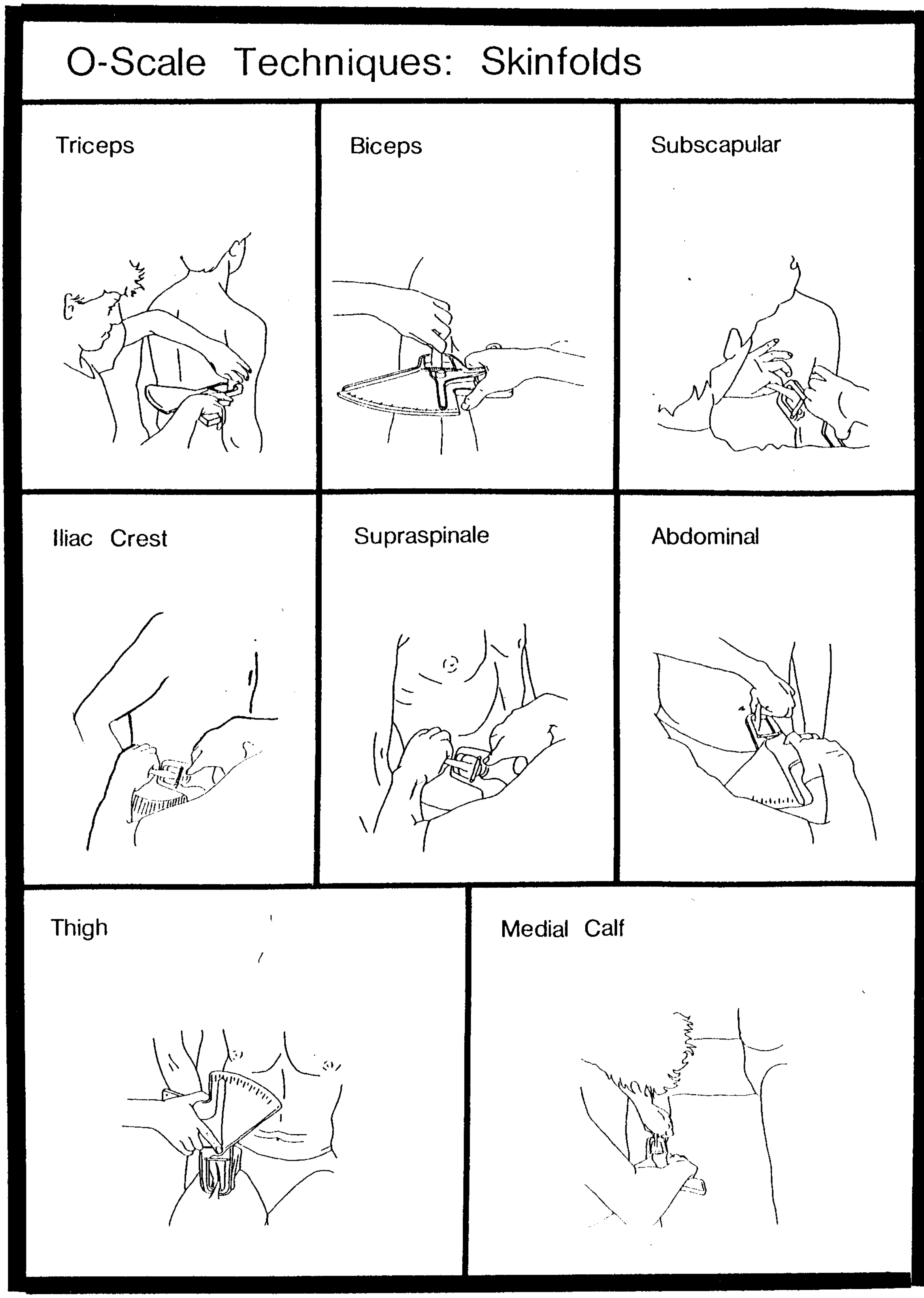
Supraspinale: Often identified as the **suprailiac** skinfold, the technically correct name "supraspinale" specifies the landmark and avoids confusion with the iliac crest skinfold. The ilio-spinale is the undermost tip of the anterior superior iliac spine. Having located the spinale, the measurer moves along an imaginary line extending to the axilla until the thumb reaches the level of the ilium. The grasp is made raising the natural fold which extends downwards and inwards obliquely. The calipers are applied at right-angles to the fold 1 cm medially from the grasping fingers.

Abdominal: The measurer raises a vertical fold adjacent to the left of the Omphalion (navel),grasps the fold at this level and applies the calipers below and at right angles to the fold.

Front Thigh: The subject is seated to give support to the right hamstring muscles which tends to take tension off of the front thigh skinfold; it is raised at the mid-inguinal-patellar distance to run parallel to the long axis of the Femur. The grasp should encompass a double fold of skin and the subcutaneous tissue. The calipers are applied at right angles to the firmly controlled fold.

Medial Calf: This is facilitated by having the subject flex at the knee and put his or her foot on a box or chair. A vertical fold is raised by a grasp of the right medial calf skinfold at the level of the estimated greatest girth. The caliper application is at right angles to the fold 1 cm below the grasping fingers.

Figure BI.2 : O-SCALE Skinfold Techniques



GIRTHS: (Figure BI.3) Girths are measured by a flexible tape, calibrated in centimeters with millimeter gradations. The girths are measured to to the nearest .1 cm with the tape at right angles to the long axis of a bone or body segment. The aim is to obtain the perimeter distance of the part with the tape in contact with, but not depressing, the fleshy contour.

Relaxed Arm: The subject stands with a relaxed, pendant right arm. Relaxed arm girth is the perimeter distance at right angles to the long axis of the Humerus at the mis acromiale-radiale level.

Flexed Arm: This is defined as the maximum circumference of the right arm raised to the horizontal position. The subject is encouraged to "make a muscle" by tensing while fully flexing his elbow joint.

Forearm: The tape from the arm girth is lowered to encircle the relaxed forearm, elbow extended and with palm facing upwards. The tape is manipulated by loosening and tightening it with the thumb and index fingers while adjusting the level with the third finger to obtain the maximum girth at right-angles to the long axis of the radius.

Wrist: The perimeter of the right wrist, distal to the styloid processes is measured, with the arm extended in a relaxed position with palm facing upwards.

Chest: The perimeter distance of the chest is taken horizontally at the level of the mesosternale. The measurement is taken with the subject standing erect and arms at the sides. The reading is taken at the end of a normal expiration.

Waist: The horizontal perimeter at the level of the noticeable waist narrowing is located approximately half way between the costal border and the iliac crest. In subjects where the waist is not apparent an arbitrary waist measurement is made at this level.

Gluteal: This is the horizontal perimeter of the level of the greatest posterior protruberance and at approximately the symphysion pubis level anteriorally. The subject during this measure stands erect with feet together.

Thigh: The horizontal perimeter of the right thigh is measured when the subject stands erect, legs slightly parted, weight equally distributed on both feet. The tape is raised to a level two centimeters below the gluteal line.

Calf: The subject stands with weight distributed equally on each foot. A series of perimeter measures is obtained by manipulation of the tape as was done for the forearm. The maximum calf girth is the largest measure obtained with the tape at right angles to the long axis of the tibia. Measurement is made to the nearest 0.1cm.

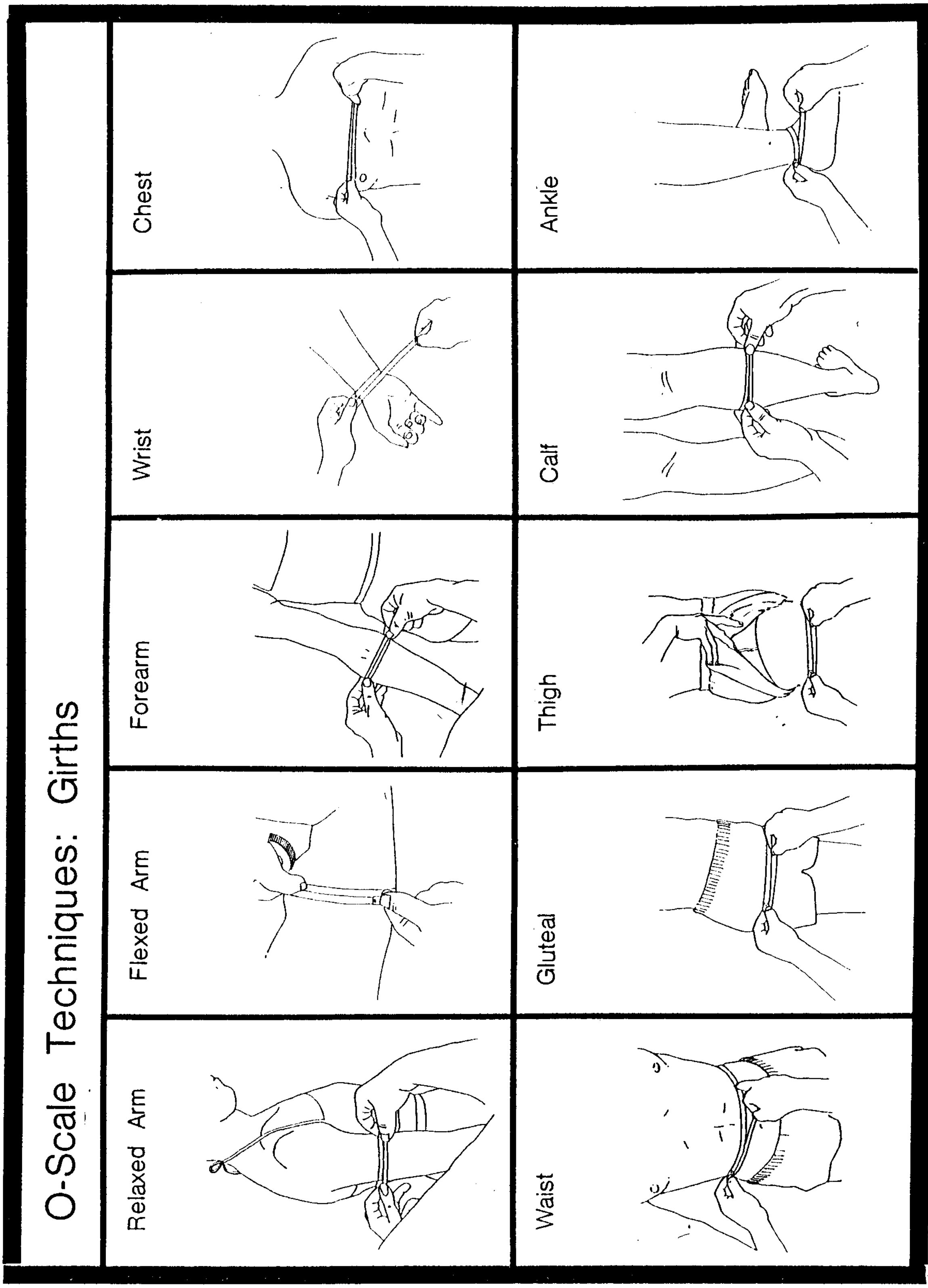
Ankle: The perimeter of the narrowest part of the lower leg superior to the symphysion tibiale defines the position of measurement.

BONE BREADTHS: Bone breadths are measured to the closest 0.01 cm using a modified vernier caliper. These calipers have extended branches with round pressure plates 15 mm in diameter.

Biepiocondylar Humerus Width: The distance between medial and lateral epicondyles of the Humerus is measured when the arm is raised forward to the horizontal and the forearm is flexed to a right angle at the elbow. The small bone caliper is applied pointing upwards to bisect the right angle formed at the elbow. The epicondyles are palpated by the third digits starting proximal to the sites. The measured distance is somewhat oblique since the medial epicondyle is lower than the lateral.

Biepicondylar Femur width: This is the distance between medial and lateral epicondyles of the Femur when the subject is seated and the leg is flexed at the knee to form a right angle with the thigh. The small bone caliper is applied pointing downwards to bisect the right angle formed at the knee. The epicondyles are palpated by the third digits starting proximal to the sites. The caliper pressure plates are applied firmly.

Figure BI.4 : O-SCALE Girth Techniques



ESTIMATION OF MISSING DATA IN O-SCALE NORMATIVE DATA BASE

For production of the O-SCALE system it was necessary to have a normative data assembly containing values for height, weight, 8 skinfolds (Triceps, Subscapular, Biceps, Iliac Crest, Supraspinale, Abdominal, Front Thigh, Medial Calf), 10 girths (Relaxed Arm, Flexed Arm, Forearm, Wrist, Chest, Waist, Gluteal, Thigh, Calf, Ankle), 4 skinfold-corrected girths (Relaxed Arm, Chest, Thigh, Calf), and biepicondylar Humerus and Femur widths. The major problem besetting the production of percentile distributions for the adult data was that there were a number of variables that were not measured as part of the LIFESTYLE data acquisition. In the LIFESTYLE anthropometric proforma the measurements were Free Standing Stature, Weight, 5 skinfolds (Triceps, Subscapular, Biceps, Supraspinale, Medial Calf), Flexed Arm girth, Calf girth and Humerus and Femur widths. The task was therefore undertaken of estimating the missing values for the other variables necessary for the O-SCALE system. For stretch stature, the Mexico City Olympic Games data made available by Dr. Carter was used. The Mexico City Games data was invaluable in that stretch stature and free standing stature had been measured on all of the athletes. A stepwise multiple regression analysis could therefore be used to produce an equation to predict stretch stature from all other anthropometric variables. For the remaining variables it was decided to predict the values of the UNKNOWN variables from those variables that were already contained within the data i.e. those that were KNOWN, using relationships determined in a similar smaller sized sample. Unfortunately, the variables that had not been measured in the LIFESTYLE data were girths and skinfolds which were not as well correlated with height as the ergonometric variables used by Barkla (1961) and Pheasant (1982a), and could also be associated with significant skewness. The approach of Barkla and Pheasant was therefore, not appropriate to the prediction of girths and skinfolds in the LIFESTYLE data, since there could be reasonably be expected to be similar poor correlations with height and significant skewness in the skinfolds and girths of the LIFESTYLE data. A comparison of the degree of skewness and correlations with height between heights and skinfolds and girths was achieved by calculation of said values in the CANAD young adult university male and female samples. These problems of skewness and low correlations with height indicated that a different procedure was required to give reasonable estimates of population parameters for required variables which were not measured in the LIFESTYLE data.

The proposed procedure was to take a smaller independent sample containing all the required variables, establish predictive multiple regression equations for the unknown variables, from the known variables, and then to apply these predictive equations to the large LIFESTYLE data base. Frequency distributions could then be established based on this new larger LIFESTYLE data base. The detailed design of the predictive procedure with validation comparisons was outlined in Figure BI.4.

As illustrated in Figure BI.4 the tactic used to produce percentiles for all required variables was to predict values in the LIFESTYLE data set for those variables that were not measured from those variables that were measured. This required predictive multiple regression equations for each of the UNKNOWN variables using only KNOWN variables as predictors. A smaller independent sample was measured which contained all of the required anthropometric variables. This specially collected data set composed of 110 females and 103 males aged 18 - 70 years is described in Table BI.2. This was named the PREDICTOR data set as it was used to produce the prediction formulae to be applied to the LIFESTYLE data set. All data was collected by the author or a trained colleague (H.H.). No selection on terms of age was made other than subjects were to be between the ages of 18 to 70 years. The resultant bias happened to be towards the young end of the age scale. The following description of the procedures taken in the production of values for missing variables will be listed as a series of Steps. These steps correspond to the numbers that appear on the flow chart shown as Figure BI.4.

STEP 1: Multiple regression predictive equations were developed for all of the UNKNOWN variables in the LIFESTYLE data set. In order to check on their predictive ability a split sample analysis procedure was developed. A random 50% sampling of the males and also the females in the PREDICTOR data set was made using a pseudo-random number generator facility of the SPSSX package. Using the stepwise multiple regression programme of SPSSX along with the sample weight facility to give equal representation of age groups (10 year increment) multiple regression equations were produced for all variables. Only the KNOWN variables from the LIFESTYLE data set (Age, Height, Weight, Triceps, Subscapular, Biceps, Supraspinale and Medial Calf Skinfolds, and Flexed Arm and Maximal Calf Girths, and Humerus and Femur widths) were allowed to be included as predictor variables. One equation was produced for each variable for each sex. Age specific equations were not produced since age was included as a possible predictor variable and the analysis was weighted for equal contribution of age groups.

STEP 2: These predictive equations were then applied to the other 50% sample and comparison of predicted and observed values for each variable was made using oneway analysis of variance to test for differences between means, and Bartlett's Box F test to test for homogeneity of variances.

STEP 3: A new set of multiple regression equations were then produced using the entire PREDICTOR data set and the same weighting procedures as in step 1.

STEP 4: These equations were applied to the LIFESTYLE data set and predictions were made of both KNOWN and UNKNOWN LIFESTYLE variables.

STEP 5: Comparison is then made of predicted KNOWN variables to their actual KNOWN value. Because of the problem of regression to the mean the variance of the predicted values was too small in comparison to actual KNOWN values. Two methods for the expansion of the variance were then applied to the predicted values. The first method was to add a randomly generated error term to all individually predicted values. This error term was a number randomly selected from a normal distribution whose mean was zero and standard deviation is equal to the standard error of estimate of the predictive equation being used. This was called the S.E.E. expansion. A second tactic was to add a random error term calculated as a randomly selected value from a distribution with mean of zero and a standard deviation equal to the standard error of the predictive equation expressed as a percentage of the mean value for that variable in the PREDICTOR sample on which the equation was developed. This method was termed the %S.E.E. expansion.

These two expansions were proposed based on an understanding of the derivation of the standard error of estimate of a regression equation. When a regression model is developed it explains a portion of the total variance as indicated by the r^2 value. The total variance (S^2t) is the sum of the variance explained by the model (S^2m) and the error variance (S^2e):

$$S^2t = S^2m + S^2e$$

In the simplest model of the linear regression equation each actual value of Y is equal to the regression model plus an error term. As in:

$$Y = mX + c + e$$

where

m = slope
X = independent variable
c = intercept
e = error term (actual - predicted values)

The error variance (S^2e) is equal to the sum of squared error terms (e = actual - predicted values) divided by the square root of the number of observations. The standard error of the estimate is square root of the error variance. Because the predicted values in the LIFESTYLE data do not have an error term, the resultant distribution of predicted values has an overall reduced variance. This was corrected for by introducing an error term for each predicted value. This error term was derived knowing the standard error of estimate of the regression equation in the PREDICTOR sample. This error term was randomly selected from a normal distribution of values with mean equal to zero and the standard deviation equal to the standard error of estimate of the regression equation developed on the PREDICTOR sample. The effect of skewness tended to cause this method to introduce too little error variance into the upper part of the distribution and too much variance into the lower end of the distribution. This was overcome by using a percent standard error of estimate based on the mean of the value in the PREDICTOR sample. For example, the triceps skinfold standard error of estimate for the male subjects was 2.27mm; the percent standard error of estimate was therefore 100(2.27/10.2) = 22.3% where 10.2mm was the mean value for the triceps skinfold in the PREDICTOR sample. The error term to be added to each predicted value in the LIFESTYLE data using the equation developed in the PREDICTOR sample in this second expansion, was therefore selected from a normal distribution with mean zero and standard deviation equal to the percent standard error of estimate.

While the literature often reports methodologies for the prediction of missing data, none of these are similar to the methodology developed in this thesis. Investigators are interested in the prediction of missing values to complete data sets that may then be used for hypothesis testing. The methodology developed in this thesis would be totally inappropriate for this purpose, because in introducing the random error term the covariance matrix would be disturbed thus effecting relationships between variables within the data set. However, in this thesis the only intended use for the resultant data set is the production of normative percentile distributions for each value. **The prediction and expansion tactic developed in this thesis is therefore only appropriate when the purpose is to estimate distributions for normative scaling where individual values are subsumed in the normative range, and this tactic should**

never be used when further hypothesis testing is required on the resultant data set.

After the predictions and two forms of expansion, four distributions for each of the KNOWN variables were now available for analysis.

1) The actual measured values.

2) The predicted values.

3) The predicted values expanded using S.E.E..

4) The predicted values expanded using %S.E.E..

In order to test for significant differences between the distributions of actual KNOWN and the three predicted KNOWN values, an analysis of prediction errors was carried out. For each of the three predictions an error term was calculated as actual-predicted value. Because of the problem of regression to the mean, values higher than the mean tended to be underestimated whereas values below the mean tended to be overestimated. A plot of error against actual value would therefore tend to show a pattern of positive error at higher values and negative values at lower values. If the expansion used on the prediction improved the situation then there should have been a reduction in the relationship between error and actual size.

STEP 6: An additional analysis was carried out on the predictive ability of the multiple regression equations. This entailed predicting all variables in the CANAD data set (Appendix 1). This contained all the variables required for the O-SCALE system.

STEP 7: Actual and predicted values for al! variables in the CANAD data set were compared.

STEP 8: THe final step was to predict the values of the LIFESTYLE UNKNOWN variables using the %SE expansion to approximate the true distributions. These values in conjunction with the original KNOWN variables constituted the O-SCALE normative data base.

Figure BI.4: Schematic representation of steps taken in the production of the O-SCALE system normative data set.

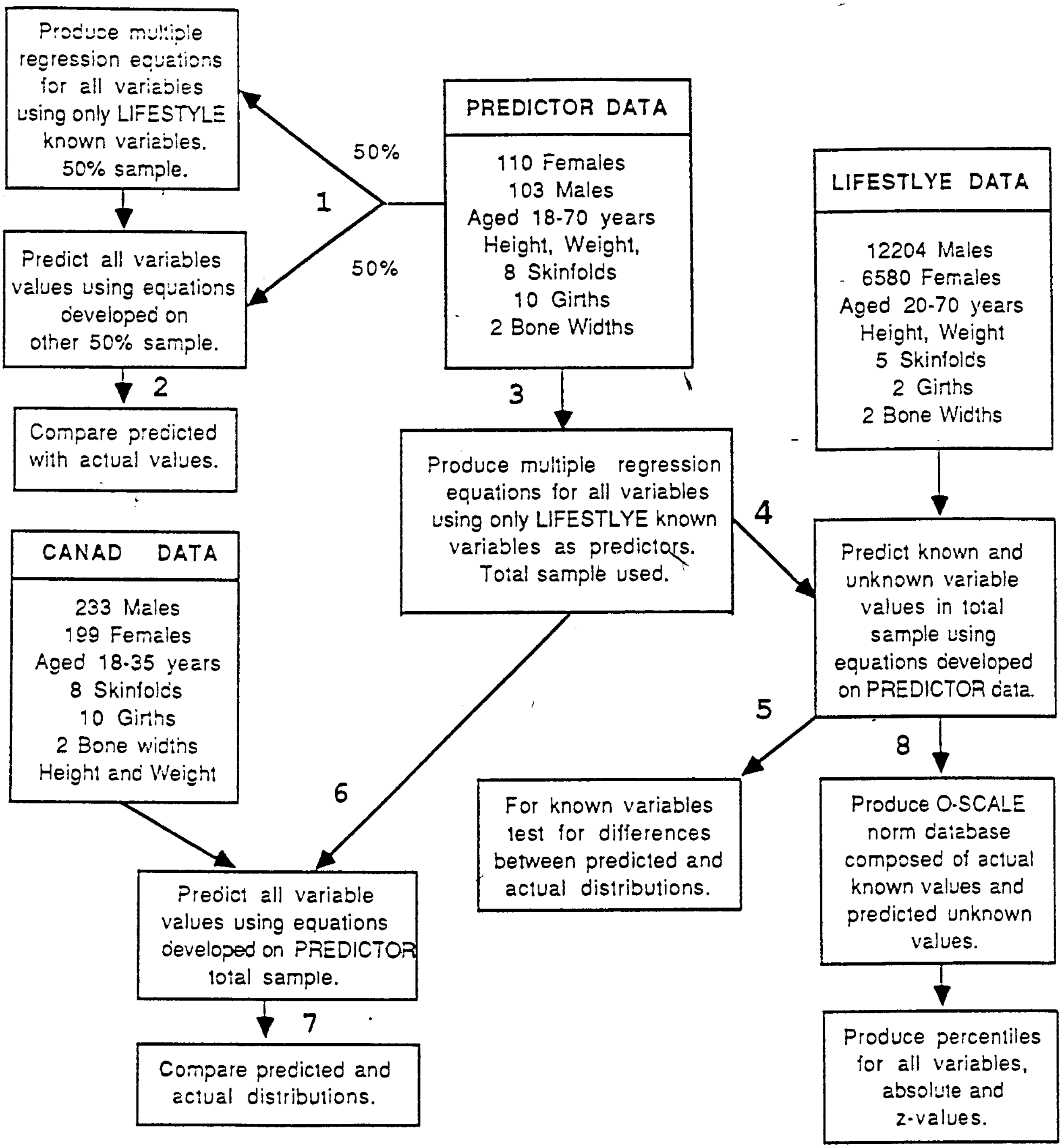


Table BI.2: Means and standard deviations (in brackets) of anthropometric variables for male and female data comprising the PREDICTOR data set.

	MALE (N=103)	FEMALE (N=110)
Age	37.5 (17.5)	32.0 (17.2)
Weight	77.3 (10.6)	59.5 (8.2)
Height	177.1 (6.8)	164.4 (7.4)
SKINFOLDS		
Triceps	10.2 (4.5)	16.8 (5.1)
Subscapular	12.5 (5.4)	12.6 (5.1)
Biceps	4.9 (2.7)	7.3 (3.0)
Iliac Crest	16.4 (9.2)	12.2 (5.1)
Supraspinale	9.3 (6.1)	11.9 (5.5)
Abdominal	17.8 (11.1)	17.9 (8.0)
Front Thigh	12.8 (5.9)	23.3 (7.3)
Medial Calf	8.0 (3.6)	14.4 (5.0)
GIRTHS		
Relaxed Arm	31.2 (3.2)	27.3 (2.5)
Flexed Arm	33.2 (3.1)	28.1 (2.6)
Forearm	28.0 (1.9)	23.9 (1.5)
Wrist	17.1 (0.9)	14.9 (0.8)
Chest	99.6 (6.8)	85.6 (4.8)
Waist	84.3 (8.6)	69.9 (6.8)
Gluteal	98.4 (6.3)	95.0 (6.3)
Thigh	56.8 (4.6)	55.7 (4.3)
Calf	37.6 (2.4)	35.3 (2.2)
Ankle	22.5 (1.8)	21.0 (1.2)
BONE WIDTHS		
Humerus	7.25 (0.39)	6.30 (0.39)
Femur	9.96 (0.54)	9.02 (0.43)

The net result of this process was that the data assembly comprised data from 16 to 18 years of age from the COGRO data set; data from 17 to 20 years of age from the CANAD data set and from 15 to 70 years of age from the LIFESTYLE data set, with predicted values of missing data in the LIFESTYLE and COGRO compilations.

ADIPOSITY AND PROPORTIONAL WEIGHT RATINGS

A decision was made that the O-SCALE system should consist of a general description of physique as in somatotype or percentage body fat, followed by a more detailed appraisal of individual anthropometric items. Two basic descriptors of physique were selected as the basis for the O-SCALE system. These were an adiposity rating (A) and a proportional weight rating (W). Adiposity was defined as being represented by a proportional sum of six skinfolds (pS6SF). This was calculated using the following formula:

Adiposity: pS6SF = Sum 6 Skinfolds x (170.18/Stature)

where: Sum 6 Skinfolds = Sum of triceps, subscapular, supraspinale abdominal, front thigh and medial calf skinfolds.

Proportional Weight (pWT) was calculated by the following formula:

Proportional Weight: pWT = Weight x $(170.18/\text{Stature})^3$

A and W Ratings were derived for each of the adiposity and proportional weight scores, by comparison to age and sex specific norms, expressed as stanine scores. The stanine distribution was one of many rating systems available based on the normal distributions. It provided 9 categories, of which the central 7 were even widthed in that they were 0.5 standard deviation apart. The first and ninth categories were open ended. Figure BI.6 showed the relationship of stanine categories to percentiles of the normal distribution.

Figure BI.5: Stanine ratings in comparison to percentiles of the normal distribution with associated category boundary percentiles

STANINE CATEGORIES

	1	2	3	4	5	6	7	8	9
Percentages	4	7	12	17	20	17	12	7	4
Boundary Percentiles	4	11	23	40	60	77	89	96	

For example, a person categorized as being in the bottom 4% with respect to their same age and sex norm would be rated as a "1", while the upper 4% would receive a rating of 9. The norms were derived for each sex and in age groups yearly from 6 to 18 years, years 18 and 19 together and in 5 year increments thereafter to age 70 years. Values of the adiposity and proportional weight percentiles 4, 11, 23, 40, 60, 77, 89 and 96 for each age and sex group were derived using the frequencies programme of the SPSSX statistical package (SPSS Inc. 1986). These percentiles represented the cut-off points for each category of the A and **W-ratings**.

MICROCOMPUTER RESOLUTION OF DATA

In addition to the general description of physique obtained via the A and **W-ratings**, further detailed analysis was provided using microcomputer analysis of the anthropometric data. An IBM compatible GWBASIC programme was written to allow for entry of anthropometric data and calculation of A and W ratings. In addition the programme allowed for the listing of anthropometric data in comparison to age and sex specific norms for each variable and calculation of Ross-Wilson Phantom z-values for all variables.

The general formula for the use of the Phantom geometrically scales all measures to the Phantom stature (170.18), obtains the difference from the given Phantom values (P) and expresses this as a deviation (s). In computational notation the formula is:

$$Z = ((\ v\ *\ ((\ 170.18/h\ )^{d}\ ))\ -\ P\ )\ /\ s$$

where:

Z	is a proportionality value or z-value.
v	is the size of any measured variable.
170.18	is the Phantom stature constant.
h	is the subject's obtained stature.
d	is a dimensional exponent. When scaled geometrically d=1 for all lengths, breadths, girths and skinfolds; d=2 for all areas and d=3 for all weights and masses.
P	is the Phantom value for the measured variable v.
s	is the Phantom standard deviation for variable v based on a hypothetical universal human population.

TABLE BI.3: Ross and Wilson Phantom P and s values for O-SCALE measurements.

VARIABLE	P	s
Weight	64.58	8.60
Height	170.18	6.29
SKINFOLDS		
Triceps	15.4	4.47
Subscapular	17.2	5.07
Biceps	8.0	2.00
Iliac Crest	22.4	6.80
Supraspinale	15.4	4.47
Abdominal	25.4	7.78
Front Thigh	27.0	8.33
Medial Calf	16.0	4.67
GIRTHS		
Relaxed Arm	26.89	2.33
Flexed Arm	29.41	2.37
Forearm	25.13	1.41
Wrist	16.35	0.72
Chest	87.86	5.18
Waist	71.91	4.45
Gluteal	94.67	5.58
Thigh	55.82	4.23
Calf	35.25	2.30
Ankle	21.71	1.33
WIDTHS		
Humerus	6.48	0.35
Femur	9.52	0.48
SKINFOLD-CORRECTED GIRTHS		
Relaxed Arm	22.05	1.91
Chest	82.46	4.86
Thigh	47.34	3.59
Calf	30.22	1.97

The P and s values used in calculation of z-values were listed in Table BI.3. It was necessary to calculate the 4th, 50th and 96th percentiles for each anthropometric item and its Ross-Wilson Phantom z-value for each age and sex category. This again was achieved by use of the SPSSX Frequencies package. The absolute measurements were then displayed on the microcomputer printout with a listing of the 4th, 50th and 96th percentile for the appropriate age and sex norm. The z-values however, were displayed graphically using a proportionality profile where the subject's z-values were plotted relative to the 4th, 50th and 96th percentiles of z-values for the appropriate age and sex norm group. Finally, calculation of percentage body fat was carried out using three different equations based on anthropometric variables and was placed at the end of the printout.

RELIABILITY OF THE O-SCALE SYSTEM ANTHROPOMETRIC TECHNIQUES

The O-SCALE system was based on anthropometry, therefore, possible measurement error was of tantamount importance in assessing the the performance of the system. Reliability of the anthropometric techniques was assessed in an independent sample using the technical error of measurement and its coefficient of variation as the criteria of reliability.

The subjects used in this study were 100 university students, 50 male 20 to 28 years of age and 50 female aged 19 to 41 years of age. They were all students taking a course in Kinanthropometry and were an independent sample from that collected as the CANAD data set. They were measured according to the 22 item O-SCALE anthropometric proforma, whose measurement techniques were listed earlier. The whole proforma was measured through once and then remeasurement was carried out. The data was then reviewed and any retest differences greater than acceptable tolerances were remeasured to resolve the difference. The mean of the closest two values was used as the criterion value. Data was collected in this fashion because of the time constraint of a 2 hour lab period when measurement was carried out. All skinfolds were measured by the author (RW), all girths were measured by a criterion anthropometrist (WDR), with stature weight and the bone widths being measured by other criterion anthropometrists. The data used for this investigation were the values of the first two measurements, which were carried out without reference to the values. The occasional third or fourth measurement value used to resolve differences were not included in the data analysed in this investigation.

Using the first and second measurements the technical error of measurement was calculated for each measurement for each sex. The coefficient of variation was then calculated using the mean value of the variable in question. The Technical Error was calculated as:

Technical Error = (Sum d^2 / 2n)0.5**

where:

d = difference between repeated measures

n = number of pairs of measurements

Edwards et al. (1955) and Johnston et al. (1972) indicated that the error of measurement was directly proportional to the size of measurement. Thus the Coefficient of Variation was proposed:

Coefficient of Variation = (Technical Error x 100) / Mean of the variable

These were compared to previously reported values for six of the skinfold sites (Anderson 1985).

<u>RESOLUTION OF THE MICROCOMPUTER GENERATED PROPORTIONALITY PROFILE</u>

The proportionality profile which constituted part of the microcomputer print out was composed of a text graphic utilising 45 spaces across the page. It was therefore important to determine the resolution of the proportionality profiles in terms of what change in each measurement was equal to the width of one charater space. This was determined by calculating for each age and sex norm group the difference in measurement required to move one character space. This was achieved by taking the 4th, 50th and 96th percentiles for phantom z-values for each item and calculating what change in measurement scaled to a height of 170.18 cm would be necessary to move one space on the graphic above or below the 50th percentile. The resolution was different above or below the 50th percentile because of the inherent skewness of the normative data. The z-values for the 4th (Z4), 50th (Z50) and 96th (Z96) percentiles were transformed to their equivalent size in original measurement units at a height of 170.18 cm (5' 7"). The difference between the size at the 4th percentile (V4) and the 50th percentile (V50) was divided by the number of spaces on the text graphic between the 4th and 50th percentiles, which was 10, in order to gain a measure of resolution in terms of unit of measure per space. In the case of skinfolds the units would be mm/space, for weight kg/space and for girths and bone widths cm/space. A similar procedure was carried out to calculate resolution above the 50th percentile. This was then transformed into a percentage of the 50th percentile and termed a Coefficient of Resolution, thus becoming a unit independent measure of resolution of the profile. The formulae used for these calculations were as follows:

For n = 4, 50 and 96

$$Vn = ((Zn * s) + P) / (170.18 / h)$$

where:

Zn = nth percentile of the Ross-Wilson Phantom z-value

P = Phantom mean value for given variable

s = Phantom standard deviation for given value

h = Phantom height of 170.18 cm

Vn = Equivalent size of percentile z-value at 170.18 cm

$$\text{Resolution below 50th percentile} = (V50 - V4) / 10$$

$$\text{Resolution above 50th percentile} = (V96 - V50) / 10$$

$$\text{Coefficient of Resolution} = (\text{Resolution} / V50) * 100$$

Having calculated the profile resolution and coefficients of resolution for all variables for all age and sex norm groups they were compared to the technical errors of measurement and their coefficients of variation derived for the reliability of the anthropometric measures earlier.

COMPARISON OF O-SCALE NORMS TO NATIONAL STANDARDS

The O-SCALE data for ages 16–70 years were compared with the percentiles produced from the Canada Fitness Survey of 1981 as reported in the Canadian Standardized Test of Fitness (Fitness and Amateur Sport Canada, 1986). Ideally, comparisons would have been made graphically for all available variables with all available norms. This however, would have produced an inordinate number of graphs. The decision made for the purposes of this thesis was to compare only critical measures to an accepted Canadian National sample. The measurements chosen were the two basic descriptors of triceps skinfold as an indicator of adiposity, and skinfold-corrected arm girth as an indicator of muscularity. Bailey, Carter and Mirwald (1982) have already shown the LIFESTYLE data to be comparable to that of Canadian and U.S. standards for height and weight.

THE STABILITY OF THE ADIPOSITY RATING

The resilience to error in adiposity rating was tested by adding error to the distribution of individual skinfolds and assessing how many times there was a change in the **A-rating**.

The data used for this investigation was that named the CANAD data set and described earlier. The sample consisted of 233 male and 199 female university students between the ages of 18 and 35 years. All data was collected by experienced anthropometrists. The data used in this investigation was age, stretch stature, and six skinfolds (triceps, subscapular, supraspinale, abdominal, front thigh and medial calf). The O-SCALE A (adiposity) rating was calculated for each subject. Then using a pseudorandom number generator facility of the SPSSX statistical package an error term was added to each of the the individual skinfold measurements for each subject. The error term was a value randomly selected from a distribution whose mean was zero and standard deviation was a given percentage of the actual value. This was carried out three times with the percentages used being 2.5, 5 and 10. For each of these three new data sets the O-SCALE **A-ratings** were calculated. The difference between actual **A-rating** and the new error induced **A-rating** was calculated for each of the three trials by subtracting the actual **A-rating** from the error induced **A-rating**. Thus, the difference would be negative if the new **A-rating** underestimated the actual **A-rating**.

CONTROL OF ERROR BY REPLICATION OF ANTHROPOMETRIC MEASURES

Being an anthropometrically based system the control of possible error was of tantamount importance. One of the reccommendations accompanying the collection of the anthropometric data was that three measurement trials be used and the median of the three be used as the criterion value of the three. The purpose of this study was to determine whether in fact the median was the most resilient method for the selection of a criterion value from repeated measures.

Triple measurements of six skinfolds (triceps, subscapular, supraspinale, abdominal, front thigh and medial calf), and relaxed arm, forearm and maximal calf girths were carried out by the author (RW) on 67 females aged 16 to 60 years. No particular selection criteria for subjects was used other than that they be female and had triplicate measures of all six skinfolds and three girths.

Technical errors of measurement were determined for each of the nine anthropometric variables. The technical error of measurement was determined as the square root of the average sum of squared deviations between repeat measures divided by twice the sample size as discussed earlier. This was also converted to it's coefficient of variation by dividing the technical error by the mean of the three measurements multiplied by 100.

Five tactics were then applied to the data to select a criterion of the triplicate measures. The five tactics and the code names they were referred to during this study were:

SINGLE : First measurement

MEAN-2 : Mean of the first and second measurement

MEAN-3 : Mean of all three measurements

MEAN-C : Mean of the closest two measurements

MEDIAN : Median value of the three measurements

Having selected the criterion values using the five different tactics, a random error term was added to the first measurement. This was achieved by adding an error term to each individual first measure. This error term was selected from a normal distribution with mean equal to zero and with standard deviation equal to the coefficient of variation of the anthropometric variable in question. The five tactics for selecting the criterion value were now again applied to the data set but this time containing the erroneous first measurement. This resulted in five new estimates of the criterion value which were referred to as the erroneous criterion value. The technical error of measurement was then calculated between the original criterion value for each tactic and the corresponding erroneous criterion value. This allowed for assessment of the resilience of each of the five selection tactics to imposed error on the first measurement by comparison of the magnitude of the technical errors of measurement between each criterion value and its counterpart erroneous criterion value.

This whole procedure was repeated but this time the error term added to the first measurement value was selected from a normal distribution with mean equal to zero and standard deviation equal to three times the coefficient of variation of each measurement. This larger error term was used to introduce gross errors into the data set. The technical errors were again calculated in the same fashion as before in order to compare the resilience of each tactic to the imposed gross errors.

The following chapter presented the results obtained from the above listed procedures. They were presented in the same sequence as they were discussed in this chapter.

CHAPTER II

RESULTS 1: THE DEVELOPMENT OF THE O-SCALE SYSTEM

ESTIMATION OF MISSING DATA IN O-SCALE NORMATIVE DATA BASE

Table BII.1 showed correlation coefficients between height and various heights, breadths, girths and skinfold measures. Also listed are the coefficients of skewness for the variables contained in the CANAD data set.

Table BII.1 demonstrated that the lengths and breadths were more highly correlated with height than were the skinfolds or girths. Indeed in the males, seven skinfolds, supraspinale being the exception, were not significantly correlated to height ($p>0.05$). In females six of the skinfolds, with the exceptions being subscapular and medial calf, were not significantly correlated with height. In both males and females all girths showed smaller correlations than any of the heights. With regard to skewness, all male skinfolds and triceps, subscapular and medial calf sites in females exhibited significant skewness (coefficient of skewness > 1).

Multiple regression equations were produced using a randomly selected 50% of the PREDICTOR data set allowing only the KNOWN variables from the LIFESTYLE data set to be used as predictor variables. Table BII.2 showed the frequency of 10 year age categories for the males and females in the sample. The greatest numbers were in the 20 to 30 year age group. These predictive regression equations were then applied to the other 50% of the sample.

Table BII.1: Correlation coefficients (r) of height with weight, skinfolds, heights, girths and breadths in the CANAD males (N=233) and females (N=199) along with associated coefficients of skewness (s) for all variables.

	MALES		FEMALES	
	r	s	r	s
Height	.	-0.10	.	0.18
Weight	0.52	0.49	0.64	0.55
SKINFOLDS				
Triceps	-0.08*	1.88#	0.08*	1.13#
Subscapular	-0.09*	3.71#	-0.12	1.58#
Biceps	-0.04*	2.42#	0.04*	0.91
Iliac Crest	-0.03*	1.04#	0.04*	0.99
Supraspinale	-0.13	3.20#	0.00*	0.97
Abdominal	-0.09*	1.83#	-0.04*	0.88
Front Thigh	-0.10	1.37#	0.06*	0.72
Medial Calf	-0.08*	2.14#	0.13	1.37#
HEIGHTS				
Acromiale	0.93	-0.14	0.97	0.17
Radiale	0.89	-0.27	0.94	0.17
Stylion	0.82	-0.08	0.87	0.05
Dactylion	0.75	-0.22	0.80	0.22
Spinale	0.89	-0.14	0.89	-0.21
Trochanterion	0.81	-0.36	0.91	0.05
Tibiale	0.86	-0.06	0.85	0.33
Sitting Height	0.74	0.12	0.82	0.27
GIRTHS				
Relaxed Arm	0.09	0.75	0.17	0.60
Flexed Arm	0.12	0.56	0.24	0.80
Forearm	0.27	0.37	0.35	1.34#
Wrist	0.37	-0.03	0.56	0.67
Chest	0.25	0.31	0.29	0.29
Waist	0.23	0.95	0.31	0.59
Thigh	0.20	0.40	0.35	0.19
Calf	0.25	0.19	0.37	0.38
Ankle	0.35	0.11	0.44	0.79
BREADTHS				
Biacromial	0.38	-0.31	0.55	-0.23
Biiliocristal	0.48	0.93	0.50	1.08
A.P. Chest	0.21	0.39	0.24	-0.09
Transverse Chest	0.31	0.35	0.35	0.04
Humerus	0.54	0.05	0.55	0.11
Femur	0.46	0.10	0.53	0.13

* No significant relationship
\# significant skewness

Table BII.2: Frequency of individuals in ten year age categories in PREDICTOR data set.

Age Group	MALES	FEMALES
18-19	2	11
20	50	68
30	5	5
40	22	6
50	5	4
60	15	10
70	4	6
TOTAL	103	110

Table BII.3 listed the means and standard deviations of actual and predicted values for all skinfolds and girths in the 50% sample. As can be seen for all variables no significant differences were found between means of actual and predicted using oneway analysis of variance ($p<0.05$) However, Bartlett-Box F testing showed that variance is significantly reduced ($p<0.05$) in the predicted distributions for biceps and medial calf skinfolds, flexed arm, wrist, calf and ankle girths in males and triceps, subscapular, front thigh and medial calf skinfolds, and flexed arm, wrist, chest, calf and ankle girths in females. This identified the expected problem associated with the prediction of population values using predictive equations. That being the regression towards the mean, whereby values above the mean tend to be underestimated and values below the mean tend to be overestimated. In terms of percentile distributions this would mean that the 4th and 25th percentiles would be assigned a value greater than real values should be and the 75th and 96th percentiles would be given values lower than true values. This necessitated the next step of the investigation which is to develop a technique to expand the variance in the predictions to give values for percentiles which were appropriate for the population.

In order to maximise the predictive ability of the multiple regression equations, new sex specific regression equations were developed using the entire PREDICTOR sample. The resultant multiple regression equations for males and females for each of the UNKNOWN and KNOWN variables respectively can be found in Appendix 5.

Table BII.3: Means and standard deviations (brackets) of actual and predicted anthropometric variables for randomly selected 50% subsample of PREDICTOR data.

VARIABLE	MALES (N=52)		FEMALES (N=55)	
SKINFOLDS	Actual	Predicted	Actual	Predicted
Triceps	10.8 (4.8)	10.4 (3.9)	17.1 (5.2)	17.0 (4.2)*
Subscapular	12.7 (5.2)	12.9 (4.8)	11.9 (5.0)	12.3 (3.8)*
Biceps	5.2 (3.2)	5.1 (1.7)*	7.2 (2.9)	7.5 (2.4)
Iliac Crest	17.4 (9.9)	17.1 (7.8)	12.1 (5.3)	11.9 (4.4)
Supraspinale	9.6 (6.4)	9.5 (5.3)	11.8 (5.4)	11.7 (4.7)
Abdominal	18.9 (11.9)	18.7 (10.1)	18.7 (7.8)	18.1 (6.8)
Front Thigh	13.2 (6.5)	13.2 (5.1)	24.1 (7.5)	24.0 (6.0)*
Medial Calf	8.1 (3.6)	8.3 (3.1)*	14.8 (5.1)	14.6 (3.5)*
GIRTHS				
Arm Relaxed	31.2 (3.2)	31.3 (3.1)	27.4 (2.7)	27.5 (2.6)
Arm Flexed	33.3 (2.9)	33.3 (2.4)*	28.3 (2.7)	28.3 (1.9)*
Forearm	27.9 (1.8)	28.0 (1.7)	24.0 91.9)	24.0 (1.5)
Wrist	17.1 (0.9)	17.2 (0.7)*	15.0 (0.9)	15.0 (0.6)*
Chest	99.8 (6.2)	99.7 (5.5)	85.9 (4.6)	85.5 (3.8)*
Waist	85.1 (8.0)	84.7 (7.4)	70.1 (6.6)	70.2 (5.7)
Gluteal	98.6 (6.9)	98.4 (5.4)	94.9 (5.5)	94.9 (5.3)
Thigh	56.7 (4.8)	56.6 (4.2)	55.6 (4.0)	55.7 (3.5)
Calf	37.5 (2.5)	37.6 (1.8)*	35.3 (2.5)	35.3 (1.5)*
Ankle	22.5 (2.2)	22.5 (1.4)*	21.0 (1.2)	20.9 (0.9)*

* sig difference in variances between predicted and actual using Bartlett-Box F ($p<0.05$)

Each of these predictive equations was then applied to the LIFESTYLE data to give individual predictions of both KNOWN and UNKNOWN variables. The comparison of the actual to predicted values of the KNOWN variables allowed for an evaluation of predictive ability and also the variance expansion techniques to be attempted. Two forms of expansions of the predicted distributions were carried out. As previously explained, the first utilized the standard error of estimate of the particular PREDICTOR regression equation. An error term is added to the predicted value. This error term was randomly selected from a normal distribution with mean zero and standard deviation equal to the standard error of estimate. These standard errors were listed in Table BII.4. The second expansion called the %S.E.E. expansion entailed adding an error term selected from a normal distribution with mean zero and standard deviation equal to a perecentage expressed as the standard error of estimate as a percentage of the mean for the PREDICTOR sample on which the equation was developed. These means and percentages were also displayed in Table BII.4.

Table BII.4: Means, S.E.E. and %S.E.E. for PREDICTOR equations

VARIABLE	MALE			FEMALE		
KNOWN	Mean	SEE	%SEE	Mean	SEE	%SEE
Triceps Sf	10.2	2.27	22.3	16.8	2.90	17.3
Subscapular Sf	12.5	2.77	22.2	12.6	3.12	24.8
Biceps Sf	4.9	2.20	44.9	7.3	1.68	23.0
Supraspinale Sf	9.3	3.42	36.8	11.9	2.68	22.5
Medial Calf Sf	8.0	2.22	28.8	14.4	3.63	25.2
Flexed Arm G.	33.2	1.83	5.5	28.1	1.73	4.9
Calf G.	37.6	1.59	4.2	35.3	1.47	4.2
UNKNOWN						
Iliac Crest Sf	16.4	5.29	32.3	12.2	2.57	21.1
Abdominal Sf	17.8	5.48	30.8	17.9	4.13	23.1
Fron Thigh Sf	12.8	3.20	25.0	23.3	4.33	18.6
Relaxed Arm G.	31.2	1.09	3.5	27.3	0.59	2.2
Forearm G.	28.0	0.78	2.8	23.9	0.64	2.7
Wrist G.	17.1	0.51	3.0	14.9	0.52	6.7
Chest G.	99.6	3.55	3.6	85.6	2.74	3.2
Waist G.	84.3	3.71	4.4	69.9	3.45	4.9
Gluteal G.	98.4	3.05	3.1	95.0	3.09	3.3
Thigh G.	56.8	2.06	3.6	55.7	2.28	4.1
Ankle G.	22.5	1.21	5.4	21.0	0.86	4.1

An error in prediction was calculated for each individual for each of the KNOWN variables for each of the three predictions. This error was the actual value minus the predicted value. Because of the regression towards the mean the error is related to the size of the variable, in that values above the mean tended to be underestimated and values below the mean tended to be overestimated. The purpose of the expansions was to eliminate or at least significantly reduce this relationship. In illustration of this approach Figure BII.1 showed the individual errors in prediction for maximum calf girth in the male 20 to 25 year old sample from the LIFESTYLE data set. The top graph showed the relationship between error and actual size of calf girth when the prediction used the regression equation alone. There was a significant relationship between error and actual size of calf girth (r^2=0.56, $p<0.05$) in this case. After both the S.E.E. and %S.E.E. expansions there was no significant relationship between error and actual size of calf girth (r^2=0.00, $p>0.05$ and r^2=0.00, $p>0.05$ respectively). The expansions could both be regarded as successful in that they removed any relationship of error to size. Consideration of the r^2 showed the reduction in the size to error relationship for the two expansions. Table BII.5 showed the r^2 values for the error versus actual value for all the known variables of the 20 to 25 year old LIFESTYLE males and females. For all variables, both expansions had an effect in reducing the relationship between size of variable and error.

Figure BII.1: Calf Girth size versus prediction error, using predicted values (top); predicted value plus SE expansion (middle); predicted value plus %SE expansion (bottom).

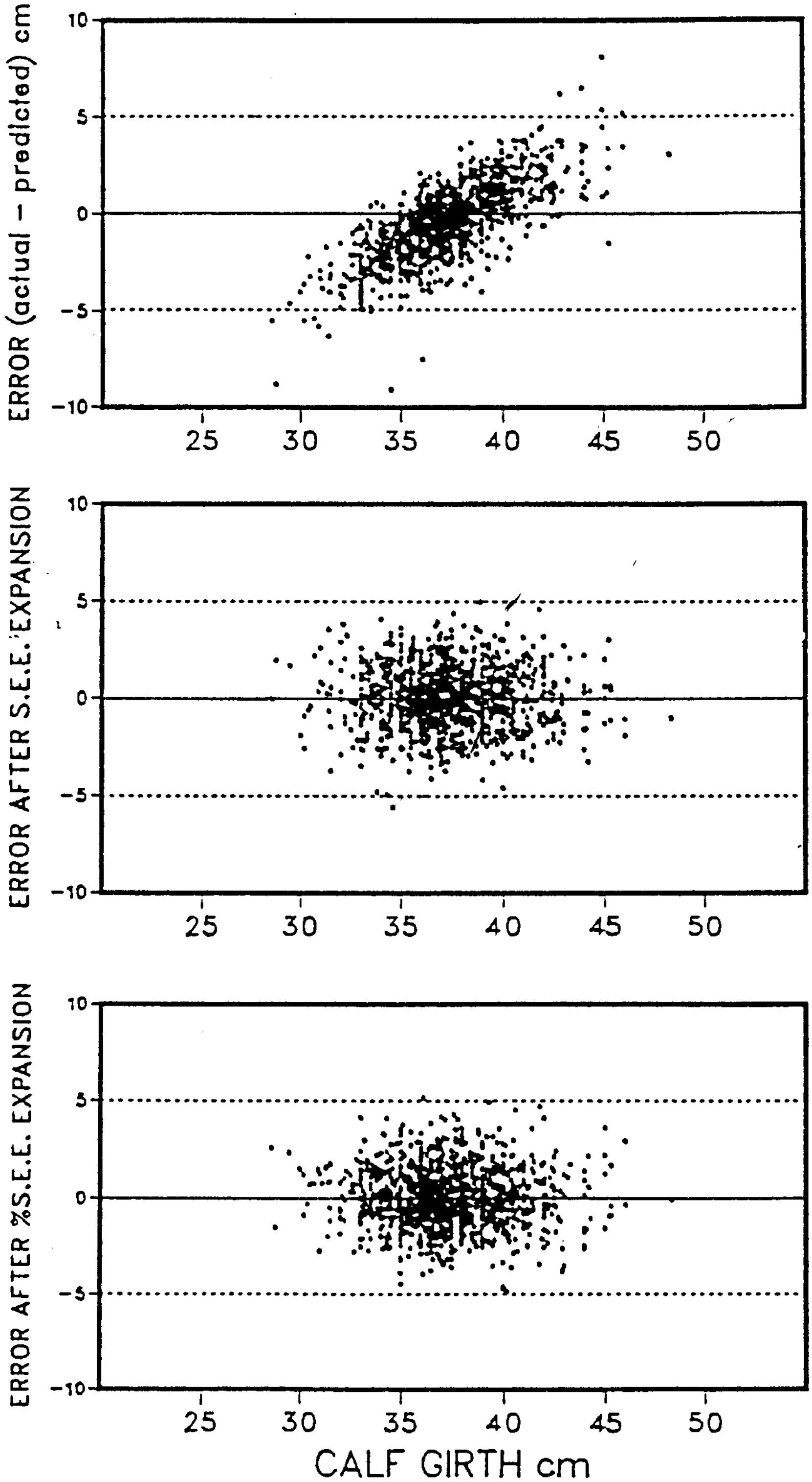


Table BII.5: R^2 values for Error versus Actual value in LIFESTYLE males and females age 20–25 years. P = Predicted, SE = Standard Error expanded, %SE = Percentage Standard Error expanded.

		MALES	FEMALES
SKINFOLDS		r^2	r^2
Triceps	P	0.11	0.45
	SE	0.07	0.27
	%SE	0.04	0.26
Subscapular	P	0.44	0.39
	SE	0.28	0.25
	%SE	0.29	0.24
Biceps	P	0.60	0.50
	SE	0.19	0.36
	%SE	0.18	0.34
Supraspinale	P	0.38	0.23
	SE	0.24	0.18
	%SE	0.18	0.13
Medial Calf	P	0.58	0.52
	SE	0.38	0.31
	%SE	0.35	0.34
GIRTHS			
Relaxed Arm	P	0.39	0.34
	SE	0.20	0.16
	%SE	0.21	0.16
Calf	P	0.56	0.46
	SE	0.00	0.30
	%SE	0.00	0.29

This analysis showed whether or not the problem of regression to the mean had been reduced, but it did not answer the question as to whether or not the equations were predicting approporiate values for the variables. This entailed comparing the means, standard deviations and percentiles of the predicted variables with the actual values. Table BII.6 showed the mean and standard deviations of the actual and predicted distributions for the KNOWN variables by sex in the entire LIFESTYLE data set. In the males all the predicted skinfold distributions had significantly different means ($p<0.05$) to the actual distributions. Predicted means were significantly higher for the triceps skinfold (+2.0mm) and lower for subscapular (-1.1mm), biceps (-0.4mm), supraspinale (-2.3mm) and medial calf skinfolds (-1.0mm). The relaxed arm girth was not significantly different and the calf girth was significantly larger (+0.3cm). The expanded values showed similar patterns, except that the calf girth was not significantly different for either expansion. In the females the pattern of differences was similar. The triceps skinfold was predicted to be significantly larger (+1.6mm), the subscapular was smaller (-0.8mm) as was the biceps (-1.1mm) and medial calf skinfolds (-1.0mm). The supraspinale skinfold showed a reversed pattern of being significantly larger (+0.2mm). Both relaxed arm (+0.7cm) and maximum calf girths (+0.5cm) were significantly larger. Table BII.6 showed the 5th, 25th, 50th, 75th and 95th percentiles for the KNOWN variables for the entire LIFESTYLE data set aged 20 - 70 years. Adjusting for the systematic under or over prediction of variables the percentiles in the %SEE expanded distributions were more similar to the actual distributions than the predicted or SE expanded values. The SE expansion seemed to predict particularly low values for the 5th percentile in the skinfolds.

Table BII.6: Means and standard deviations for actual and predicted KNOWN variables for males and females in entire LIFESTYLE data set. Significant differences indicated between means of actual and predicted by analysis of variance (ANOVA) and significant differences in variances between actual and predicted distributions by Bartlett's Box F (Bart).

		MALES (N=12,204)				FEMALES (N=6,580)			
		Mean	S.D.	Anova	Bart	Mean	S.D.	Anova	Bart
TPSF	A	10.7	4.1			17.2	5.8		
	P	12.7	4.3	*		18.8	4.8	*	
	SE	12.6	4.8	*		18.9	5.6	*	
	%SE	12.7	5.3	*		18.8	5.8	*	
SSSF	A	16.0	6.3			14.8	6.1		
	P	14.9	4.5	*		14.0	5.2	*	
	SE	14.8	5.3	*		13.9	6.1	*	
	%SE	14.8	5.7	*		14.0	6.4	*	
BISF	A	6.1	2.6			9.0	4.1		
	P	5.7	1.6	*	*	7.9	2.9	*	
	SE	5.7	2.6	*		7.8	3.3	*	
	%SE	5.7	3.0	*		7.9	3.5	*	
SISF	A	13.9	7.0			13.7	6.9		
	P	11.6	5.3	*		13.9	5.7		
	SE	11.6	6.3	*		13.9	6.3		
	%SE	11.5	7.0	*		14.0	6.7		
MCSF	A	9.4	4.1			16.1	6.0		
	P	8.4	2.7	*	*	14.7	4.4	*	
	SE	8.4	3.4	*		14.6	5.7	*	
	%SE	8.4	3.6	*		14.6	5.7	*	
AGF	A	33.5	2.7			28.1	2.8		
	P	33.6	2.4			28.8	2.4	*	
	SE	33.5	3.0			28.8	3.0	*	
	%SE	33.5	2.9			28.8	3.0	*	
CAG	A	37.4	2.6			34.8	2.7		
	P	37.7	1.9	*		35.3	2.1	*	
	SE	37.4	3.0			35.3	2.6	*	
	%SE	37.4	3.0			35.3	2.7	*	

* Significant difference (p<0.05)
\# Significant difference (p<0.05)

Table BII.7: Percentiles of predicted and actual KNOWN variables for entire LIFESTYLE data set. A = Actual, P = Predicted, SE = Standard error of estimate expanded, %SE = Percentage Standard error of estimate expanded.
TPSF, SSSF, BISF, SISF and MCSF represent Triceps, Subscapular Biceps, Supraspinale and Medial Calf skinfold respectively. AGF and CAG represent the flexed arm and maximal calf girths.

		MALES					FEMALES				
		Percentiles					Percentiles				
		5	25	50	75	95	5	25	50	75	95
TPSF	A	5.1	7.8	10.0	13.0	19.1	8.8	13.0	16.5	20.4	28.5
	P	6.8	9.6	12.0	14.9	21.2	12.2	15.3	18.0	21.4	28.6
	SE	5.4	9.3	12.1	15.4	21.9	10.3	14.9	18.2	22.0	29.5
	%SE	5.6	8.9	11.8	15.5	23.3	10.6	14.5	17.9	21.9	30.4
SSSF	A	7.8	11.4	14.9	19.4	28.7	7.3	10.4	13.4	18.0	28.4
	P	8.0	11.6	14.3	17.4	23.7	7.1	10.4	13.1	16.6	24.2
	SE	6.3	11.1	14.4	18.1	24.7	4.7	9.9	13.2	17.4	25.3
	%SE	6.8	10.7	14.0	18.0	26.1	5.7	9.6	12.8	17.1	26.9
BISF	A	3.0	4.2	5.5	7.4	11.7	3.9	6.0	8.1	11.0	17.1
	P	3.6	4.6	5.5	6.6	8.9	4.0	5.9	7.3	9.4	13.7
	SE	1.1	3.9	5.7	7.5	10.5	2.8	5.6	7.5	9.7	14.3
	%SE	1.2	3.7	5.4	7.4	11.7	3.3	5.4	7.2	9.6	14.9
SISF	A	5.0	8.6	12.4	17.8	27.2	5.4	8.7	12.1	17.2	28.6
	P	4.0	7.7	10.8	14.5	22.3	6.3	9.8	12.9	16.8	25.7
	SE	1.5	7.2	11.0	15.4	23.6	4.9	9.4	13.1	17.4	26.3
	%SE	2.4	6.5	10.1	15.1	26.1	5.3	9.1	12.7	17.4	27.9
MCSF	A	4.2	6.4	8.5	11.4	18.0	7.0	12.0	15.5	19.4	28.0
	P	4.7	6.5	8.0	9.8	13.8	8.5	11.7	14.0	17.0	23.5
	SE	2.8	6.0	8.1	10.5	14.8	5.5	10.7	14.3	18.1	25.5
	%SE	3.4	5.8	7.8	10.2	15.6	6.4	10.6	13.9	17.7	26.4
AGF	A	29.0	31.8	33.5	35.2	38.5	24.0	26.2	27.9	29.6	33.6
	P	29.9	32.0	33.3	34.8	38.1	25.4	27.1	28.4	30.0	33.8
	SE	28.6	31.5	33.4	35.4	39.1	23.9	26.8	28.5	30.5	34.4
	%SE	28.8	31.5	33.3	35.3	39.1	24.2	26.7	28.5	30.5	34.6
CAG	A	33.0	35.7	37.3	39.0	42.2	30.5	33.0	34.7	36.5	39.9
	P	34.9	36.4	37.5	38.8	41.3	32.3	33.9	35.1	36.4	39.4
	SE	32.3	35.4	37.3	39.4	43.0	31.3	33.6	35.2	36.9	40.1
	%SE	32.2	35.3	37.3	39.3	43.0	31.2	33.6	35.1	36.9	40.3

As a supplemental test of the predictive equations individual values were predicted for the CANAD male and female samples. Table BII.8 showed the mean and standard deviations of the actual predicted and expanded distributions for all variables. The equations were seen to work better in prediction of CANAD values than they did for the LIFESTYLE KNOWN variables. Again the %SE expanded distributions appeared to be the best estimate of actual values based on ANOVA and Bartlett's box F.

Table BII.8: CANAD means (sd) of predicted and actual values for all eight skinfolds and ten girths required in the O-SCALE norms.

MALES (N=233)

	Actual	Predicted	SE Expanded	%SE Expanded
TPSF	9.5 (4.2)	9.4 (3.8)	9.6 (4.3)	9.5 (4.2)
SSSF	10.4 (4.8)	9.9 (3.4)	9.9 (4.7)	9.9 (4.2)
BISF*	4.2 (2.1)	4.4 (1.3)	4.2 (2.9)	4.9 (2.6)
ILSF*	13.5 (6.8)	13.5 (6.1)	13.4 (7.6)	13.1 (6.7)
SISF	7.6 (4.7)	7.5 (4.8)	7.6 (5.8)	7.7 (5.1)
ABSF	13.0 (7.8)	13.7 (7.7)	13.3 (9.4)	13.8 (9.4)
THSF	12.3 (5.6)	12.4 (5.0)	12.4 (6.1)	12.3 (5.8)
MCSF	8.0 (4.0)	7.5 (2.7)	7.5 (3.4)	7.3 (3.0)
AGR	30.6 (2.7)	31.1 (2.5)	31.1 (2.9)	31.1 (2.7)
AGF	32.9 (2.7)	33.6 (1.8)	33.4 (2.5)	33.5 (2.5)
FAG	27.9 (1.8)	28.0 (1.4)	28.0 (1.7)	27.9 (1.5)
WRG	17.0 (0.8)	16.9 (0.7)	16.8 (0.8)	17.0 (0.8)
CHG	96.4 (6.1)	97.7 (5.1)	98.0 (6.2)	97.4 (6.0)
WAG	79.2 (5.9)	79.1 (6.2)	79.3 (7.3)	79.3 (6.7)
GLG*	98.3 (5.1)	98.4 (4.9)	98.6 (6.6)	98.6 (5.1)
THG	56.5 (3.9)	57.2 (3.1)	57.0 (3.6)	57.2 (3.8)
CAG	37.3 (2.1)	37.6 (1.5)	37.2 (2.6)	37.3 (2.6)
ANG	22.4 (1.3)	22.4 (1.2)	22.3 (1.8)	22.3 (1.6)

* N = 80

FEMALES (N=199)

	Actual	Predicted	SE Expanded	%SE Expanded
TPSF	16.3 (4.9)	15.4 (2.9)	15.4 (4.2)	15.1 (3.9)
SSSF	12.2 (4.7)	11.6 (3.3)	11.7 (4.2)	11.5 (4.4)
BISF*	6.7 (2.3)	6.7 (1.7)	6.6 (2.6)	6.8 (2.4)
ILSF*	11.8 (4.9)	11.9 (3.9)	11.4 (4.4)	11.6 (4.5)
SISF	10.3 (4.5)	10.9 (4.3)	10.9 (5.2)	10.9 (5.3)
ABSF	16.5 (6.9)	15.5 (5.1)	15.1 (6.8)	15.5 (6.4)
THSF	24.6 (7.8)	22.7 (5.8)	22.6 (7.1)	23.0 (7.2)
MCSF	14.4 (5.3)	13.8 (3.2)	13.9 (4.6)	13.7 (5.1)
AGR	26.4 (2.1)	26.9 (2.2)	26.9 (2.3)	26.9 (2.1)
AGF	27.2 (2.1)	27.8 (1.6)	27.7 (2.3)	27.6 (2.2)
FAG	23.7 (1.4)	23.5 (1.2)	23.4 (1.4)	23.5 (1.4)
WRG	14.9 (0.7)	14.8 (0.5)	14.7 (0.7)	14.8 (0.7)
CHG	84.9 (4.4)	84.6 (3.4)	84.6 (4.4)	84.8 (4.5)
WAG	68.2 (4.7)	67.5 (4.2)	67.3 (5.7)	67.7 (5.5)
GLG*	94.1 (5.3)	94.2 (5.1)	93.6 (6.2)	94.5 (5.6)
THG	55.6 (3.8)	55.0 (3.4)	54.8 (4.4)	55.3 (4.2)
CAG	35.1 (2.1)	35.3 (1.5)	35.3 (2.1)	35.3 (2.2)
ANG	20.9 (1.3)	20.8 (0.8)	20.8 (1.2)	20.9 (1.2)

* N = 105

ADIPOSITY AND PROPORTIONAL WEIGHT RATINGS

Having derived the composite O-SCALE data base, Tables BII.9 to BII.10 displayed the resultant stanine category cut-off points at percentiles 4, 11, 23, 40, 60, 77, 89, and 96 for Adiposity and Proportional Weight ratings for males and females respectively, derived using the frequencies package of the SPSSX statistical package. These categorizations were also displayed graphically in Figures BII.2 to BII.3. Figure BII.3 showed that there was a steady rise in proportional weight with increasing age in both males and females from ages 16 to 70 years. There was a slight reduction in all the percentiles during the last decade for males and in the upper percentiles for the females. The stanine boundary percentiles curves were remarkably smooth considering that no smoothing procedure had been undertaken. This reflected the stability of large size sample data base. The proportional sum of six skinfolds curves (Figure BII.2) reflected similar patterns to those of the proportional weight curves, with females exhibiting the greatest rise in the curves with increasing age.

Table BII.9: ADIPOSITY RATING
Stanine ratings for proportional sum of six skinfolds for male and female age categories.

M A L E S

S T A N I N E   R A T I N G

A G E (years)	1	2	3	4	5	6	7	8	9
16-17.999	31.6	36.6	41.6	46.8	53.8	62.6	83.4	143.5	
18-19.999	32.3	39.6	45.7	52.0	62.5	74.5	104.0	128.4	
20-24.999	35.0	40.9	48.1	57.8	71.5	89.0	109.0	130.0	
25-29.999	38.3	45.5	54.5	66.8	81.8	99.5	119.3	144.0	
30-34.999	41.9	49.8	60.3	72.2	87.3	103.9	121.3	145.5	
35-39.999	43.9	53.0	62.3	73.9	88.1	102.5	121.9	143.0	
40-44.999	46.0	53.9	64.2	74.6	87.5	102.5	121.0	142.5	
45-49.999	44.7	55.2	64.8	76.3	90.5	106.8	123.4	147.0	
50-54.999	47.2	56.3	66.3	75.7	87.8	105.0	121.0	140.0	
55-59.999	46.9	56.8	65.8	76.4	87.5	101.1	115.9	136.0	
60-64.999	47.3	53.9	64.8	74.5	87.2	98.3	116.8	134.3	
65-69.999	43.0	53.0	60.5	71.6	84.3	92.9	104.8	121.5	

F E M A L E S

S T A N I N E   R A T I N G

A G E (years)	1	2	3	4	5	6	7	8	9
16-17.999	57.9	65.2	75.9	88.8	101.1	113.2	124.2	162.8	
18-19.999	62.4	69.2	78.8	93.0	108.6	124.3	143.9	173.3	
20-24.999	64.0	72.5	81.2	92.0	104.2	118.9	138.0	164.0	
25-29.999	65.2	74.1	82.2	93.0	107.9	122.9	141.0	169.2	
30-34.999	64.1	72.0	81.9	94.6	108.0	126.0	144.3	172.2	
35-39.999	64.5	73.9	85.5	97.9	112.1	131.7	148.0	178.4	
40-44.999	69.5	80.5	90.3	102.4	120.7	140.9	161.1	187.3	
45-49.999	72.5	83.2	97.7	110.5	125.7	141.8	165.1	194.0	
50-54.999	70.0	84.5	96.2	112.5	127.8	144.8	168.3	196.5	
55-59.999	46.9	90.1	102.6	115.7	130.5	152.8	169.9	198.2	
60-64.999	78.3	85.3	96.8	114.6	130.6	146.4	166.0	194.0	
65-69.999	74.3	84.8	97.0	110.4	130.7	140.7	153.4	164.6	

Table BII.10: PROPORTIONAL WEIGHT RATING
Stanine ratings for proportional weight for male and female age categories.

M A L E S

S T A N I N E   R A T I N G

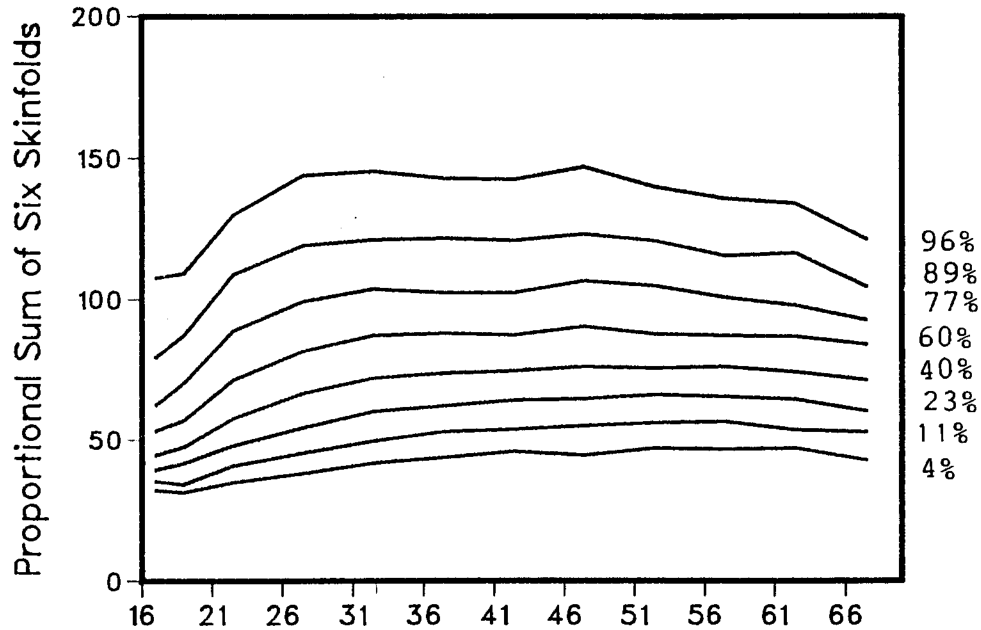
A G E (years)	1	2	3	4	5	6	7	8	9
16-17.999	46.4	51.4	54.0	56.4	60.1	62.3	68.0	74.3	
18-19.999	49.5	53.1	56.5	60.1	63.7	66.8	70.9	78.9	
20-24.999	51.3	54.8	57.8	61.8	65.6	69.4	74.6	80.1	
25-29.999	53.1	56.2	59.8	63.2	67.5	71.4	76.4	84.3	
30-34.999	53.8	57.7	61.2	64.6	68.7	73.2	78.3	85.2	
35-39.999	55.2	58.6	61.8	65.4	69.7	73.8	79.0	86.2	
40-44.999	55.6	59.1	62.7	66.4	69.7	73.8	78.9	86.0	
45-49.999	55.6	59.6	63.5	66.8	70.8	75.0	79.7	86.8	
50-54.999	55.9	59.9	63.4	66.6	70.7	74.8	79.6	86.3	
55-59.999	56.6	60.4	63.5	66.7	71.3	76.1	80.7	87.8	
60-64.999	55.9	60.3	63.3	66.3	70.5	74.8	79.8	87.3	
65-69.999	53.0	57.5	62.1	66.5	69.5	73.9	77.8	81.3	

F E M A L E S

S T A N I N E   R A T I N G

A G E (years)	1	2	3	4	5	6	7	8	9
16-17.999	48.8	53.8	56.1	59.2	62.7	64.8	71.1	76.5	
18-18.999	52.8	55.8	58.4	62.0	65.8	69.4	73.7	82.2	
20-24.999	52.2	55.2	57.6	60.8	64.2	68.3	72.9	80.0	
25-29.999	52.5	55.2	57.7	61.0	64.8	68.9	74.8	83.0	
30-34.999	52.3	55.3	58.5	61.5	64.8	69.1	74.8	84.5	
35-39.999	53.1	56.2	58.8	62.4	66.3	70.7	76.7	88.0	
40-44.999	54.4	57.6	60.8	63.8	68.1	73.2	80.2	89.2	
45-49.999	55.2	58.7	62.0	65.2	69.8	74.6	82.3	91.8	
50-54.999	54.2	57.8	62.2	65.3	69.6	74.3	82.7	93.0	
55-59.999	55.5	59.1	62.5	66.8	72.8	78.1	84.4	95.5	
60-64.999	56.3	59.0	63.8	67.4	71.9	77.5	85.4	93.5	
65-69.999	53.3	58.7	65.3	69.2	74.8	78.8	84.3	91.7	

Figure BII.2: Stanine boundary percentile curves for Adiposity rating for males and females, based on composite O-SCALE data assembly. Boundaries at percentiles 4, 11, 23, 40, 60, 77, 89 and 96.



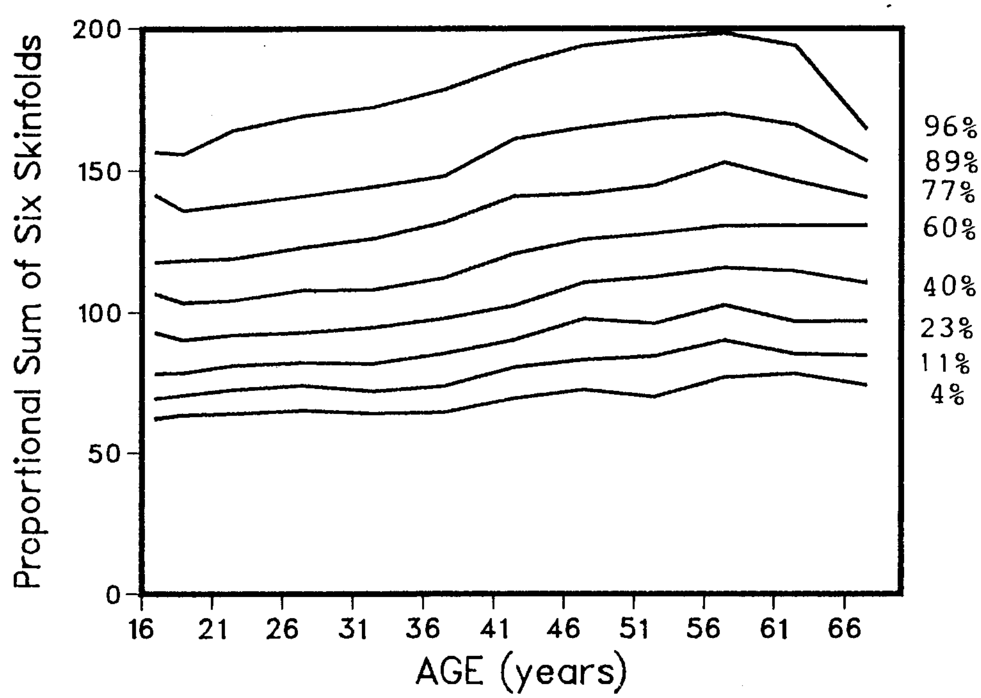
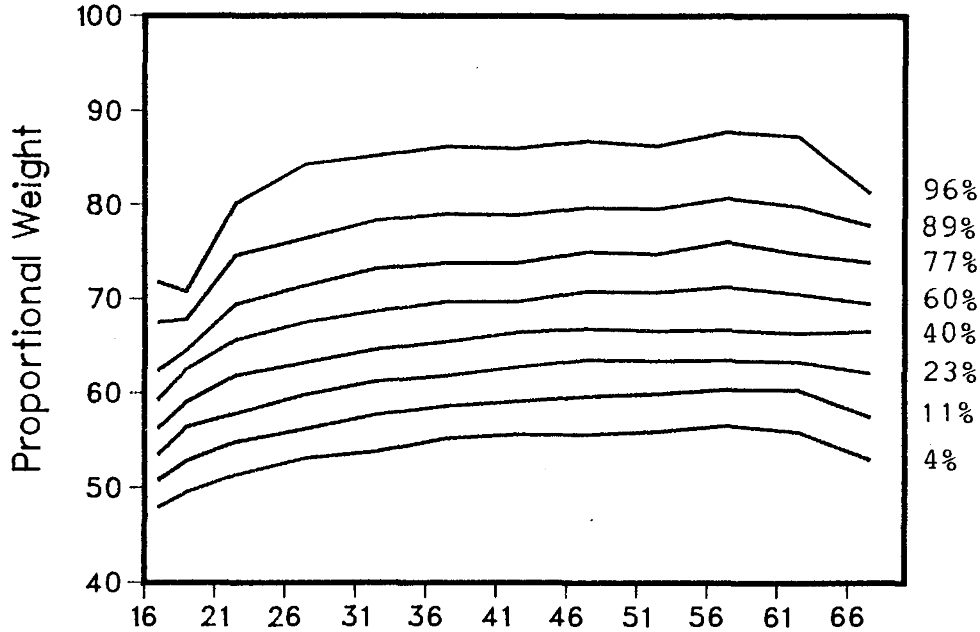
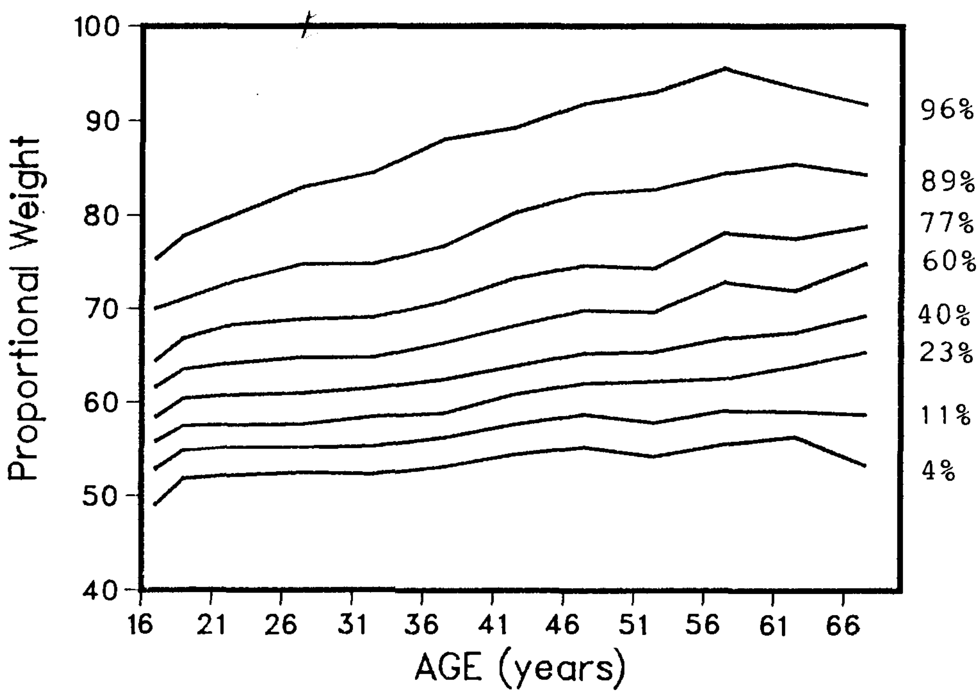


Figure BII.3: Stanine boundary percentile curves for Proportional Weight rating for males and females, based on composite O-SCALE data assembly. Boundaries at percentiles 4, 11, 23, 40, 60, 77, 89 and 96.





MICROCOMPUTER RESOLUTION OF DATA

Further analysis in the O–SCALE system was provided by a microcomputer generated report. The IBM compatible GWBASIC programme written by the author was listed in Appendix 1. The 4th, 50th and 96th percentiles for individual anthropometric items and their Phantom z–values were produced from the composite O–SCALE data set using the frequencies package of the SPSSX package and were listed in Appendix 2. Page one of the report (Figure BII.4) contained a listing of the basic information of age, sex, height and weight. This was accompanied by the calculated sum of six skinfolds, proportional sum of six skinfolds and the proportional weight. A text graphic displaying asterisks for the A and W stanine ratings concluded the first page.

Figure BII.4: First Page of O–SCALE printout

```
---------------------------------------
  O-SCALE RATING FOR MILITARY GIRL
---------------------------------------

Date : 85-08-12

FEMALE 22.74 years of age.

Height = 159cm.     Weight = 72.3kg.

Proportional Weight = 88.6kg.

Sum of 6 Skinfolds (Harpenden) = 97mm.

Height-scaled Sum of 6 Skinfolds = 103.8mm.

I   I   I   I   I   I   I   I   I   I
I.1.I.2.I.3.I.4.I.5.I.6.I.7.I.8.I.9.I

A                 *

W                                 *

I...I...I...I...I...I...I...I...I...I
    4%.11%.23%.40%.60%.77%.89%.96%
```

Subsequently, each printout contained a second page (Figure BII.5) listing the subject's measurements along with the 4th, 50th and 96th percentiles for the appropriate age and sex norm. This was followed by the proportionality profile. The proportionality profile consisted of a text graphic of the phantom z-value of each anthropometric variable for the subject plotted relative to the 4th, 50th and 96th percentiles for the appropriate age and sex norm. This gave an analysis of physique which was comprehensive yet could be readily evaluated. The 4th, 50th and 96th percentiles for the norms for individual measurements for absolute and z-values were again produced using the frequencies option of the SPSSX package. The proportionality profile was a text graphic, with the grid for the graphic consisting of 45 dashes, with the dashes at positions 7, 17 and 27 being replaced by vertical lines, representing the 4th, 50th and 96th percentiles of the appropriate norm. The asterisk for the subject's z-value was plotted relative to these respective vertical lines. If the z-value was less than the 50th percentile for the z-value for the norm group then the asterisk was plotted via linear interpolation relative to the 4th and 50th percentiles. If the z-value was higher or equal to the 50th percentile for the norm then the asterisk was plotted relative to the 50th and 96th percentiles. The values of the 4th, 50th and 96th percentiles for both absolute and z-values for each of the age and sex norm groups were presented in Appendix 4.

In the O-SCALE print-out the second page (Figure BII.5) consisted only of a listing of the measurements in comparison to the norm 4th, 50th and 96th percentiles due to the large number of variables. The third page (Figure BII.6) consisted of the longer proportionality profile. In addition, percentage body fat was calculated using three different sets of anthropometric prediction formulae and presented with a warning on their use as a fourth page (Figure BII.7). The details of these formulae were given in chapter CII.

Figure BII.5: Second Page of O-SCALE printout

SIZE - This is a listing of your measurements. To the right of your measurements are shown the 4th, 50th and 96th percentiles for your own age and sex norm.

		Norm Percentiles		
		4%	50%	96%
WEIGHT	72.3	47.5	58.2	74.3
HEIGHT	159.0	154.2	165.5	176.4
SKINFOLDS				
TRICEPS SF	16.5	8.4	15.3	27.0
SUBSCAPULAR SF	18.5	7.2	12.2	25.4
BICEPS SF	6.5	3.8	7.3	15.2
ILIAC CREST SF	15.3	6.8	11.4	26.0
SUPRASPINALE SF	11.3	5.5	11.0	24.2
ABDOMINAL SF	16.5	6.8	15.5	32.7
FRONT THIGH SF	17.5	11.0	22.4	39.2
MEDIAL CALF SF	10.2	7.6	15.2	28.0
GIRTHS				
ARM G. (RLXD)	32.9	22.2	26.7	31.5
ARM G. (FLXD)	33.5	23.5	27.1	32.0
FOREARM G.	25.6	21.3	23.3	26.5
WRIST G.	15.8	13.6	14.5	16.3
CHEST G.	96.1	78.4	83.8	96.0
WAIST G.	78.4	61.0	67.9	81.7
HIP G.	100.2	84.8	93.7	106.2
THIGH G.	60.5	47.8	55.9	63.8
CALF G.	37.5	30.6	34.8	39.7
ANKLE G.	21.7	18.5	20.8	23.9
BONE WIDTHS				
ELBOW W.	6.52.0	5.3	6.0	6.8
KNEE W	9.26.0	7.9	8.9	10.0
SKINFOLD-CORRECTED GIRTHS (Muscularity)				
COR.ARM G (RLXD)	27.3	18.3	22.0	25.4
COR.CHEST G.	89.9	75.4	80.6	88.7
COR.THIGH G.	54.6	40.6	48.6	55.1
COR.CALF G.	34.0	25.7	29.9	34.5

Figure BII.6: Third Page of O-SCALE printout

PROPORTIONALITY PROFILE

Your measurements are scaled to a common stature and then plotted relative to your similarly scaled same age and sex norm.

```
                      4%       50%       96%
----------------------------------------------------------------------
               .......I.........I.........I..........................
WEIGHT                                       *
               .......I.........I.........I..........................
TRICEPS SF                        *
               .......I.........I.........I..........................
SUBSCAPULAR SF                       *
               .......I.........I.........I..........................
BICEPS SF                       *
               .......I.........I.........I..........................
ILIAC CREST SF                     *
               .......I.........I.........I..........................
SUPRASPINALE SF                 *
               .......I.........I.........I..........................
ABDOMINAL SF                     *
               .......I.........I.........I..........................
FRONT THIGH SF              *
               .......I.........I.........I..........................
MEDIAL CALF SF            *
               .......I.........I.........I..........................
ARM G. (RLXD)                                 *
               .......I.........I.........I..........................
ARM G. (FLXD)                                  *
               .......I.........I.........I..........................
FOREARM G.                                *
               .......I.........I.........I..........................
WRIST G.                                 *
               .......I.........I.........I..........................
CHEST G.                                   *
               .......I.........I.........I..........................
WAIST G.                                 *
               .......I.........I.........I..........................
HIP G.                                  *
               .......I.........I.........I..........................
THIGH G.                                *
               .......I.........I.........I..........................
CALF G.                                *
               .......I.........I.........I..........................
ANKLE  G.                            *
               .......I.........I.........I..........................
ELBOW W.                                 *
               .......I.........I.........I..........................
KNEE W                               *
               .......I.........I.........I..........................
COR.ARM G (RLXD)                                  *
               .......I.........I.........I..........................
COR.CHEST G.                                   *
               .......I.........I.........I..........................
COR.THIGH G.                                 *
               .......I.........I.........I..........................
COR.CALF G.                                *
               .......I.........I.........I..........................
----------------------------------------------------------------------
```

PERCENTAGE BODY FAT

The O-SCALE SYSTEM is a replacement for the traditional prediction of percentage body fat, which has on many occasions given dubious results in individual assessments. As an illustration of the problem of using percentage body fat prediction formulae, the following are predictions using only three of many published prediction equations. They are not selected as being the bestor the worst, merely as typical of results that might be achieved using the data of this subject and percent fat prediction equations. As can be seen, all three predictions are different. Which is the right answer? There are many factors that contribute to the different predictions. The justification for the production of the O-SCALE SYSTEM is that this problem exists for individual assessments. The O-SCALE therefore, replaces percentage body fat prediction, but also gives information not only on fatness, but also on muscularity and body proportions

PERCENTAGE BODY FAT PREDICTIONS	
YUHASZ	18.6%
SLOAN	22%
DURNIN & WOMERSLEY	29.7%

RELIABILITY OF ANTHROPOMETRIC TECHNIQUES

Table BII.11 showed the mean, standard deviation of average of first and second trials, technical error of measurement and coefficient of variation for each measurement for both males and females. The coefficients of variation were seen to be lowest in the measurement of stature being 0.06% for males and 0.07% for females. This was closely followed by those for weight, being 0.08% for males and 0.10% for females. The highest coefficients of variation were found as expected in the skinfold measures with coefficients of variation for the eight skinfolds ranging from 3.23% to 5.11% in males and 2.65% to 7.35% in females. The most reliable site was the triceps in both the males and the females. In the males the site exhibiting the lowest reliability was the biceps which also had the lowest mean value, whereas in the the females the worst site was the iliac crest. Table BII.12 showed the reliabilities of the skinfolds in comparison to those reported by Anderson (1985) for six of the sites. Anderson reported reliabilities for both sexes combined, but it can be seen that the reliabilities are comparable if not better in the present study.

The girths displayed considerably lower coefficients of variation ranging from 0.32% to 0.83% for males and 0.32% to 0.81% for females. The highest reliabilities were seen in the calf and gluteal girths for both males and females. The poorest reliabilities were shown by the relaxed arm and wrist girths in males and the relaxed arm and ankle girths in the female sample. The reliabilities of the bone widths at the humerus and femur sites were comparable to those of the girths, being higher (0.81% for males and 0.97% for females) for the humerus than for the femur (0.61% for males and 0.56% for females). The skinfold-corrected girths exhibited higher coefficients of variation than the normal girths due to the contribution of skinfold measurement error to its calculation. The coefficients for the four corrected girths ranged from 0.85% to 1.02% for males and 0.64% to 1.09% for females.

The technical error was also calculated for the sum of six skinfolds. At 1.49% for males and 1.73% for females this represented a considerable reduction over the coefficients of variation for the individual skinfolds. This highlighted an advantage of the use of sum of scores in that there was greater resiliency to measurement error in comparison to the individual scores themselves.

TABLE BII.11: Means (standard deviations) of average of first and second measurements, technical errors of measurement (TE) and coefficients of variation (CV) for males and females.

	MALES (N=50)			FEMALES (N=50)		
Variable	Mean (sd)	TE	CV	Mean (sd)	TE	CV
Stature	176.6 (7.1)	0.11	0.06	164.9 (7.6)	0.12	0.07
Weight	74.6 (11.2)	0.06	0.08	57.2 (8.6)	0.06	0.10
Skinfolds						
Triceps	9.3 (4.0)	0.30	3.23	15.1 (4.5)	0.40	2.65
Subscapular	11.0 (5.5)	0.36	3.27	11.1 (4.1)	0.36	3.24
Biceps	4.5 (2.1)	0.23	5.11	6.5 (2.8)	0.29	4.46
Iliac Crest	16.0 (9.0)	0.62	3.88	11.3 (5.1)	0.83	7.35
Supraspinale	7.4 (5.2)	0.34	4.86	9.8 (4.5)	0.40	4.08
Abdominal	15.9 (11.3)	0.62	3.90	15.1 (5.8)	0.87	5.76
Front Thigh	11.4 (4.2)	0.47	4.12	22.9 (6.4)	0.64	2.79
Medial Calf	7.6 (3.0)	0.28	3.68	13.6 (4.4)	0.45	3.31
Girths						
Relaxed Arm	31.3 (2.8)	0.26	0.83	26.5 (2.3)	0.21	0.79
Flexed Arm	33.4 (2.9)	0.25	0.75	27.2 (2.3)	0.18	0.66
Forearm	28.2 (1.7)	0.19	0.67	23.5 (1.3)	0.13	0.55
Wrist	16.9 (0.8)	0.14	0.83	14.7 (0.6)	0.09	0.61
Chest	97.8 (5.4)	0.80	0.82	85.3 (5.4)	0.51	0.60
Waist	80.5 (6.9)	0.57	0.71	67.1 (5.6)	0.45	0.67
Gluteal	97.2 (5.9)	0.48	0.49	93.4 (5.2)	0.43	0.32
Thigh	57.3 (3.9)	0.44	0.70	54.9 (4.2)	0.44	0.73
Calf	37.5 (2.6)	0.12	0.32	34.9 (2.0)	0.12	0.34
Ankle	22.5 (1.3)	0.13	0.58	21.0 (1.1)	0.17	0.81
Widths						
Humerus	7.2 (0.4)	0.07	0.97	6.2 (0.3)	0.05	0.81
Femur	9.9 (0.5)	0.06	0.61	9.0 (0.4)	0.05	0.56
Corrected-Girths						
Relaxed Arm	28.3 (2.4)	0.29	1.02	21.7 (1.9)	0.22	1.01
Chest	94.4 (4.7)	0.80	0.85	81.8 (4.7)	0.52	0.64
Thigh	53.7 (3.6)	0.47	0.88	47.7 (3.7)	0.52	1.09
Calf	35.2 (2.5)	0.15	0.88	30.6 (1.9)	0.21	0.69
Sum of Six Skinfolds	62.5 (30.5)	0.93	1.49	87.7 (25.4)	1.52	1.73

TABLE BII.12: Coefficients of Variation of Technical Errors of Measurement for skinfold measures.

		Male	Female
Present Study	Triceps	3.23	2.65
	Subscapular	3.27	3.24
	Biceps	5.11	4.46
	Iliac Crest	3.88	7.35
	Supraspinale	4.86	4.08
	Abdominal	3.90	5.76
	Front Thigh	4.12	2.79
	Medial Calf	3.68	3.31
		BOTH SEXES	
Anderson (1985)	Triceps	4.78	
	Subscapular	4.42	
	Supraspinale	6.20	
	Abdominal	5.62	
	Front Thigh	6.35	
	Medial Calf	6.36	

RESOLUTION OF PROPORTIONALITY PROFILE

Having determined the reliability of the anthropometry it was important to compare it to the resolution of the proportionality profile. This was necessary to be able to state that if there was a change in position on the profile in serial measurements what were the chances of this being due purely to measurement error and not a change in the true value. In order to achieve this comparison it was necessary to quantify the change in size of each variable that was neccesary to bring about a one text character space shift in the profile. There were 24 norm groups and because of the differences in the norms this meant that there was slightly different resolution for each group. Also the profile below the 50th percentile was plotted relative to the 4th and 96th percentile, whereas the profile above the 50th percentile was plotted relative to the 50th and 96th percentiles. Due to the essential skewness in the normative data the resolution was different above and below the 50th percentile. Resolution in units of measure per space, and its coefficient of variation, termed the coefficient of resolution, in comparison to the 50th percentile was calculated for all variables, for each age and sex group, above and below the 50th percentile, according to the equations described in the methods section. Tables BII.13 to BII.16 showed the resolution and their coefficients above and below the 50th percentile for each anthropometric item for males and females respectively. Because there were 12 groups per sex, and thus 12 coefficients per sex the resolution and the coefficients were displayed as a range from the minimum to the maximum value found in the 12 groups. Also listed in the tables were the technical error of the measurements and their coefficients of variation discussed in the previous section. In all Tables BII.13 and BII.15 the pattern was similar in that the technical error tended to be lower than the minimum value of resolution of the profile. Only in the Biceps skinfold for the males and the Iliac Crest skinfold for the females was the technical error within the range of resolution. In each case it was in range for the resolution below the 50th percentile, but not for the resolution above the 50th percentile. In terms of the size independent measure of resolution the coefficient of resolution a similar pattern was evident in Tables BII.14 and BII.16. In the males the Biceps skinfold, but also the Supraspinale and Front Thigh skinfolds, the forearm, wrist and chest girths and the skinfold-corrected chest girth were in range for coefficients of resolution below the 50th percentile but not within range above the 50th percentile.

Therefore, it was concluded that the anthropometric measurements were generally more precise than the text graphic increments for graphical resolution of the profile using standard dot matric printers.

x TABLE BII.13: Ranges for Resolution of O-SCALE Proportionality Profile Text Graphic for male norm groups 16 - 65 years of age.

VARIABLE	TECHNICAL ERROR	RANGES OF RESOLUTION OF PROFILE Below 50th Centile	Above 50th Centile	
Weight (kg)	0.06	1.16 - 1.34	1.59 - 2.02	kg/space
SKINFOLDS (mm)				
Triceps	0.30	0.40 - 0.54	0.67 - 0.98	mm/space
Subscapular	0.36	0.50 - 0.91	1.16 - 1.52	"
Biceps	0.23	0.19 - 0.33	0.49 - 0.66	"
Iliac Crest	0.62	0.73 - 1.00	1.34 - 2.02	"
Supraspinale	0.34	0.49 - 0.80	1.39 - 1.65	"
Abdominal	0.62	1.13 - 1.60	2.07 - 2.69	"
Front Thigh	0.47	0.54 - 0.79	0.79 - 1.38	"
Medial Calf	0.28	0.37 - 0.51	0.65 - 1.03	"
GIRTHS (cm)				
Relaxed Arm	0.26	0.44 - 0.60	0.37 - 1.07	cm/space
Flexed Arm	0.25	0.40 - 0.54	0.50 - 0.59	"
Forearm	0.19	0.21 - 0.28	0.31 - 0.37	"
Wrist	0.14	0.17 - 0.22	0.26 - 0.29	"
Chest	0.80	0.82 - 1.08	1.03 - 1.44	"
Waist	0.57	0.89 - 1.16	1.56 - 2.00	"
Gluteal	0.48	0.77 - 0.88	0.94 - 1.27	"
Thigh	0.44	0.64 - 0.68	0.51 - 0.81	"
Calf	0.12	0.41 - 0.48	0.46 - 0.53	"
Ankle	0.13	0.38 - 0.42	0.39 - 0.46	"
WIDTHS (cm)				
Humerus	0.07	0.11 - 0.14	0.11 - 0.16	cm/space
Femur	0.06	0.15 - 0.16	0.14 - 0.16	"
CORRECTED-GIRTHS (cm)				
Relaxed Arm	0.29	0.33 - 0.43	0.35 - 0.43	cm/space
Chest	0.80	0.73 - 0.82	0.82 - 1.11	
Thigh	0.47	0.62 - 0.73	0.55 - 0.69	
Calf	0.15	0.40 - 0.48	0.44 - 0.52	

TABLE BII.14: Ranges for Coefficients of Resolution of O-SCALE Proportionality Profile Text Graphic for male norm groups 16 - 65 years of age.

VARIABLE	COEFFICIENT OF VARIATION (Percentage)	RANGES OF COEFFICIENTS OF RESOLUTION Percent/Space Below 50th Centile	Above 50th Centile
Weight	0.08	1.54 - 1.76	2.11 - 2.60
SKINFOLDS			
Triceps	3.23	3.93 - 5.06	6.85 - 10.59
Subscapular	3.27	4.05 - 5.43	6.99 - 12.05
Biceps	5.11	3.23 - 5.05	8.05 - 13.23
Iliac Crest	3.88	3.92 - 5.39	6.74 - 14.44
Supraspinale	4.86	4.81 - 5.72	10.05 - 17.93
Abdominal	3.90	5.39 - 7.49	8.58 - 16.42
Front Thigh	4.12	4.04 - 5.64	6.45 - 10.71
Medial Calf	3.68	4.35 - 5.38	8.72 - 12.00
GIRTHS			
Relaxed Arm	0.83	1.35 - 1.82	1.15 - 3.32
Flexed Arm	0.75	1.13 - 1.54	1.39 - 1.71
Forearm	0.67	0.66 - 0.94	1.04 - 1.22
Wrist	0.83	0.77 - 1.09	1.32 - 1.49
Chest	0.82	0.82 - 1.10	1.05 - 1.39
Waist	0.71	1.09 - 1.29	1.72 - 2.39
Gluteal	0.49	0.78 - 0.90	0.95 - 1.27
Thigh	0.70	1.06 - 1.18	0.91 - 1.35
Calf	0.32	1.08 - 1.23	1.15 - 1.34
Ankle	0.58	1.53 - 1.77	1.65 - 1.90
WIDTHS			
Humerus	0.97	1.02 - 1.33	0.98 - 1.62
Femur	0.61	1.07 - 1.27	1.02 - 1.16
CORRECTED-GIRTHS			
Relaxed Arm	1.02	1.11 - 1.38	1.14 - 1.38
Chest	0.85	0.75 - 0.87	0.87 - 1.17
Thigh	0.47	1.10 - 1.34	1.04 - 1.24
Calf	0.88	1.10 - 1.33	1.24 - 1.37

TABLE BII.15: Ranges for Resolution of O-SCALE Proportionality Profile Text Graphic for female norm groups 16 - 65 years of age.

VARIABLE	TECHNICAL ERROR	RANGES OF RESOLUTION OF PROFILE Below 50th Centile	Above 50th Centile	
Weight	0.06	1.08 - 2.11	1.85 - 2.71	kg/space
SKINFOLDS				
Triceps	0.40	0.76 - 1.03	1.03 - 1.43	mm/space
Subscapular	0.36	0.55 - 1.06	1.26 - 1.77	"
Biceps	0.29	0.41 - 0.65	0.87 - 1.16	"
Iliac Crest	0.83	0.59 - 1.07	1.41 - 1.95	"
Supraspinale	0.40	0.63 - 1.25	1.43 - 1.88	"
Abdominal	0.87	0.98 - 1.83	1.52 - 2.22	"
Front Thigh	0.64	1.21 - 1.46	1.71 - 2.04	"
Medial Calf	0.45	0.84 - 1.12	1.26 - 1.45	"
GIRTHS				
Relaxed Arm	0.21	0.51 - 0.63	0.58 - 0.74	cm/space
Flexed Arm	0.18	0.45 - 0.52	0.57 - 0.76	"
Forearm	0.13	0.24 - 0.34	0.36 - 0.48	"
Wrist	0.09	0.15 - 0.17	0.24 - 0.30	"
Chest	0.51	0.77 - 1.24	1.34 - 1.75	"
Waist	0.45	0.76 - 1.25	1.42 - 2.00	"
Gluteal	0.43	0.83 - 1.55	1.27 - 1.83	"
Thigh	0.44	0.68 - 1.19	0.59 - 1.19	"
Calf	0.12	0.46 - 0.60	0.50 - 0.69	"
Ankle	0.17	0.27 - 0.40	0.34 - 0.46	"
WIDTHS				
Humerus	0.05	0.11 - 0.16	0.12 - 0.14	cm/space
Femur	0.05	0.15 - 0.21	0.17 - 0.22	"
CORRECTED-GIRTHS				
Relaxed Arm	0.22	0.35 - 0.48	0.41 - 0.73	cm/space
Chest	0.52	0.63 - 0.92	0.87 - 1.26	"
Thigh	0.52	0.73 - 1.05	0.73 - 0.94	"
Calf	0.21	0.40 - 0.50	0.50 - 0.70	"

TABLE BII.16: Ranges for Coefficients of Resolution of O-SCALE Proportionality Profile Text Graphic for Female norm groups 16 - 65 years of age.

VARIABLE	COEFFICIENT OF VARIATION (Percentage)	RANGES OF COEFFICIENTS OF RESOLUTION Percent/Space Below 50th Centile	Above 50th Centile
Weight	0.10	1.82 - 3.41	3.15 - 4.32
SKINFOLDS			
Triceps	2.65	4.46 - 5.87	5.01 - 8.23
Subscapular	3.24	4.20 - 5.97	7.16 - 11.39
Biceps	4.46	4.98 - 6.07	8.89 - 12.77
Iliac Crest	7.35	4.78 - 7.38	10.32 - 16.60
Supraspinale	4.08	5.33 - 6.75	8.87 - 15.58
Abdominal	5.76	6.07 - 6.92	5.98 - 12.09
Front Thigh	2.79	5.12 - 6.99	5.00 - 8.41
Medial Calf	3.31	5.27 - 6.63	7.63 - 8.86
GIRTHS			
Relaxed Arm	0.79	1.76 - 2.08	2.04 - 2.49
Flexed Arm	0.66	1.41 - 1.68	1.97 - 2.46
Forearm	0.55	0.89 - 1.26	1.38 - 1.85
Wrist	0.61	0.74 - 0.90	1.39 - 1.74
Chest	0.60	0.91 - 1.41	1.53 - 2.02
Waist	0.67	1.09 - 1.64	1.88 - 2.86
Gluteal	0.32	0.88 - 1.14	1.32 - 1.89
Thigh	0.73	1.18 - 2.06	1.01 - 2.11
Calf	0.34	1.23 - 1.66	1.44 - 1.88
Ankle	0.81	1.25 - 1.76	1.45 - 2.02
WIDTHS			
Humerus	0.81	1.19 - 1.82	1.24 - 1.55
Femur	0.56	1.17 - 1.84	1.45 - 2.00
CORRECTED-GIRTHS			
Relaxed Arm	1.01	1.43 - 1.96	1.69 - 3.05
Chest	0.64	0.77 - 1.11	1.07 - 1.52
Thigh	1.09	1.44 - 2.12	1.37 - 1.88
Calf	0.69	1.26 - 1.59	1.57 - 2.25

COMPARISON OF O-SCALE TO NATIONAL STANDARDS

Triceps Skinfold

Figure BII.9 showed the percentile curves for Triceps skinfold for O-SCALE norms (solid lines) in comparison to Canada Fitness Survey norms (dashed lines). Both males and females showed similar differences in that the Canadian norms were all higher than the equivalent percentiles for the O-SCALE norm. It was clear from these curves that the O-SCALE norm represented a leaner sample.

Skinfold-Corrected Arm Girth

Figure BII.10 showed the percentile curves for Skinfold-Corrected Arm Girth for the O-SCALE norms (solid lines) in comparison to the Canada Fitness Survey norms (dashed lines). In the female curves there was greater similarity than in the males. The 25th, 50th and 75th percentiles for females were similar apart for more fluctuation in the Canadian norm. There appeared to be slightly more variance in the Canadian sample. The male curves generally had a trend for marginally greater girths in the O-SCALE norm up to age 60, thereafter the pattern was reversed. It was concluded that the females were similar in the two samples, with the males being slightly more muscular in the O-SCALE norms in the earlier years.

Figure BII.8 : Comparison of Percentiles for Triceps Skinfold between O-SCALE (____) and Canadian Standardised Test of Fitness (----) standards age 20 - 70 years

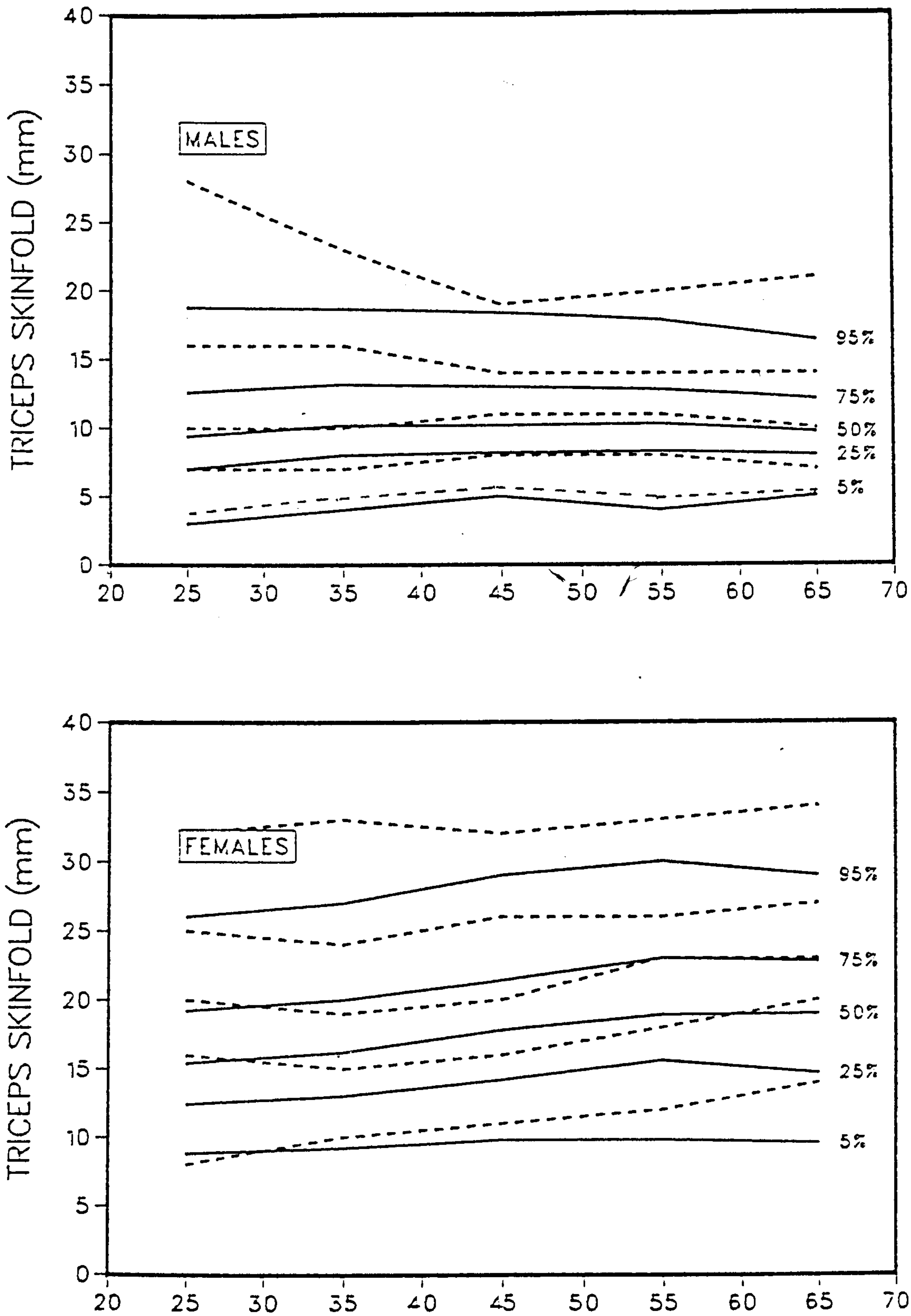
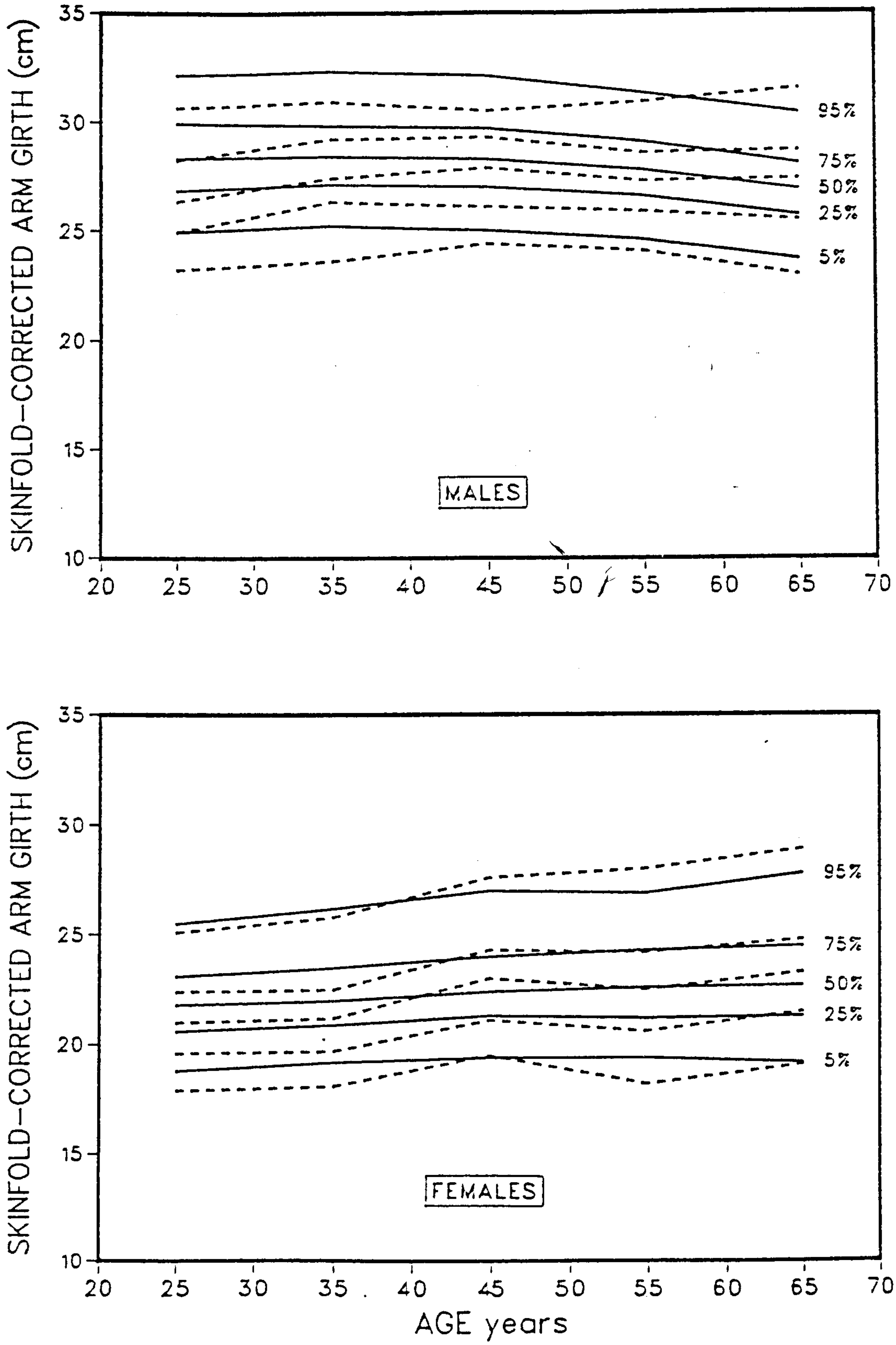


Figure BII.9 : Comparison of Percentiles for Skinfold-Corrected Arm Girth between O-SCALE (_____) and Canadian Standardised Test of Fitness (----) standards age 20 - 70 years



STABILITY OF THE SUM OF SIX SKINFOLDS IN ASCRIBING AN ADIPOSITY RATING

Previously it was demonstrated that the sum of six skinfolds had greater reliability than any of its component skinfolds alone, as assessed by the technical error of measurement. The purpose of this investigation was to determine how resilient the sum of skinfolds was to imposed error when transformed into a stanine rating. For this investigation the CANAD data set of measurements on 233 male and 199 female university students was used. Using the random number generation facility of the SPSSX statistical package previously described, a random error was imposed on the data by an error term being added to each of the skinfold measurements. This error term was selected from a normal distribution with mean of 0 and a standard deviation equal to an arbitrary percentage of the measurement. This was in fact carried out three times with different percentages being selected. The three percentages were 2.5%, 5% and 10%. The 2.5% and 5% values represented values similar to coefficients of variation of the anthropometric techniques technical errors of measurement as listed earlier. The 10% value represented gross errors 3 to 4 times those that would be tolerated by a trained anthropometrist. The O-SCALE **A-ratings** were then calculated on the original data. **A-ratings** were then calculated for the three erroneus data sets and the original **A-rating** subtracted from the new erroneous value. This gave rise to difference values such that it was negative if the new rating was lower and positive if the new rating was higher. Table BII.17 showed the results of this analysis. when a standard deviation of 2.5% was used 1.7% of the males and 3.0% of the females had a new rating lower than the original **A-rating**. Only 1.3 % of the males and 2.0% of the females were given a higher rating. When 5% standard deviation was used the values rose to 5.6% of males and 6.5% of males were underestimated and 3.0% of males and 6.0% of the females were overestimated. When the gross errors represented by the standard deviation of 10% were introduced the values increased to 12.4% of the males and 14.1% of the females being underestimated and 8.2% of the males and

15.1% of the females being overestimated. Remarkably, the maximum change in rating with any of the imposed error was one rating of the **A-rating** scale. No individual change by more than one category. The results showed that the stanine rating scale was particularly robust to imposed random error even when gross errors were introduced only 20.6% of the males and 29.2% of the females received different **A-ratings**. Thus, it was concluded that the sum of skinfolds was resilient to error in **A-ratings** and when median values of three measures were used as in the prescribed protocol it was appreciated that the **A-rating** was a highly stable value.

Table BII.17: Frequency of Adiposity Ratings with imposed random error in each skinfold. -1 = **A-rating** was one category lower after imposed error. 0 = **A-rating** was the same after imposed error. +1 = A rating was one category higher after imposed error.

	Standard Deviation of Normal Distribution from which Random Error Term was Selected								
	2.5%			5%			10%		
	-1	0	+1	-1	0	+1	-1	0	+1
A RATING									
MALES									
1		27			24			23	4
2	1	27	2	4	26	2	5	18	3
3		31			30		5	25	2
4		43		1	41		5	36	2
5	2	43		4	42	1	7	38	3
6	1	30		2	28	3	4	25	4
7		19	1	1	15	1	2	14	1
8		4		1	4		1	4	
9		8			8			8	
Total	4		3	13		7	29		19
Percentage	1.7%		1.3%	5.6%		3.0%	12.4%		8.2%
FEMALES									
1		16			15	1		14	3
2		20		1	19	2	2	17	7
3		27	1		23	1		14	6
4	2	34	1	4	33	3	8	23	6
5	2	33	1	3	29	3	8	25	4
6		30	1	2	27	1	3	25	1
7	1	17		2	17		3	15	2
8	1	13		1	13	1	3	10	1
9		6			5		1	5	
Total	6		4	13		12	28		30
Percentage	3.0%		2.0%	6.5%		6.0%	14.1%		15.1%

CONTROL OF ERROR BY REPLICATION OF SKINFOLDS

Table BII.18 showed the mean of each of the anthropometric variables, their technical errors of measurements and coefficients of variation. The technical errors of measurement were similar although larger than those calculated for the same measurements in the young adult female sample used in chapter BII. The Coefficients of Variation ranged from 3.6% for the triceps and front thigh skinfolds to 5.0% for the abdominal skinfold. Values of 0.5 to 0.6% were observed for the girths. These coefficients were used to compute the random error term added to the first measurement of each variable for each individual to create the erroneous data set. The error term was selected from a normal distribution with standard deviation equal to the coefficient of variation. The resultant technical errors of measurement between the criterion value of the original data set and the criterion value for the erroneous data set for each of the five selection criteria were shown in Table BII.16.

Table BII.18 : Mean, Technical Errors of Measurements and Coefficients of Variation of Anthropmetric Variables.

VARIABLE	MEAN	T.E.	C.V.
SKINFOLDS			
Triceps	14.9	0.536	3.6
Subscapular	11.6	0.493	4.2
Supraspinale	9.8	0.487	5.0
Abdominal	13.9	0.672	4.8
Front Thigh	23.7	0.846	3.6
Medial Calf	13.4	0.614	4.6
GIRTHS			
Relaxed Arm	27.7	0.155	0.6
Forearm	23.9	0.118	0.5
Calf	35.1	0.176	0.5

Table BII.19 : Technical Errors of Measurement between Actual and Erroneous Criterion Values.

SINGLE = First measurement.
MEAN-2 = Mean of first and second measurements.
MEAN-3 = Mean of all three measurements.
MEAN-C = Mean of closest two measurements.
MEDIAN = Median of the three measurements.

VARIABLE	SINGLE	MEAN-2	MEAN-3	MEAN-C	MEDIAN
SKINFOLDS					
Triceps	0.32	0.16	0.11	0.15	0.12
	0.97	0.48	0.32	0.28	0.22
Subscapular	0.33	0.17	0.11	0.13	0.10
	0.99	0.50	0.33	0.22	0.20
Supraspinale	0.30	0.15	0.10	0.11	0.09
	0.90	0.45	0.30	0.20	0.17
Abdominal	0.57	0.28	0.19	0.18	0.17
	1.70	0.85	0.57	0.39	0.33
Front Thigh	0.63	0.32	0.21	0.23	0.19
	1.90	0.95	0.63	0.42	0.34
Medial Calf	0.51	0.26	0.17	0.21	0.19
	1.54	0.77	0.51	0.32	0.32
GIRTHS					
Relaxed Arm	0.11	0.05	0.04	0.06	0.04
	0.33	0.16	0.11	0.09	0.07
Forearm	0.08	0.04	0.03	0.03	0.02
	0.23	0.11	0.08	0.07	0.05
Calf	0.11	0.06	0.04	0.06	0.04
	0.34	0.17	0.11	0.07	0.06

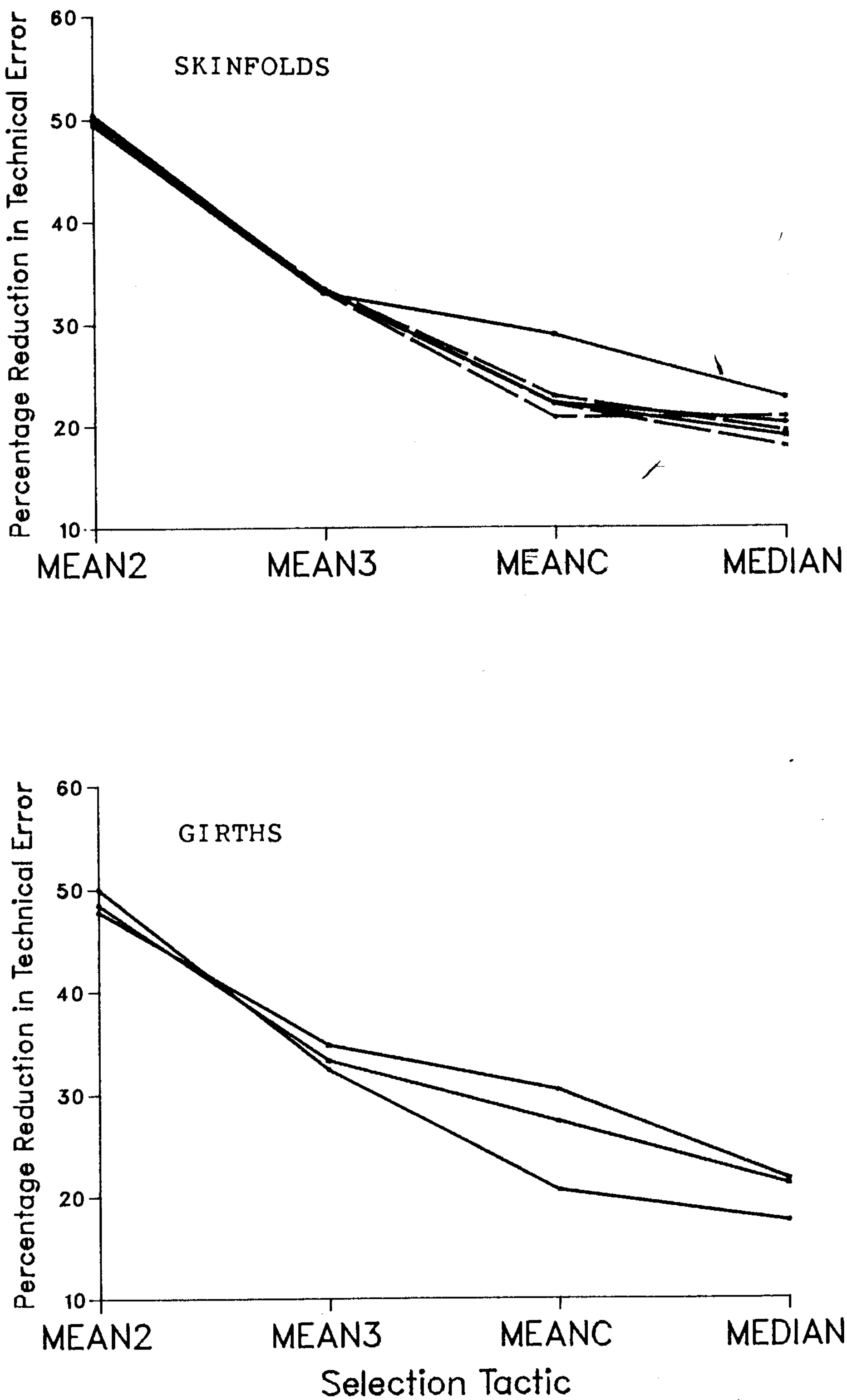
Table BII.20 : Percentage reduction in Technical Error of Measurement

MEAN-2 = Mean of first and second measurements.
MEAN-3 = Mean of all three measurements.
MEAN-C = Mean of closest two measurements.
MEDIAN = Median of the three measurements.

VARIABLE	MEAN-2	MEAN-3	MEAN-C	MEDIAN
SKINFOLDS				
Triceps	50.0	34.4	46.9	37.5
	49.5	33.0	28.9	22.7
Subscapular	51.5	33.3	39.4	30.3
	50.5	33.3	22.2	20.2
Supraspinale	50.0	33.3	36.7	30.0
	50.0	33.3	22.2	18.9
Abdominal	49.1	33.3	31.6	29.8
	50.0	33.5	22.9	19.4
Front Thigh	50.8	33.3	36.5	30.2
	50.0	33.2	22.1	17.9
Medial Calf	51.0	33.3	41.2	37.3
	50.0	33.1	20.8	20.8
GIRTHS				
Relaxed Arm	45.5	36.4	54.5	36.4
	48.5	33.3	27.3	21.2
Forearm	50.0	37.5	37.5	25.0
	47.8	34.8	30.4	21.7
Calf	54.5	36.4	54.5	36.4
	50.0	32.4	20.6	17.6

Table BII.20 showed the percentage reduction in technical error of measurement for the four selection tactics other than the SINGLE from the technical error of the SINGLE tactic. The percentage reduction for the mean of the first two measurements was around 50% for each of the variables with either one coefficient of variation induced error or three times the coefficient of variation. The percentage reduction in technical error for the mean of three measurements tactic was seen to be around 33%. These two observations were expected based on the mathematics of the situation. The deviations from exact values of 50% and 33.3% were a result of rounding errors in calculation of the percentages since this was carried out using technical errors rounded to two decimal places. The results for the mean of the two closest and the median tactics could not be predicted however. For the mean of the closest two tactic the reduction in technical error from the SINGLE tactic ranged from 31.6 to 54.5% for the one coefficient of variation erroneous sample and 20.6 to 30.4% for the three times coefficient of variation erroneous sample. For each variable the reduction in technical error was greater for the three times coefficient of variation erroneous sample than the one times sample. This indicated that the mean of the closest two values tactic was more resilient to the gross errors induced in the three time coefficient of variation approach. The reduction in technical error was greater in the mean of three tactic than the mean of the closest two tactic for seven of the variables, only the abdominal skinfold and forearm girth values being lower for the smaller error sample. Whereas all variables showed greater reduction in technical errors for the mean of the closest two tactics than for the mean of three tactic. The reduction in technical error for the median tactic ranged from 25.0 to 37.5% in the small error sample and 17.6 to 22.7% in the gross error sample. The median tactic exhibited the greatest resilience to imposed error as judged by the technical error of measurement between criterion value and criterion value from the erroneous data set. The technical error was the lowest for the median tactic for all variables for the small and gross imposed error samples except at the medial calf skinfold for the small error imposed sample, where the difference was minimal. The technical error reduction for the gross error sample was consistently smaller than that for the small error sample in the median tactic, indicating that the median tactic was more resilient to the gross errors than to the smaller errors.

Figure BII.10 : Percentage Reduction in Technical Error due to 3 times the Coefficient of Variation imposed error for six skinfold sites (top) and three girths (bottom).



CHAPTER III

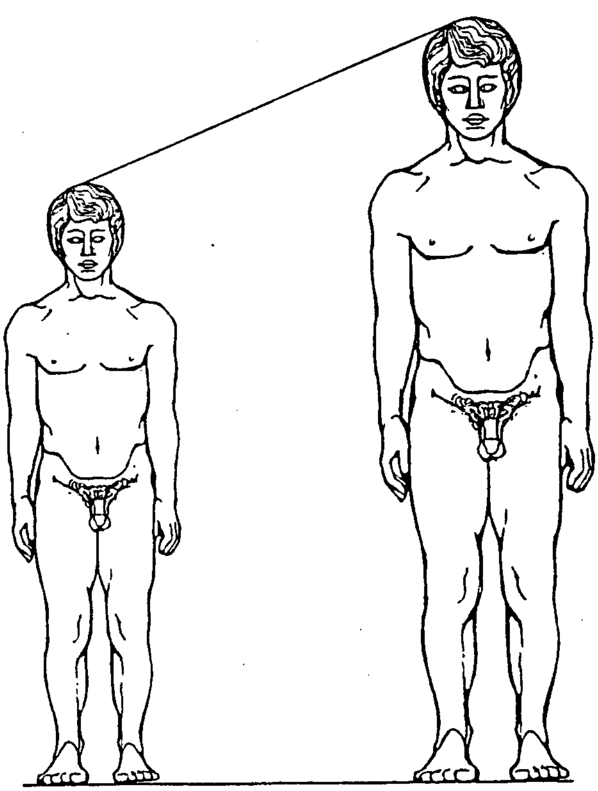
DISCUSSION 1: THE DEVELOPMENT OF THE O-SCALE SYSTEM

Geometric Scaling and the A- and W-ratings

The first component of the O-SCALE system was the dual general physique descriptors of Adiposity (**A-rating**) and Proportional Weight (**W-rating**). The two scores, sum of six skinfolds and weight, which were used to derive these ratings were both geometrically scaled to a common stature of 170.18 cm. As discussed previously, when scaling geometrically, with change in size there was no concommitant change in SHAPE or COMPOSITION. One could represent this as individuals becoming larger or smaller versions of themselves during the scaling, as illustrated in Figure BIII.1.

Figure BIII.1: Geometric Scaling of Human Physique

WITH CHANGE IN SIZE THERE IS NO CHANGE IN SHAPE OR COMPOSITION



This approach has found expression in the Ross-Wilson Phantom tactic for proportionality assessment, and also in the Ponderal Index and its inverse as the Ectomorphic component of the Heath-Carter Somatotype. As the O-SCALE was designed to assess shape and thus indirectly composition, distortion of such aspects during scaling would be inappropriate. In calculating proportional weight the value of 3 for the dimensional exponent maintained the geometrical similarity of the relationship between weight and stature. As reported earlier the Body Mass Index or Quetelet's Index, utilizing an exponent of 2, was widely proposed as the best combination of weight and height. However, this decision was based on the requirement of finding the best indicator of Obesity or "Fatness". The criteria used for this assertion were highest correlation with a measure of fatness (% fat, sum of skinfolds) and lowest correlation with height. As the human design is for increasing linearity with increasing height, the exponent of 2 would be the most often chosen, due to its closeness to the true sample specific value for the dimensional exponent in adult samples. In the O-SCALE system however, the proportional weight was not intended as a measure of obesity but one of ponderosity. The aim was to produce a score which reflected relative weight but where constancy of shape and composition were maintained during the scaling. The proportional weight with its exponent of 3 was therefore the only possible choice. The geometric similarity scaling in the O-SCALE system was compatible with that used with other somatometric and proportionality methods such as the Heath-Carter Somatotype. In fact, the Adiposity and Proportionality scores could be regarded as mathematically equivalent to Somatotype Endomorphy and Ectomorphy ratings respectively, with the difference being that the A and **W-ratings** were expressed in relation to age and sex specific norms.

The Adiposity (A) rating was based on the proportional sum of six skinfolds (triceps, subscapular, supraspinale, abdominal, front thigh and medial calf). The skinfold sites were selected based on determinative discussion at the Koerner Conference at the University of British Columbia, July 1973, by a study group convened by S.R. Brown, which included

Montreal Olympic Games Anthropological Project Investigators, J.E.L. Carter, M. Hebbelinck, W.D. Ross, with A.R. Behnke and M.V. Savage being the other participants. The six sites chosen were selected for various reasons:

- Representation of regions known to show large variations in subcutaneous adipose tissue thickness.
- Regional representation of the whole body.
- Ease of location of landmarks.
- Previous use of these six sites in the Montreal Olympic Games Anthropological Project (Carter 1982).

Since the Adiposity (A) rating was intended as a general descriptor the sum of six skinfolds was selected. The decision was in keeping with the findings in the factorial analysis study of Jackson and Pollack (1985) which showed a "fatness" factor where loading was not appreciably different for the skinfolds at different sites. The reliability study of the sum of six skinfolds as a basis of the **A-rating** which was part of the thesis, showed that in the CANAD young adult male and female samples the six sites were seen to contribute equally to the sum as tested by the Cronbach statistic. Garn, in a recent paper (1987) supported the use of a proportional sum of skinfolds in the prediction of percentage body fat. It should be noted that the O-SCALE system used the sum of skinfolds as an indicator of subcutaneous adiposity in comparison to age and sex specific norms. Thus a given sum of skinfolds would have different meaning in individuals of different ages and sex. An added feature of the use of the sum of skinfolds was it's resilience to error. Technical error of measurement was seen to be lower in the sum (1.49% in Males, 1.73% in Females) than in each of the individual sites (Males range 3.23% - 5.11%, Females range 2.65% - 5.76%).

In addition it was seen that the **A-rating** itself was resilient to considerable imposed error. When random error selected from a normal distribution with a standard deviation equal to 2.5%, was introduced into the CANAD data set skinfold measures only 1.3% of the males and 2.0% of the females received a higher rating; as well only 1.7% of the males and 3.0% of the females received a lower **A-rating**. With 5% random error only 3.0% of the males and 6.0% of the females received a higher and only 5.6% of the males and 6.5% of the females received a lower **A-rating**. Even when 10% error was introduced only 8.2% of the males and 15.1% of the females received a higher and 12.4% of the males and 14.1% of the females received a lower **A-rating**. The discrepancy was never greater than one stanine category. The resilience of the stanine scale to considerable imposed error was a feature deemed desirable in a general descriptor of physique.

The Stanine scale was selected primarily because it provided seven categories of even width (0.25 standard deviations) in relation to the normal distribution, with categories 1 to 9 being open ended covering the two extremes which each represent 4% of the population. In theory this provided for categories that were equidistant apart in terms of values of the proportional scores. In practice it was seen that there was as expected a certain degree of skewness present in the normative data, and resulted in the upper categories being progressively further apart. This was accepted as a biological characteristic reflected properly in the system.

While the ratings and subsequent proportionality profile were seen to organise information in a meaningful pattern, its individual interpretation, as in all measurement systems depended upon the precision and accuracy of the individual items, the effect of treatment of the items and the physical display of the results.

Reliability of Anthropometric Techniques

In developing any system based on anthropometry an evaluation of the reliability of the measurement was essential. To this end the technical errors of measurement and their associated coefficients of variation were determined in an independent sample of 50 male and 50 female university aged young adults measured by trained anthropometrists. These reliability indicators were shown to be comparable to values reported in the literature. Thus, the O-SCALE techniques of measurement were demonstrated to be reliable when carried out by a trained anthropometrist. Meaningful resolution of the data using the O-SCALE system requires precise and accurate anthropometric techniques that are consistent with the prescribed standardised techniques. Measurement error may therefore be minimised by having the practitioner adhere to the following additional guidelines.

- **Training with a Criterion Anthropometrist:** The most direct way to achieve technical competence in measurement is under guided learning and comparison of measurer with a "criterion anthropometrist"; one so designated because of extensive experience in reliability studies with other experienced anthropometrists.
- **Practice:** Persistent practice with monitoring of repeated measurements and occasional comparison with measurements on the same individual by colleagues or criterion anthropometrists is the basis for achieving technical excellence.
- **Calibration of Equipment:** Regular calibration of all equipment (weight scales, skinfold calipers, flexible anthropometric tapes) is a essential requirement for measurement accuracy.
- **Repeat Measurement:** Repeated measures serve to reduce blunders when discrepancies are resolved by additional measurements and permit the assessment of the technical error of measurement for each data set and encourage precision.

Selection of Criterion Value of Repeated Measures

Various strategies could be adopted for the selection of the criterion value from a replicated series. One possibility is to choose to measure only twice and resolve differences by a third measurement if the first two were different by more than some given tolerance. If not different by more than the tolerance the mean of the first two measurements would be used as the criterion value, otherwise the mean of the closest pair would be used. The standard protocol recommended for use with the O-SCALE system was to make a three measurement series, and select the median as the criterion value. As discussed by Ross and Marfell-Jones (1982), the mean generally is the most representative measure of central tendency of sampled values. However, in anthropometry the hazards are two-fold:

- Blunders; Misreading, mistakes in recording.
- Mislocated landmark.

The median would be less influenced by these errors, which can be considerable in magnitude. This contention was tested when gross errors were programmed into a set of triplicate anthropometric measures (triceps, subscapular, supraspinale, abdominal, front thigh and medial calf skinfolds and relaxed arm, forearm and maximum calf girths) for 67 females between the ages of 18 and 70 years. Four tactics for the selection of the criterion value (mean of the first two, mean of all three, mean of the two closest and the median) were compared via a technical error of measurement for resilience to imposed random error in the first of the three sets of data. The percentage reduction in technical error was seen to approximate 50% when the mean of the first two was compared to the first value alone. The reduction was approximately 66% when the mean of all three was used. The median was shown to be consistently the most resilient to the imposed error, thus strongly supporting the decision to recommend the median as the best selection of the criterion value from a repeated set of measurements. An additional advantage to the use of the median is that it reduces the potential for arithmetic and rounding errors which may occur when means are calculated manually.

Resolution of the Proportionality Profile

The purpose of the A and W-ratings was to serve as general descriptors of physique in comparison to age and sex specific norms. In order to provide a more detailed appraisal of individual items a microcomputer programme for data resolution was developed. Information was provided on how the size of each variable compared to the 4th, 50th and 96th percentiles for the appropriate age and sex norm group. A graphic display was also provided of Ross-Wilson z-values for each variable in comparison to the same similarly scaled norms. This was termed the Propotionality Profile. Use of the z-values was consistent with the geometric scaling used for both the A and **W-ratings** The text graphic for the profile utilised 45 spaces, thus establishing a certain level of resolution. The degree of this resolution was assessed by calculating how much change it would take in the different measurements to move one space on the profile. The reliability of the anthropometric measurements quantified in terms of the technical error of measurement were compared to the resolution of the profile for each age and sex norm. It was apparent that the resolution of one space on the graphic was equal to or greater than the technical error of measurement for each of the measures. This confirmed the appropriateness of the chosen resolution of the graphic. While gross errors would result in appreciable deviations, with the selection of the median of triplicate measures by a trained anthropometrist, one could reasonably expect any change in the profile to have reflected true change rather than measurement error.

Characteristics of the O-SCALE norms

A basic tactic of the O-SCALE system was to compare individual values and proportionality scores to a composite normative data assembly stratified by age and sex specific categories. Comparison to a normative data set requires one to establish the status of the norm before interpretation can be made.

After design of the component parts of the O-SCALE system, a normative data set was required for the production of the O-SCALE norms. It was necessary that this data should contain values for height, weight, eight skinfolds (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, medial calf), ten girths (relaxed arm, flexed arm, forearm, wrist, chest, waist, gluteal, thigh, calf, ankle) and two bone widths (humerus and femur). Unfortunately, although the norms could not have been produced without access to the

LIFESTYLE data (made available through the generosity of Dr. D. Bailey), many of the needed variables were lacking. Data on weight, five of the 8 skinfolds, two of the 10 girths and the two bone widths were only available. It was decided that the values for each individual for each of the unknown variables would be predicted using known relationships in a smaller sample containing all of the variables. The PREDICTOR sample that was produced contained complete data on 110 females and 103 males aged 18 to 70 years. The multiple regression equations produced for all variables were applied to the LIFESTYLE data set. Reduction in variance of the predicted values was compensated for by two expansions. For one, an error term randomly selected from a distibution of mean zero and standard deviation equal to the standard error of the estimate of the regression equation being used for that variable, was added to the predicted value. This was termed the standard error (SE) expansion. The alternate expansion was similar, except that the standard error was expressed as a percentage of the mean value for that variable in the originating PREDICTOR sample (%SE). Both expansions proved to increase the variance of the predicted distribution of known variables in the LIFESTYLE data set. The %SE expansion was chosen for use in the final predictions of the normative data set because the SE expansion appeared to have an exaggerated effect on lower percentiles resulting in some negative individual values being produced for most of those skinfolds. Both of the expansions seemed to slightly underpredict the values for the higher percentiles. It was felt that this might be due to skewness in the skinfold and girth data. In an attempt to rectify this, the whole analysis was redone with $\log_{10}$ transforms of all girths and skinfolds. The resultant regression equations and predicted distributions were not appreciably different. As an attempt to correct for skewness through $\log_{10}$ transformation failed to improve the technique, the simpler methodology was presented.

There were significant systematic under- and overestimations that occurred with application of the regression equations to the LIFESTYLE KNOWN variables. This could be attributed to the poor predictive ability of the derived equation or to some differences in the interrelationships of the variables. As a supplementary test of the applicability of the equations, they were applied to the CANAD male and female samples. Interestingly, the KNOWN LIFESTYLE variables that were previously under- or over-estimated were predicted well in the CANAD samples. A distinction of the CANAD and PREDICTOR data sets is that the measurers were all trained by the same criterion anthropometrist (W.D.R.). One might expect more commonality in measurement techniques between these two samples in comparison to the LIFESTYLE data set. This may explain the systematic differences in predictions of the equation when applied to the LIFESTYLE data.

The resultant composite norms were compared by way of triceps skinfold, relaxed arm girth and skinfold-corrected relaxed arm girth to a Canadian National norm produced by the Canada Fitness Survey (1985). This analysis showed that although the lower percentiles (50th and below) were similar for weight and triceps skinfold and relaxed arm girth that the higher percentiles were lower in comparison to the national standards. This indicated tht fewer "fat" individuals were present in the O-SCALE norm, thus the norm represented a leaner alternative to the national standard. As discussed earlier this may be desirable in that an individual would be compared to what could be referred to as a healthier norm.

Skinfold Calipers

The design of caliper is important in comparability of skinfold measures to the O-SCALE norms. The Harpenden and Slim Guide skinfold calipers are recommended for use with the O-SCALE system. Present day Slim Guide calipers give equivalent measures to those obtained with the Harpenden caliper. This was not always the case; the early models of the Slim Guide caliper had greater jaw pressures than the Harpenden. To compensate for this difference the author developed a regression equation predicting Harpenden equivalent values from Slim Guide values. This equation was:

Harpenden = 1.03 (Slim Guide) + 0.64

However, this is no longer required for the newer models as the manufacturers have modified the springs on the caliper to give the same jaw pressures as the Harpenden caliper. The cheaper cost and durability of the Slim Guide caliper presents itself as the ideal caliper for use bythe Health and Fitness professional.

The purpose of this part of the thesis was to describe the development of the O-SCALE system and justify it's component parts. The subsequent part of the thesis dealt with the application of the O-SCALE system to individual analyses and comparison to results obtained using percentage body fat estimates and the Heath-Carter Somatotype.

PART C

APPLICATION OF THE O-SCALE SYSTEM

CHAPTER I

METHODS 2: APPLICATION OF THE O-SCALE SYSTEM

In selecting individual analyses for inclusion in this thesis there was the problem that it may appear that only the best examples had been included, thus showing the system in its most favourable light. Since the space for presentation of individual profiles was limited it was decided to present only a limited number of individual anlayses but that these be randomly selected profiles where possible in order to evaluate the features of the system with minimal selection bias. The profiles presented were divided into three categories.

1) Individuals from the CANAD data set with various physiques.

Individuals were classified as having balanced, adiposity or weight dominant, physiques. Dominance was defined by the relative values of the O-SCALE system A and **W-ratings**. A *Balanced* physique was defined as being when the A and **W-ratings** were equal. An *Adiposity Dominant* physique was defined as being when the **A-rating** was greater than the **W-rating**. A *Weight Dominant* physique was defined as being when the **A-rating** was less than the **W-rating**.

The CANAD data set was used as the base from which the individuals were selected. It was decided to select three males and three females from the data set to represent each of the three physique categories. Selection was made by first dividing the sample into three groups by the criterion of balanced, adiposity or weight dominance previously defined. Using the random sampling facility of the SPSSX statisatical package, three male and three female subjects were selected from the data set for each of the three physique categories. O-SCALE analyses were then carried out on these individuals.

In addition to the O-SCALE analyses several other accepted methodologies for physique and body composition assessment were applied to the data of the individuals to allow comparison to the O-SCALE results. The alternative methodologies used were:

a) Heath-Carter Anthropometric Somatotype.

ENDOMORPHY

$$\text{Endomorphy} = -0.7182 + 0.1451(X) - 0.00068(X^2) + 0.0000014(X^3)$$

where X = Sum of Triceps, Subscapular and Supraspinale Skinfolds

(For height-corrected Endomorphy, X is multiplied by 170.18/Height in cm)

MESOMORPHY

$$\text{Mesomorphy} = (0.858 \times \text{Humerus Breadth}) + (0.601 \times \text{Femur Breadth}) + (0.188 \times \text{Skinfold-corrected Arm Girth}) + (0.161 \times \text{Skinfold-corrected Calf Girth}) - (0.131 \times \text{Height}) + 4.5$$

where Skinfold-corrected Arm Girth

= Flexed Arm Girth - Triceps Skinfold(cm)

Skinfold-correctd Calf Girth

= Max. Calf Girth - Medial Calf Skinfold(cm)

ECTOMORPHY

Ectomorphy = HWR x 0.732 - 28.58

where HWR = height / cube root of weight

If HWR < 40.75 but > 38.25 then

Ectomorphy = HWR x 0.463 - 17.63

If HWR < or = 38.25 then Ectomorphy = 0.1

b) Body Mass Index (BMI).

BMI = (WT/HT^2)

Where WT = Body Weight (kg)

and HT = Stretch Stature (m)

c) Percent fat predictions using three different sets of equations based on anthropometric variables. The three sets of equations used were chosen for the following reasons:

a) Each used anthropometric measures common to the O-SCALE anthropometric proforma.

b) The Yuhasz formula was widely used in Canada and was also used in assessment of Olympic athletes in the MOGAP study.

c) The Durnin and Womersley formulae were extensively used in Canada and represented a formula where only upper body sites were used.

d) The Sloan equations represented extensively used equations where only two skinfolds were used to make the prediction of percentage body fat.

The equations were referred to by a two character code: DW = Durnin and Womersley (1974), SL = Sloan, Burt and Blyth (1962,females) or Sloan (1967,males), YZ = Yuhasz (Carter 1982).

The actual equations used were:

DURNIN & WOMERSLEY (1974)

Density was determined by calculating the $\log_{10}$ sum of four skinfolds (Log_{10}S4SF) and putting it into an equation of the form:

$$\text{Density} = C - m \, \mathrm{Log}_{10}\mathrm{S4SF}$$

where S4SF = Sum of Biceps, Triceps, Subscapular and Iliac Crest Skinfolds

There are age and sex specific values for C and m. The C and m values and the standard error of estimate (SEE) for the density equations are as follows:

MALES	17-19	20-29	30-39	40-49	50+
C	1.1620	1.1631	1.1422	1.1620	1.1715
m	0.0630	0.0632	0.0544	0.0700	0.0779
SEE	0.0073	0.0084	0.0087	0.0082	0.0092

FEMALES	16-19	20-29	30-39	40-49	50+
C	1.1549	1.1599	1.1423	1.1333	1.1339
m	0.0678	0.0717	0.0632	0.0612	0.0612
SEE	0.0089	0.0109	0.0125	0.0107	0.0082

SLOAN, BURT & BLYTH (1962)

FEMALES 17-25 years of age

$$\text{Density} = 1.0764 - 0.00081\mathrm{ILSF} - 0.00088\mathrm{TPSF}$$

where ILSF = Iliac Crest Skinfold
TPSF = Triceps Skinfold

S.E.E. = 0.0082 gm/ml

SLOAN (1967)

MALES 18-26 years of age

$$\text{Density} = 1.1043 - 0.001327\text{FTSF} - 0.001310\text{SSSF}$$

where FTSF = Front Thigh Skinfold
SSSF = Subscapular Skinfold

S.E.E. = 0.0082 gm/ml

YUHASZ

MALES

$$\%\text{Fat} = 0.1051\text{S6SF} + 2.585$$

FEMALES

$$\%\text{Fat} = 0.1548\text{S6SF} + 3.580$$

Equation produced from data by Yuhasz on University students (University of Western Ontario) for use in assessment of body fat in Montreal Olympic Games athletes (Carter 1982).

2) Individuals selected from specific Olympic events in order to demonstrate specificity of physique.

In order to test the ability of the O-SCALE system in describing the atypical physiques of elite athletes, individuals were randomly selected for analysis from the Montreal Olympic Games data (MOGAP). Three different types of Olympic Athletes with very different expected characteristics were selected. They were Rowers, Cyclists and Weightlifters. The Rowers were selected because they were the most widely sampled group in the MOGAP data set. The cyclists were selected because they represented what might be referred to as a lower body dominant sport. The weightlifters were chosen as representing heavy athletes. As the Rowers were composed of both sexes, three males and three females were selected. Three individuals from each of these sports were randomly selected and O-SCALE analyses carried out. In addition the means for age and the anthropometric items for all members of each of these groups was calculated. These were then entered into O-SCALE analyses as if they represented the status of one individual. This gave a depiction of an average profile for each of the sports. The three individual profiles were then compared to the general pattern for the group.

3) Individuals who had been measured before and after a change in body weight.

Since one of the most useful traits of the O-SCALE system was in assessing the change in physique accompanying weight loss, several analyses were included of individuals who had undergone a change in body weight. The data available to the author in this domain was limited. Thus, the profiles selected for inclusion were predicated on availability rather than random selection. The profiles shown were:

1) Female Before and After Dietary and Exercise Modification:
(A8-W8 to A5-W6)

2) Male Monitored during 75 day Walk from Brussels to Nice:
(A6-W8 to A3-W7 to A2-W7)

3) Male undergoing dietary modification without an increase in habitual activity level .
(A6-W6 to A4-W4)

4) Male Body Builder 9 days before and at time of Competition.
(A1-W8 to A1-W8)

Group comparisons of physique using O-SCALE system A and W Ratings

The O-SCALE system was designed for individual assessments of human physique. However, the A and **W-ratings** as basic descriptors of physique in comparison to age and sex specific norms may be used for group analyses. Group analysis was illustrated by testing for differences between the A and **W-rating** distributions for male university and Montreal Olympic males, and for a similar comparison in the female groups.

The subjects used in this study were again the 233 males and 199 males comprising the CANAD young adult university sample, along with the 309 males and 148 females comprising the Montreal Olympic Games (MOGAP) sample.

The distributions of the four groups with respect to combinations of A and **W-ratings** were displayed by 9 x 9 frequency distribution grids. Within the samples the relationship between the A and **W-ratings** was tested using a Contingency coefficient.

Differences in distribution of both A and **W-ratings** from those of the O-SCALE norms were tested using the Chi-Square test with the O-SCALE norm distributions being used as the expected frequencies. The 0.05 probability level was used for acceptance of significance. Since there were 9 categories there were 8 degrees of freedom and thus the critical value of the chi-square statistic was 2.73.

Differences were also tested between the A and W distributions for the same sex CANAD and MOGAP groups. In these cases the CANAD frequencies were used as the expected frequencies in the Chi-Square analysis. Again 2.73 was the critical value of the statistic ($p<0.05$, d.f.= 8).

CHAPTER II

RESULTS 2: APPLICATION OF THE O-SCALE SYSTEM

Individual O-SCALE Analyses

The following four steps are recommended as a strategy for facilitate ease of interpretation of O-SCALE analyses:

- Observe the sex, age, race, height and weight of the the subjects. There are certain expectations of physique associated with various categories of people. For instance Tall individuals would be expected to have a tendency toward linearity, and vice versa for short individuals.
- Observe the A- and **W-ratings.** Initially the location of each, gives an assessment of status of adiposity and proportional weight in comparison to their same age and sex norm group. In addition the relative position of the two ratings gives information on the development of the musculo-skeletal component of physique. A proportional weight rating higher than the adiposity rating leads to the assumption that there is disproportionately large development of the musculoskeletal component or conversely minimization of the adiposity component.
- Observe the proportionality profile. Any differences in the adiposity and proportional weight ratings must be explainable by the pattern of the proportionality profile. A high weight in relation to the adiposity rating would be accompanied by lower ratings for skinfolds than either or both of the bone widths and corrected-girths.
- Observe any dysplasia in the proportionality profile. Within each of the categories of measurements the individual pattern of development will be displayed. For instance, a cyclist may show higher ratings of calf corrected-girth than arm corrected-girth.

Approaching interpretation of the O-SCALE analyses in the ordered approach will be seen to enhance the ease of interpretation.

Balanced Type Physiques

In the CANAD data set 48 males (20.6%) and 36 females (18.1%) were identified as having the same values for both A and **W-ratings**. These were defined as individuals having a balanced type of physique. Three males and three females were selected from this group using the random sampling facility of the SPSSX statistical package. Their O-SCALE analyses were shown in Figure CII.1 for the male subjects A, B and C, and for the females in figure CII.2 as subjects D, E and F. In the male analyses (figure CII.1) all three coincidentally had a A of 5 and a **W-rating** of 5. Subject A was a 24.56 year old male, 186.0 cm in stature and 84.9 kg in body weight. His sum of six skinfolds was 65.2 mm. His proportional weight was 65.0 kg and his proportional sum of skinfolds was 59.7 mm. Subject was similar in stature to subject A in that he was 184.4 cm tall with a body weight of 82.2 kg, being a 24.90 year old male. His sum of six skinfolds was 70.0 mm, proportional weight 64.6 kg and his proportional sum of skinfolds was 64.6 mm. Subject C was a 31.94 year old male, 183.5 cm in height and 85.3kg in body weight. His sum of six skinfolds was 78.0 mm, his proportional weight was 68.0 kg and his proportional sum of skinfolds 72.3 mm. All three subjects were very similar in basic dimensions and as previously stated each was rated as a 5 in Adiposity and a 5 in proportional weight. Despite the similarities in height and weight and sum of skinfolds of these individuals the proportionality profiles of subjects A, B, and C showed that distinctive differences in their physiques. Subject A had ratings for skinfolds around the 50th percentile, except for low values in the the abdominal and particularly the supraspinale which was just above the 4th percentile. The girths for subject A were rated close to the 50th percentile apart from forearm girth and ankle girth which were higher with calf girth being the highest rated girth. Chest girth was rated as the proportionally smallest girth in relation to the norm. Both humerus and femur width were rated at around the 50th percentile. The corrected girths showed a pattern of having the greatest rating indicating muscularity in the calf girth, with the other three being located just below the 50th percentile. Subject B showed a pattern of skinfolds at or below the 50th percentile, the subscapular skinfold being the lowest rated and the abdominal and front thigh skinfolds being the only ones located above the 50th percentile.The girths were all rated at or just below the 50th percentile except for the waist girth which was located one space above. Humerus and femur width received ratings just below the 50th percentile. The corrected girths all showed similar ratings with the chest and then the thigh being marginally higher rated girths, being at and just below the 50th percentile respectively. Subject C had ratings for the triceps and supraspinale skinfolds at the 4th percentile with subscapular, iliac crest, front thigh and medial calf having ratings midway between the 4th and 50th percentiles. Only the subscapular and the abdominal skinfolds had values higher than the 50th percentile. For the girths, the wrist, chest and waist received the lowest ratings of midway between the 4th and 50th percentiles. The thigh girth was the highest with the other girths all being just below at or just above the 50th percentile. Humerus and femur width were interesting in that humerus width was rated very low and the femur width was rated just below the 50th percentile. In the corrected girths, the arm and chest were rated two thirds of the way between the 4th and 50th percentiles, whereas the thigh girth was rated extremely high being just over mid-way between the 50th and 96th percentiles, and the calf girth was rated just above the 50th percentile. In conclusion all three male Balanced Type Physiques having the same adiposity and proportional weight ratings still showed differences in their proportionality profiles. For instance subject C showed a pattern of considerably more muscular development in the lower girths than in the arm and chest girth and in the skinfolds they were actually relatively lowly rated apart from the triceps and abdominal skinfolds which were the two sites contributing to the rating of 5 in adiposity. Subjects A and B were relatively similar in physique except for a disproportionately large corrected calf girth in subject A. Despite the differences in the physique of these individuals when the proportionality profiles were examined. It was observed that the ratings of 5 and 5 for A and **W-ratings** respectively were explained by the relative contributions of skinfold measures, girths, bone widths and corrected girths, for each of the individuals.

Figure CII.1a: O-SCALE Analysis for Male A with Balanced Type Physique.

MALE 24.56 years of age

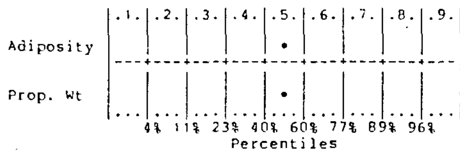
Height = 186.0 cm

Weight = 84.9 kg

Proportional Weight = 65.0 kg

Sum of 6 Skinfolds = 65.2 mm

Prop. Sum Skinfolds = 59.7 mm



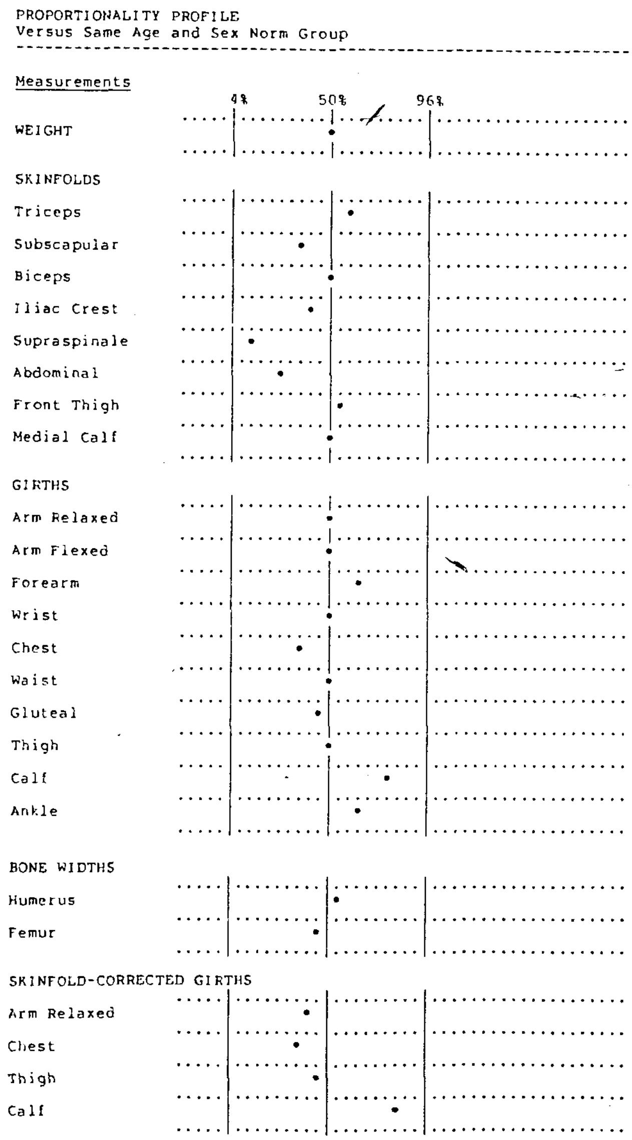


Figure CII.1b: O-SCALE Analysis for Male B with Balanced Type Physique.

MALE 24.90 years of age

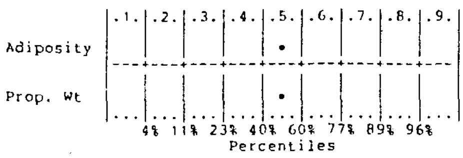
Height = 184.4 cm

Weight = 82.2 kg

Proportional Weight = 64.6 kg

Sum of 6 Skinfolds = 70.0 mm

Prop. Sum Skinfolds = 64.6 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

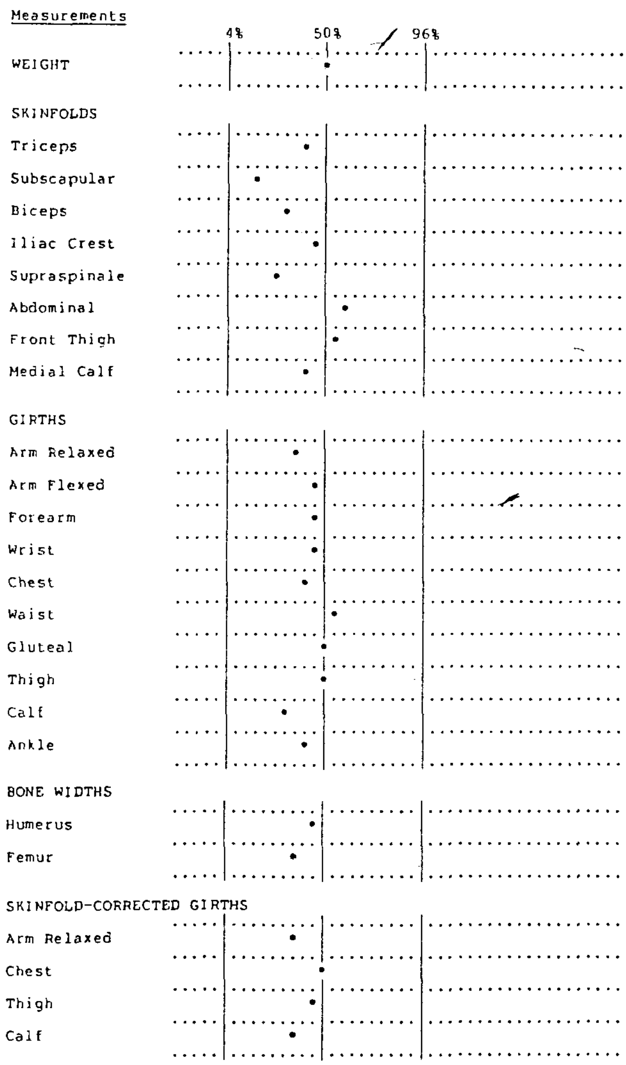


Figure CII.1c: O–SCALE Analysis for Male C with Balanced Type Physique.

MALE 31.94 years of age

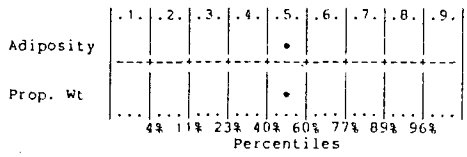
Height = 183.5 cm

Weight = 85.3 kg

Proportional Weight = 68.0 kg

Sum of 6 Skinfolds = 78.0 mm

Prop. Sum Skinfolds = 72.3 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

Measurements

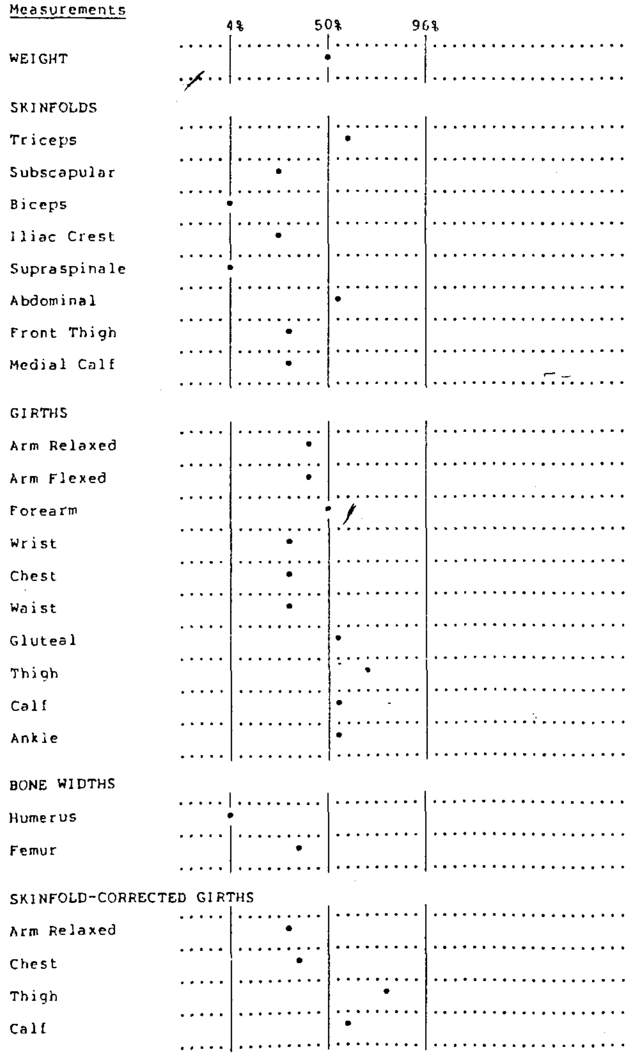


Figure CII.2a: O-SCALE Analysis for Female D with Balanced Type Physique

FEMALE 20.36 years of age

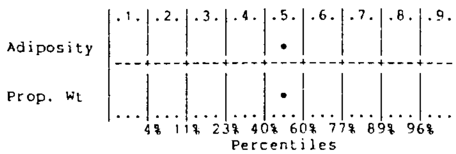
Height = 165.1 cm

Weight = 57.9 kg

Proportional Weight = 63.4 kg

Sum of 6 Skinfolds = 95.8 mm

Prop. Sum Skinfolds = 98.7 mm



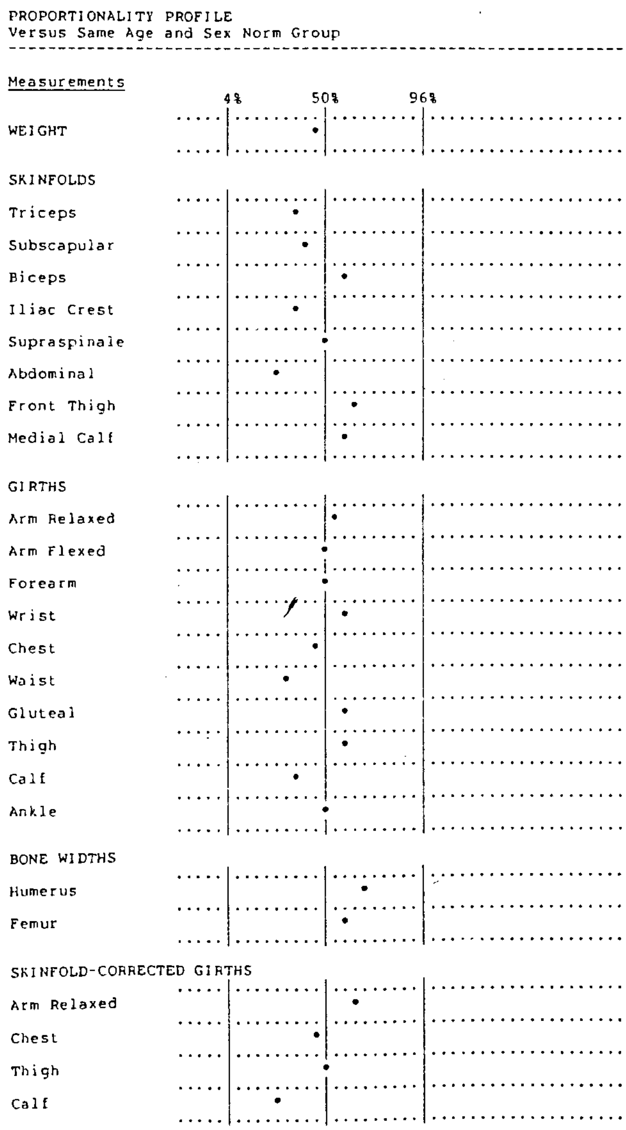


Figure CII.2b: O-SCALE Analysis for Female E with Balanced Type Physique

FEMALE 20.52 years of age

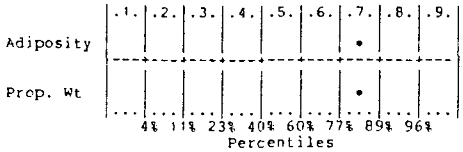
Height = 171.9 cm

Weight = 74.3 kg

Proportional Weight = 72.1 kg

Sum of 6 Skinfolds = 131.3 mm

Prop. Sum Skinfolds = 130.0 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

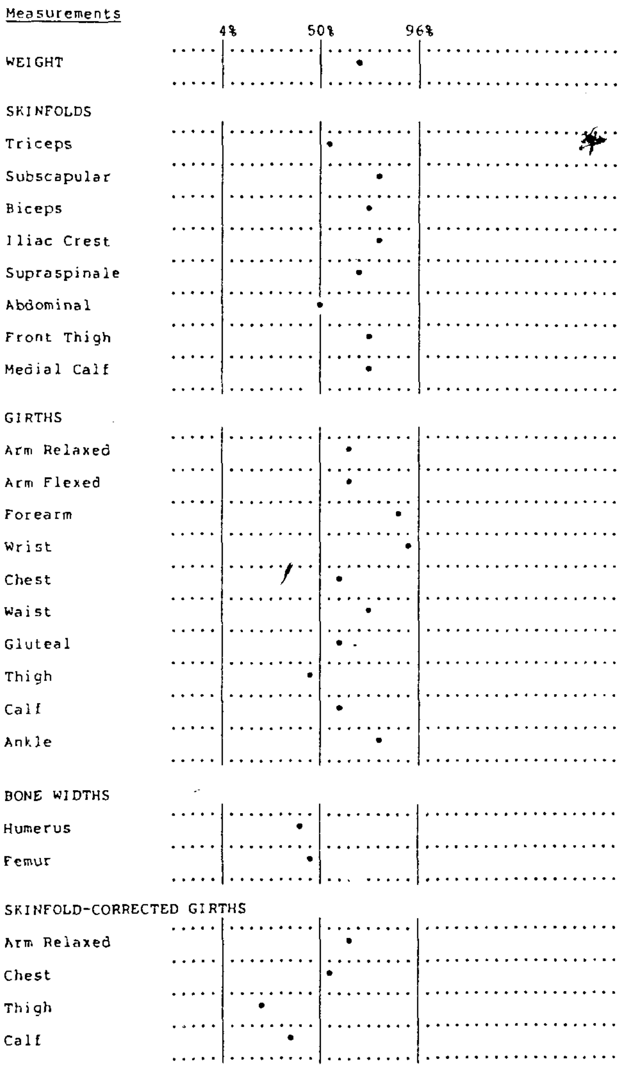


Figure CII.2c: O-SCALE Analysis for Female F with Balanced Type Physique

FEMALE 26.98 years of age

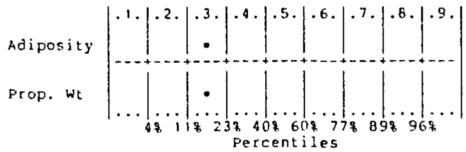
Height = 165.3 cm

Weight = 51.5 kg

Proportional Weight = 56.2 kg

Sum of 6 Skinfolds = 72.0 mm

Prop. Sum Skinfolds = 74.1 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

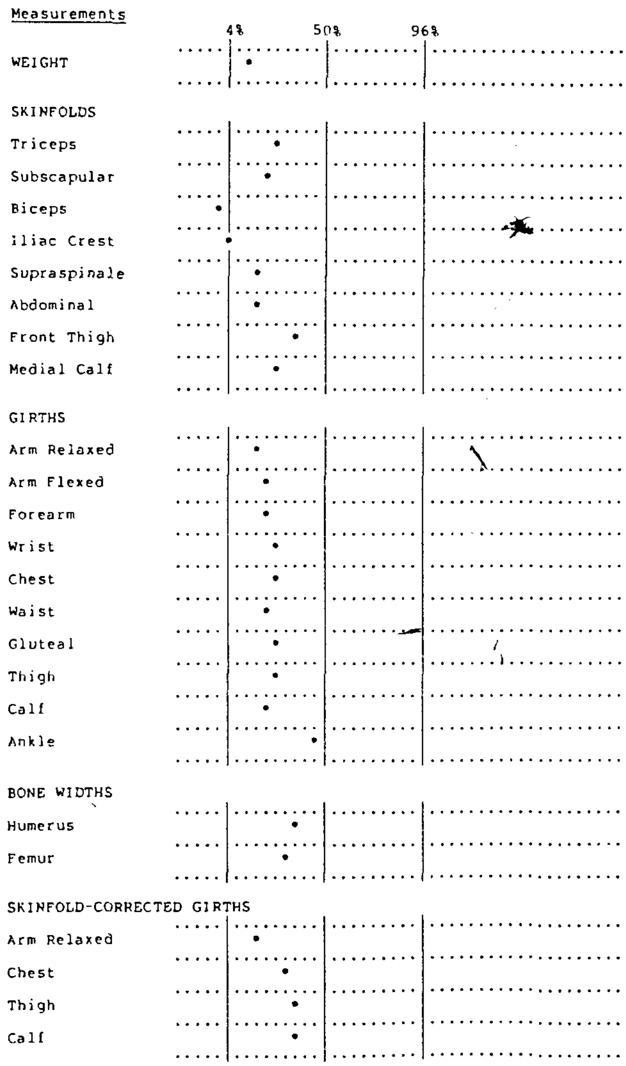


Figure CII.2 showed the O-SCALE analyses for the three females randomly selected from those exhibiting Balanced Type Physiques. Subject D was rated as a 5 in adiposity and a 5 in proportional weight, being a 20.36 year old female, 165.1 cm in stature and 57.9 kg in body weight. The sum of six skinfolds was 95.8 mm, the proportional weight was 63.4 kg and the proportional sum of six skinfolds was 98.7 mm. Subject E was a 20.52 year old female, 171.9 cm tall, 74.3 kg in body weight with a resultant proportional weight of 72.1 kg. Her sum of six skinfolds was 131.3, and her proportional sum of skinfolds was 130, giving rise to her **A-rating** of 7 and her **W-rating** of 7 also. Subject F was a 26.98 year olf female, 165.3 cm tall with a body weight of 51.5 kg and a proportional weight of 56.2 kg. Her sum of six skinfolds was 72.0 mm and her proportional sum of skinfolds was 74.1 mm. This lead to her **A-rating** being 3 and her **W-rating** also being a 3. There were no suprises in the three profiles, each individual exhibited a pattern of skinfolds, girths and bone widths that were in harmony with their weight ratings. Subject D and E both showed greater development in upper skinfold-corrected girths in relation to lower girths. However, they compensated for each other in relation to the rating for weight.

Weight Dominant Physiques

Three males and three females were randomly selected from the CANAD data set based on the criterion that the proportional weight rating was greater than their adiposity rating. This was taken to indicate that the musculoskeletal component of their physique was developed to a greater extent than their adiposity. Figure CII.3 showed the O-SCALE analyses for the three male subjects A, B and C. Subject A was a 20.21 year old male, 185.3 cm in stature and 82.7 kg in body weight. His sum of six skinfolds was 47.4 mm his proportional weight was 64.1 kg and his proportional sum of skinfolds was 43.5 mm. He was rated as a 3 in adiposity and a 5 in proportional weight. Subject B showed a greater differential between A and **W-ratings** with an **A-rating** of 2 and a proportional weight rating of 7, being a 22.41 year old male, 184.5 cm in stature and 90.3 kg in body weight. His sum of six skinfolds was 44.3 mm with his proportional weight being 70.9 kg and proportional sum of skinfolds being 40.9 mm. Subject C was rated as a 3 in adiposity and a 6 in proportional weight, being a 23.48 year old male, 170.4 cm in stature and 66.2 kg in body weight. Sum of six skinfolds was 43.5 mm proportional weight was 65.9 kg and proportional sum of skinfolds was 43.4 mm. Each of these weight dominant physiques showed a similar pattern. The skinfold measures were all displaced to the left of the proportional weight rating for each of the three individuals, and the girths were displaced to the right of the skinfold measures. The corrected girths also showed ratings higher than each of the skinfolds for the individual under consideration. Subject B having an A rating of 3 and **W-rating** of 7, and thus the greatest difference in A and **W-rating**, also exhibited the greatest difference in skinfold and corrected girth ratings. All three profiles adequately explained in terms of low skinfold ratings and high corrected girth ratings the reason for the difference in A and W ratings.

The three females randomly selected as having weight dominant physiques had their O-SCALE ratings shown in figure CII.4 as subjects D, E and F. Subject D was a 20.64 year old female, 162.4 cm in stature and 54.9 kg in body weight. Her sum of six skinfolds was 60.8 mm, her proportional weight was 63.2 kg and her proportional sum of skinfolds was 63.7 mm. Her **A-rating** was 1 and her W rating was 5. Subject E had an **A-rating** of 3 and a proportional weight rating of 7, being a 23.14 year old female of 154.3 cm in stature and 51.3 kg in body weight. Her sum of six skinfolds was 73.4 mm, her proportional weight was 68.8 kg and her proportional sum of skinfolds was 81.0 mm. Subject F was a 27.30 year old female, 172.9 cm tall and weighing 70.2 kg. Her sum of six skinfolds was 75.2 mm, her proportional weight was 66.9 kg and her proportional sum of skinfolds was 74.0 mm. This gave her an **A-rating** of 2 and a **W-rating** of 6. Despite the similarity of the three females in that they had lower adiposity ratings than proportional weight ratings, the profiles for the individuals were very different. Subject D showed low skinfold measures at all sites being at or below the 4th percentile except for relatively high ratings just below the 50th percentile for triceps and subscapular skinfolds. Subject F however showed a pattern of lower rating of skinfolds in the upper body sites, and it was the front thigh that showed the highest rating just over the 50th percentile, and the medial calf having the next highest rating. Subject E however, showed highest ratings in the abdominal and supraspinale skinfolds. The corrected girths showed dissimilar patterns in that in Subject F the corrected girths were similarly rated midway between the 50th and 96th percentiles. In Subject E the most muscular, the corrected calf girth received the highest rating above the 96th percentile, with the corrected arm and chest being the next, and lowest rating being received by the thigh girth midway between the 50th and 96th percentiles. Subject D had a highly rated corrected calf girth but relatively low rated arm girth, being midway between the 4th and 50th percentiles, whereas the corrected calf was just over midway between the 50th and 96th percentiles. Despite the differences shown in the physiques of these three females, a pattern that was clearly demonstrated was that skinfolds received ratings below those of body weight and the corrected girths, except for the corrected arm girth in Subject E, received ratings above the rating for weight. Thus, clearly as with the three males, the difference in A and W rating was wholly accounted for in the distribution of the skinfold and girth ratings.

Figure CII.3a: O-SCALE Analysis for Male A exhibiting Weight Dominant Physique

MALE 20.21 years of age

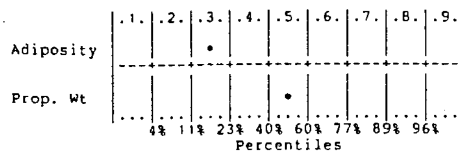
Height = 185.3 cm

Weight = 82.7 kg

Proportional Weight = 64.1 kg

Sum of 6 Skinfolds = 47.4 mm

Prop. Sum Skinfolds = 43.5 mm



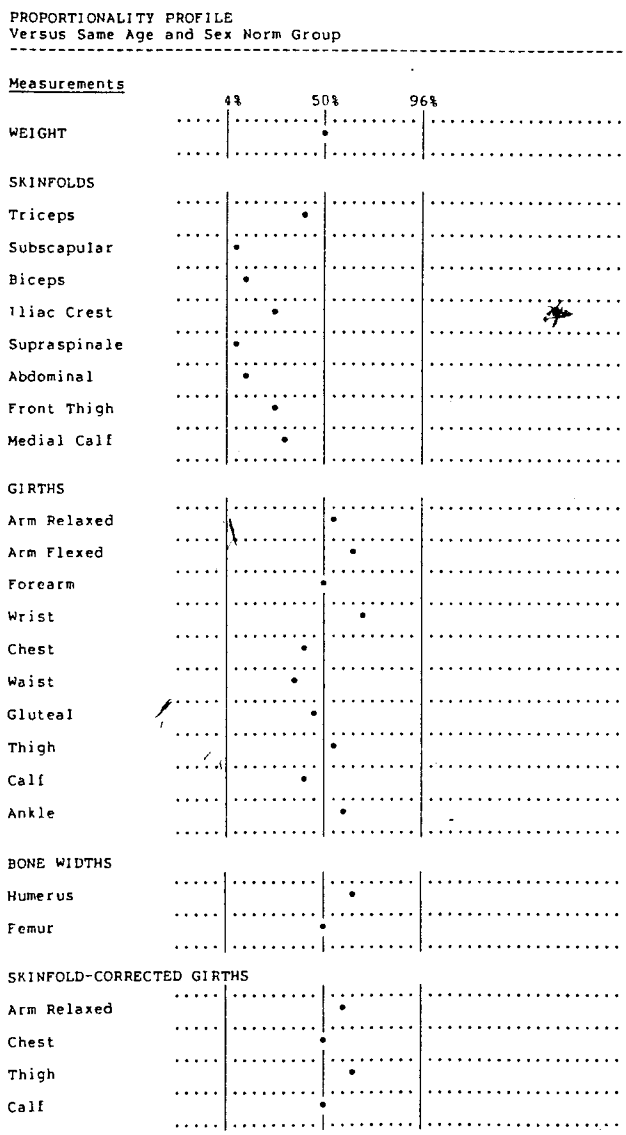


Figure CII.3b: O-SCALE Analysis for Male B exhibiting Weight Dominant Physique

MALE 22.41 years of age

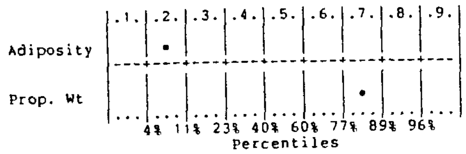
Height = 184.5 cm

Weight = 90.3 kg

Proportional Weight = 70.9 kg

Sum of 6 Skinfolds = 44.3 mm

Prop. Sum Skinfolds = 40.9 mm



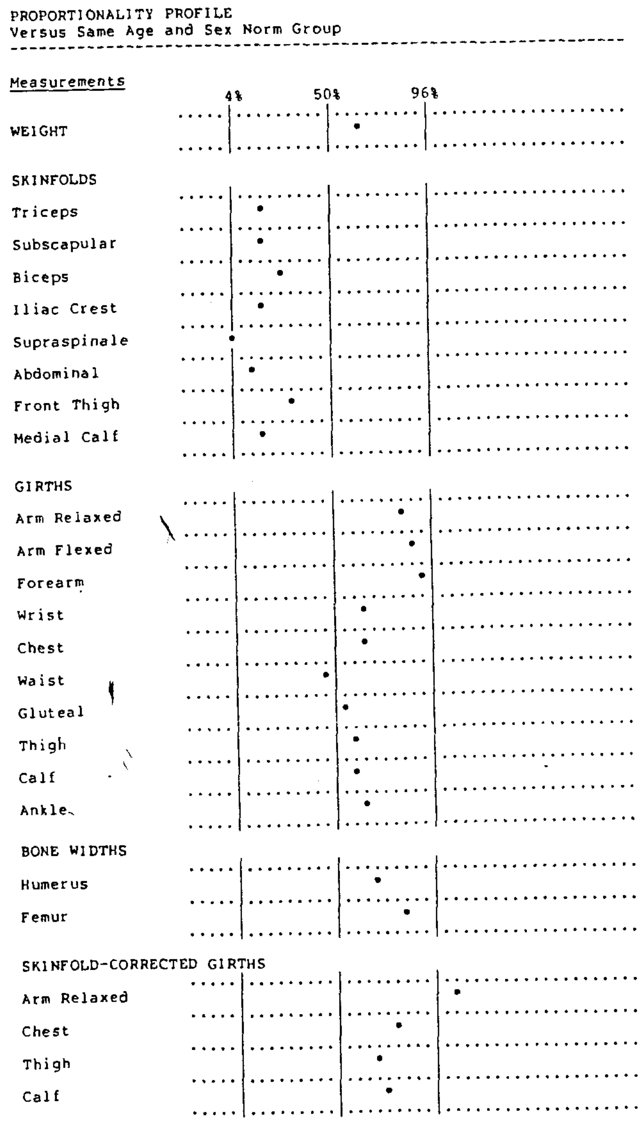


Figure CII.3c: O-SCALE Analysis for Male C exhibiting Weight Dominant Physique

MALE 23.48 years of age

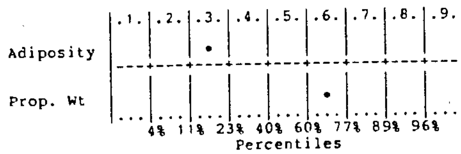
Height = 170.4 cm

Weight = 66.2 kg

Proportional Weight = 65.9 kg

Sum of 6 Skinfolds = 43.5 mm

Prop. Sum Skinfolds = 43.4 mm



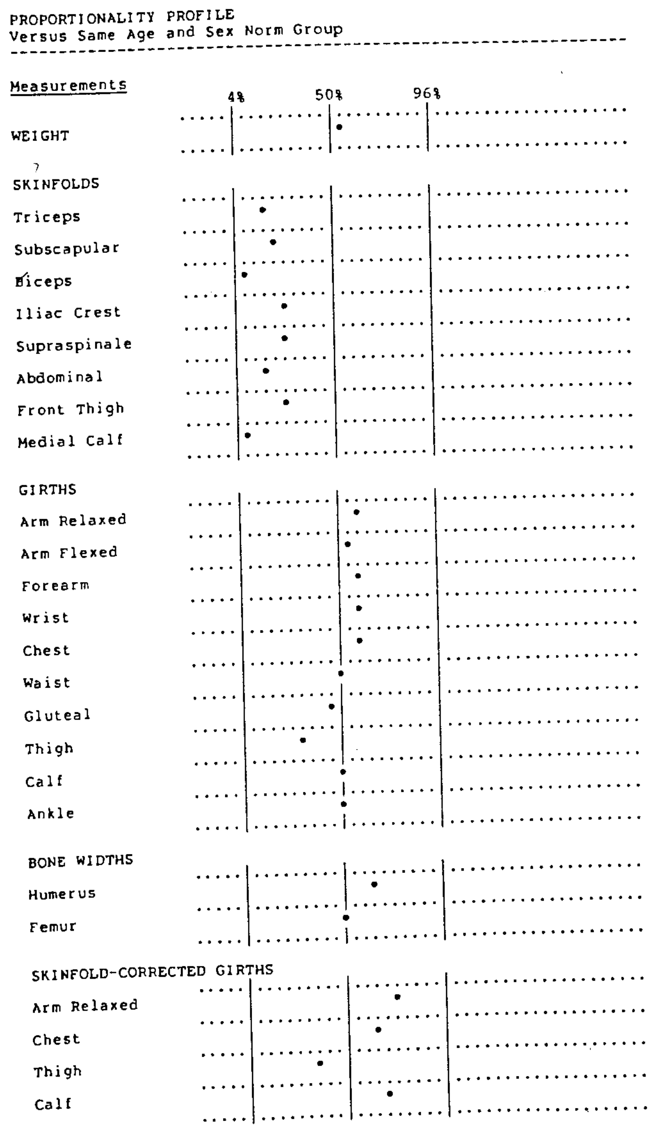


Figure CII.4a: O-SCALE Analysis for Female D exhibiting Weight Dominant Physique

FEMALE 20.64 years of age

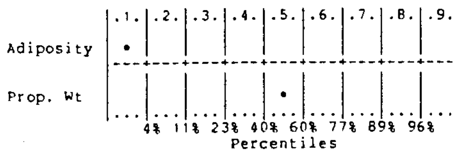
Height = 162.4 cm

Weight = 54.9 kg

Proportional Weight = 63.2 kg

Sum of 6 Skinfolds = 60.8 mm

Prop. Sum Skinfolds = 63.7 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

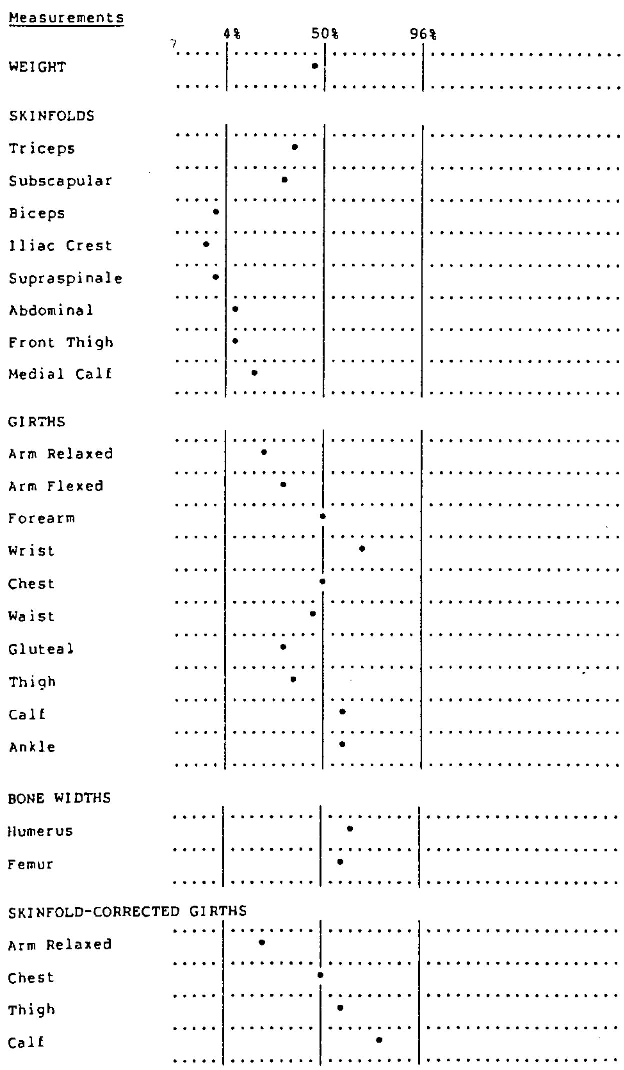


Figure CII.4b: O-SCALE Analysis for Female E exhibiting Weight Dominant Physique

FEMALE 23.14 years of age

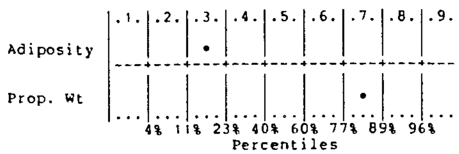
Height = 154.3 cm

Weight = 51.3 kg

Proportional Weight = 68.8 kg

Sum of 6 Skinfolds = 73.4 mm

Prop. Sum Skinfolds = 81.0 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

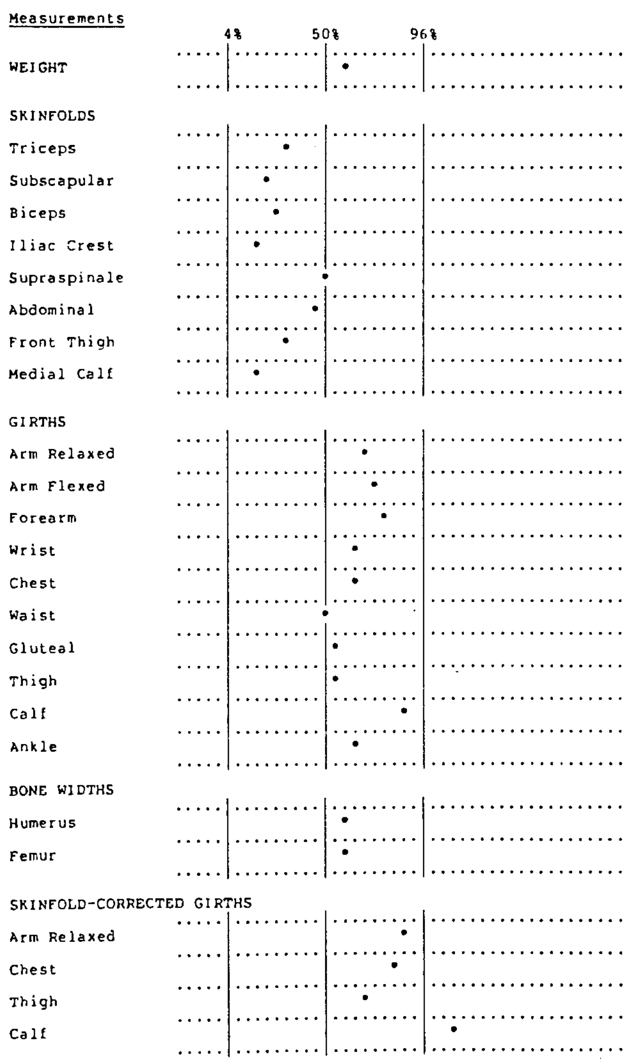


Figure CII.4c: O-SCALE Analysis for Female F exhibiting Weight Dominant Physique

FEMALE 27.30 years of age

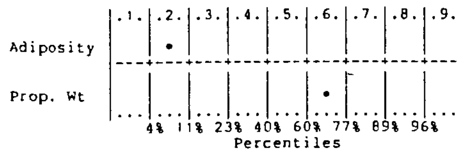
Height = 172.9 cm

Weight = 70.2 kg

Proportional Weight = 66.9 kg

Sum of 6 Skinfolds = 75.2 mm

Prop. Sum Skinfolds = 74.0 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

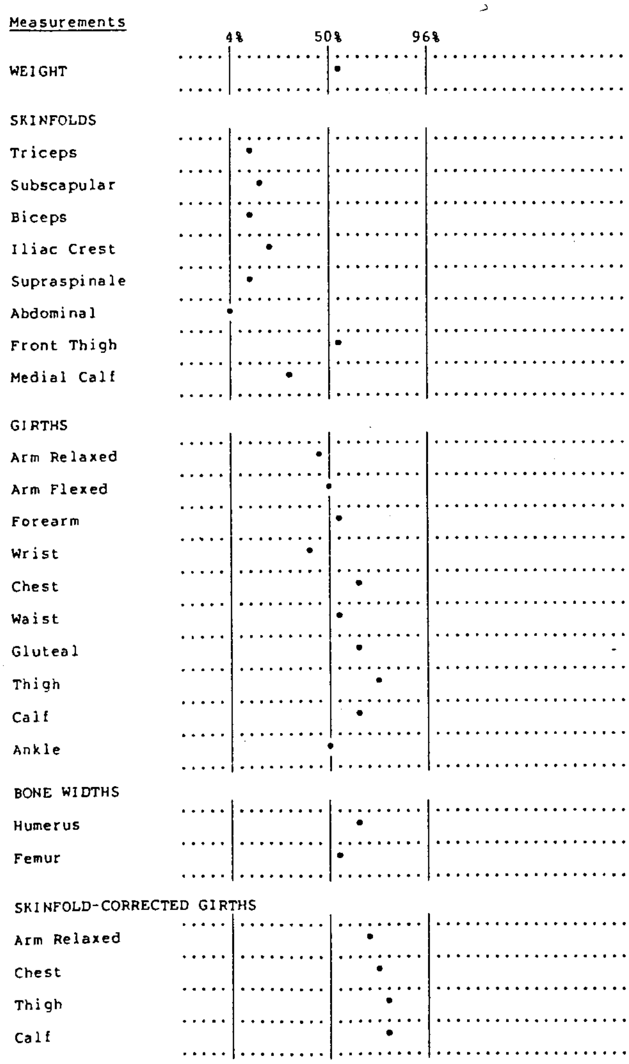


Figure CII.5a: O-SCALE Analysis for Male A exhibiting Adiposity Dominant Physique

MALE 22.65 years of age

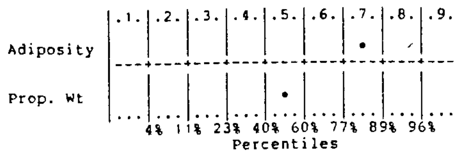
Height = 173.9 cm

Weight = 69.0 kg

Proportional Weight = 64.7 kg

Sum of 6 Skinfolds = 95.5 mm

Prop. Sum Skinfolds = 93.5 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

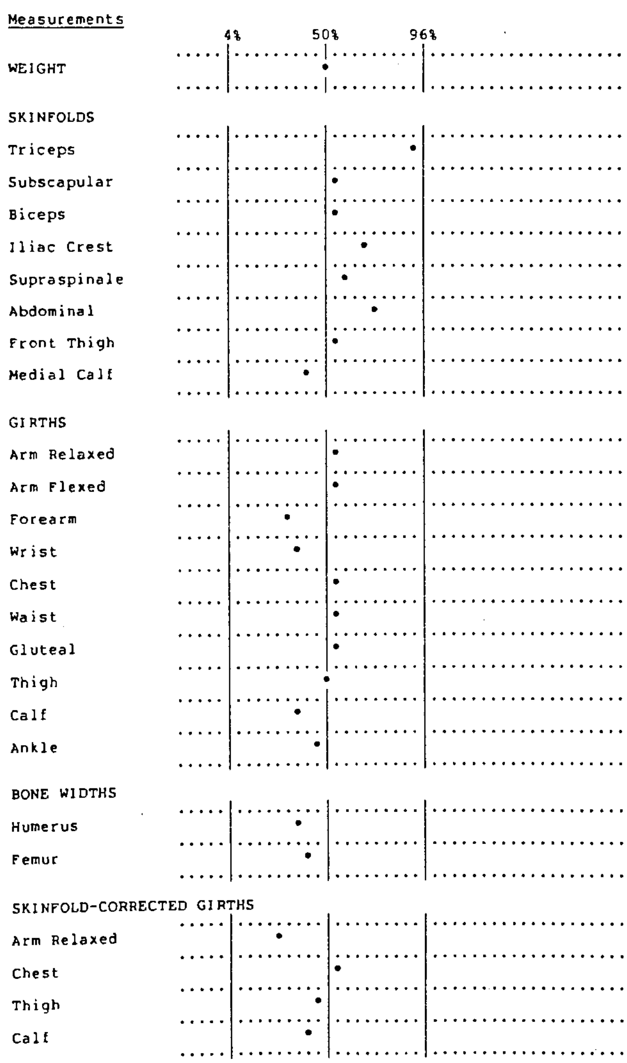


Figure CII.5b: O-SCALE Analysis for Male B exhibiting Adiposity Dominant Physique

MALE 20.53 years of age

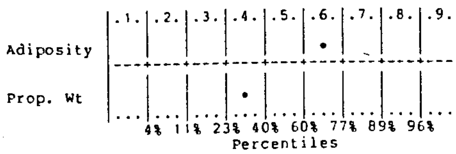
Height = 173.9 cm

Weight = 64.7 kg

Proportional Weight = 60.6 kg

Sum of 6 Skinfolds = 81.8 mm

Prop. Sum Skinfolds = 80.1 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

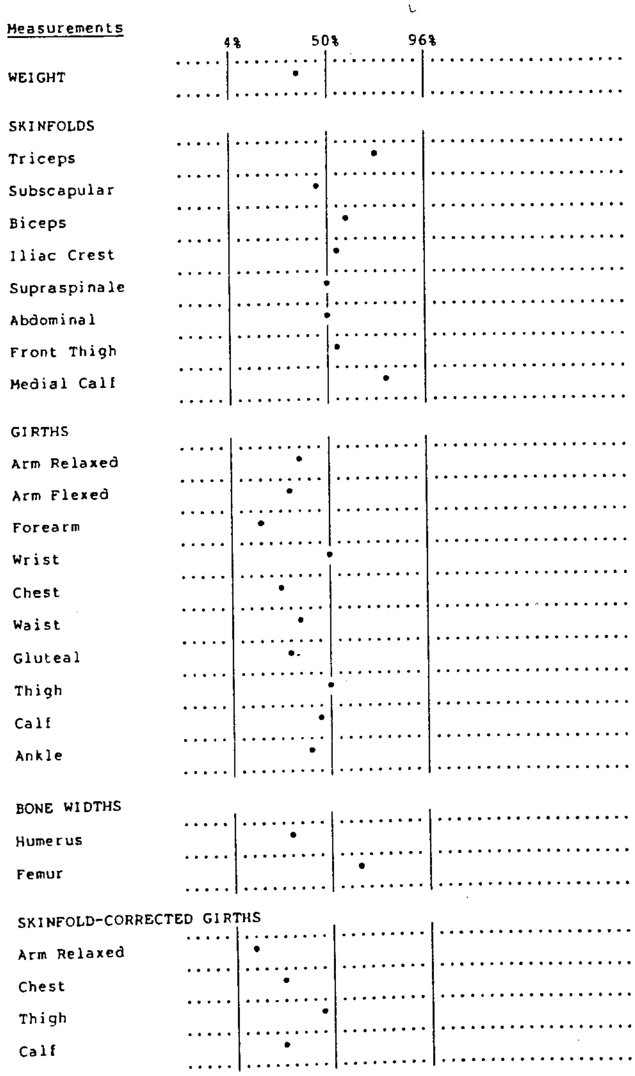


Figure CII.5c: O-SCALE Analysis for Male C exhibiting Adiposity Dominant Physique

MALE 22.84 years of age

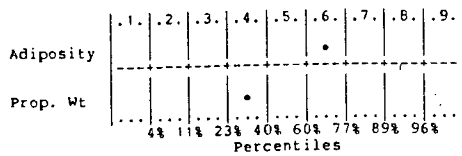
Height = 188.3 cm

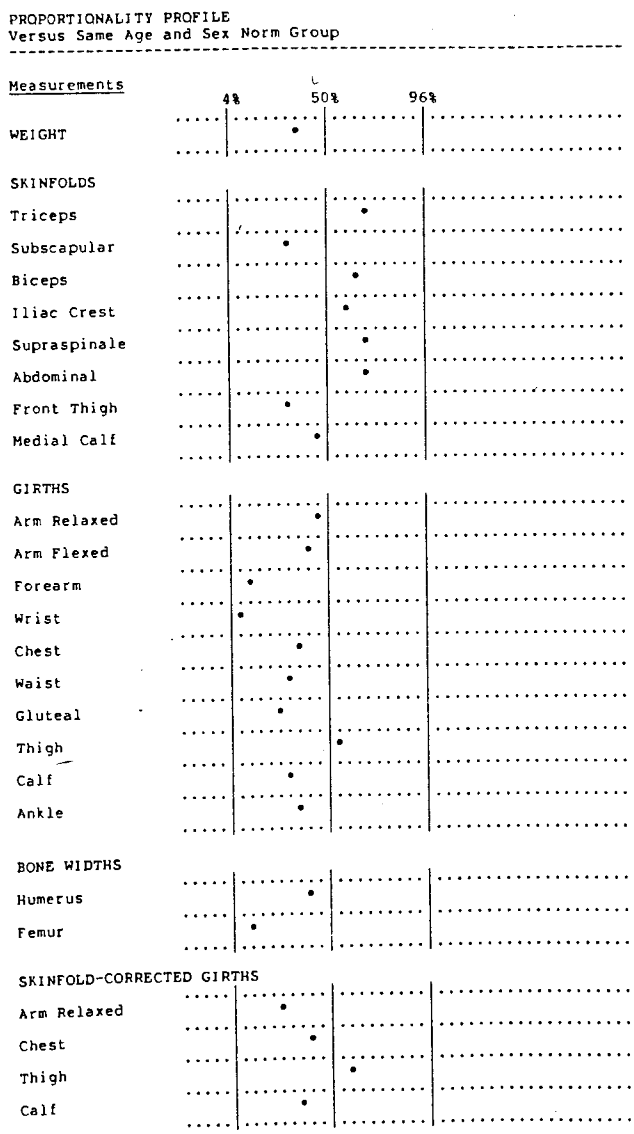
Weight = 82.9 kg

Proportional Weight = 61.2 kg

Sum of 6 Skinfolds = 91.0 mm

Prop. Sum Skinfolds = 82.2 mm





Adiposity Dominant Physiques

Three males and three females were randomly selected from the CANAD data set, by the criteria of having an **A-rating** higher than the **W-rating**. This difference was defined as being an Adiposity Dominant Physique. Figure CII.5 showed the O-SCALE analyses for the three male subjects A, B and C. Subject A was a 22.65 year old male 173.9 cm tall with a body weight of 69.0 kg. His sum of six skinfolds was 95.5 mm, his proportional weight was 67.4 kg, his proportional sum of skinfolds was 93.5 mm, giving an **A-rating** of 7 and a **W-rating** of only 5. Subject B had an **A-rating** of 6 and a **W-rating** of 4, being a 20.53 year old male, 173.9 cm tall with a body weight of 64.7 kg. His sum of skinfolds was 81.8 mm and his proportional weight was 80.1 mm. Subject C was a 22.84 year old male 188.3 cm tall weighing 82.9 kg. His sum of skinfolds was 91.0 mm, his proportional weight was 61.2 kg and his proportional sum of skinfolds was 82.2 mm. He also had an **A-rating** of 6 and a **W-rating** of 4. Subject A girth ratings around the 50th percentile which was consistent with the proportional weight rating. However, the skinfolds showed ratings between the 50th and 96th percentiles, with the triceps being just below the 96th percentile, and the abdominal and iliac crest being rated midway between the 50th and 96th percentiles. The corrected girths were below the 50th percentile except for the corrected chest girth, which was just above the 50th percentile. The lowest rated girth was the arm girth, midway between the 4th and 50th percentiles. The difference in A and **W-rating** was therefore explained by the higher rating of the skinfolds and the lower rating of the corrected girths. Subject B showed a similar pattern in that the skinfolds were rated higher than the corrected girths except for the corrected thigh girth being just below the 50th percentile. All of the skinfolds were at or above the 50th percentile except for the subscapular skinfold which was just below the 50th percentile. The girths showed a pattern consistent with the location of the proportional weight rating. Subject C showed corrected girths below the 50th percentile except for the corrected thigh girth. Whereas five of the skinfolds were above the 50th percentile, with the other three subscapular, front thigh and medial calf being below. It was demonstrated that in each of these profiles the difference in A and **W-ratings** was explained by the relatively poor development of muscularity as indicated by the corrected girths in relation to the high level of deposition of adiposity at the skinfold sites.

Figure CII.6 showed the O-SCALE analyses for the three females (Subjects D, E and F) selected as having **A-ratings** at least two higher than their **W-ratings**. Subject D was a 27.55 year old female, 156.9 cm tall with a body weight of 45.1 kg. Her proportional weight was 57.5 kg, sum of six skinfolds of 99.3 mm and a proportional sum of skinfolds of 107.6 mm. Her adiposity rating was 5, but her proportional weight rating was only 3. Subject E was a 22.63 year old female, 164.8 cm in stature, weighing 58.4 kg. Her sum of six skinfolds was 143.3 mm, her proportional weight was 64.3 kg and her proportional sum of skinfolds was 148.0 mm. Her adiposity rating was an 8 and her proportional weight rating was 6 .Subject F was a 21.67 year old female, 171.2 cm tall with a body weight of 54.0 kg. Her sum of six skinfolds was 92.5 mm, proportional weight was 53.0 kg and her proportional sum of skinfolds was 91.9 mm. This gave an **A-rating** of 4 and a **W-rating** of 2. Each of subject D, E and F showed similar results to those found in subjects A, B and C, in that the skinfolds received average ratings higher than the corrected girths. Although Subject D received wide differences in ratings for skinfolds and so to in corrected girths. However, the patterns found in each of these three physiques corroborated that found in the males, in that the difference between the weight and adiposity ratings was reflected in the higher ratings in the skinfolds relative to the corrected girths.

Figure CII.6a: O-SCALE Analysis for Female D exhibiting Adiposity Dominant Physique

FEMALE 27.55 years of age

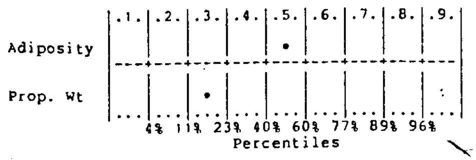
Height = 156.9 cm

Weight = 45.1 kg

Proportional Weight = 57.5 kg

Sum of 6 Skinfolds = 99.3 mm

Prop. Sum Skinfolds = 107.7 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

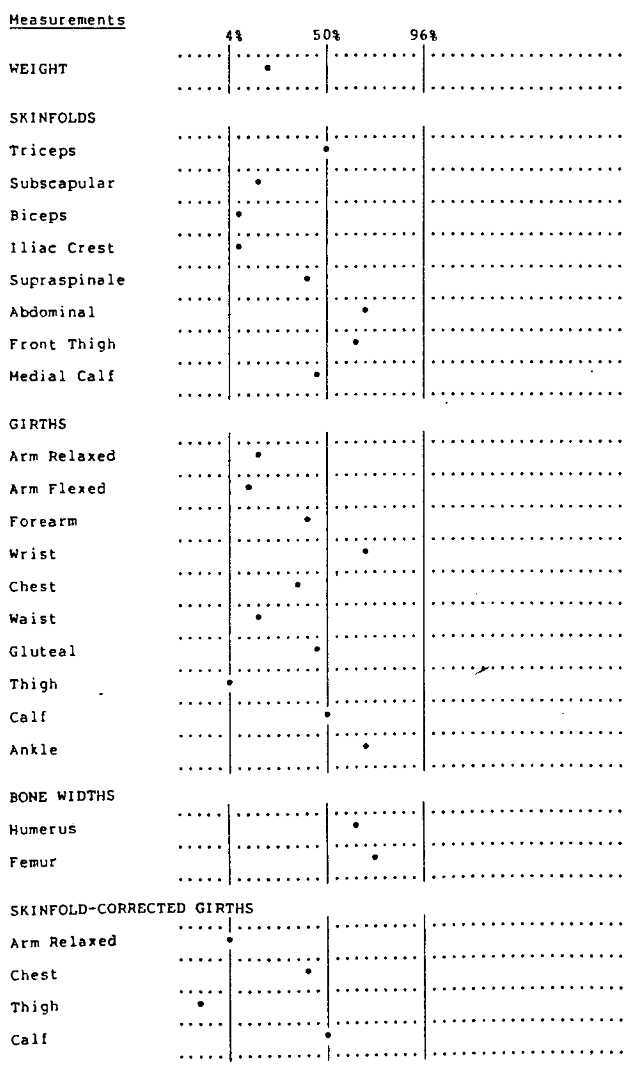


Figure CII.6b: O-SCALE Analysis for Female E exhibiting Adiposity Dominant Physique

FEMALE 22.63 years of age

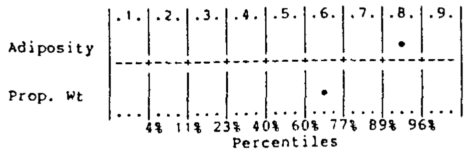
Height = 164.8 cm

Weight = 58.4 kg

Proportional Weight = 64.3 kg

Sum of 6 Skinfolds = 143.3 mm

Prop. Sum Skinfolds = 148.0 mm



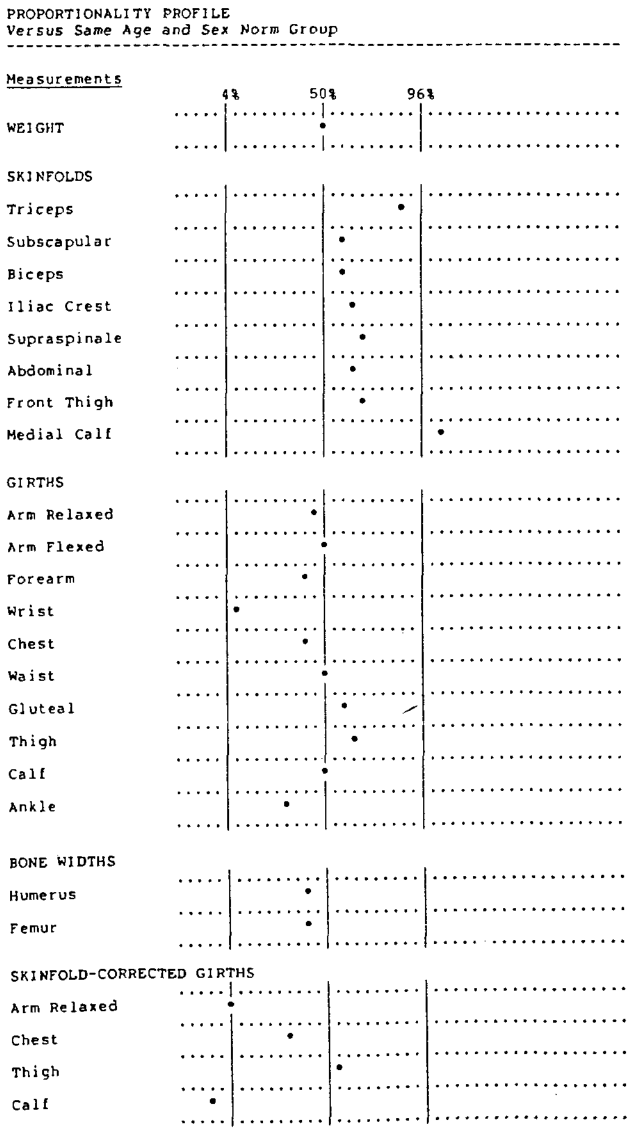


Figure CII.6c: O-SCALE Analysis for Female F exhibiting Adiposity Dominant Physique

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FEMALE 21.67 years of age

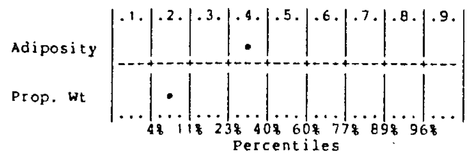
Height = 171.2 cm

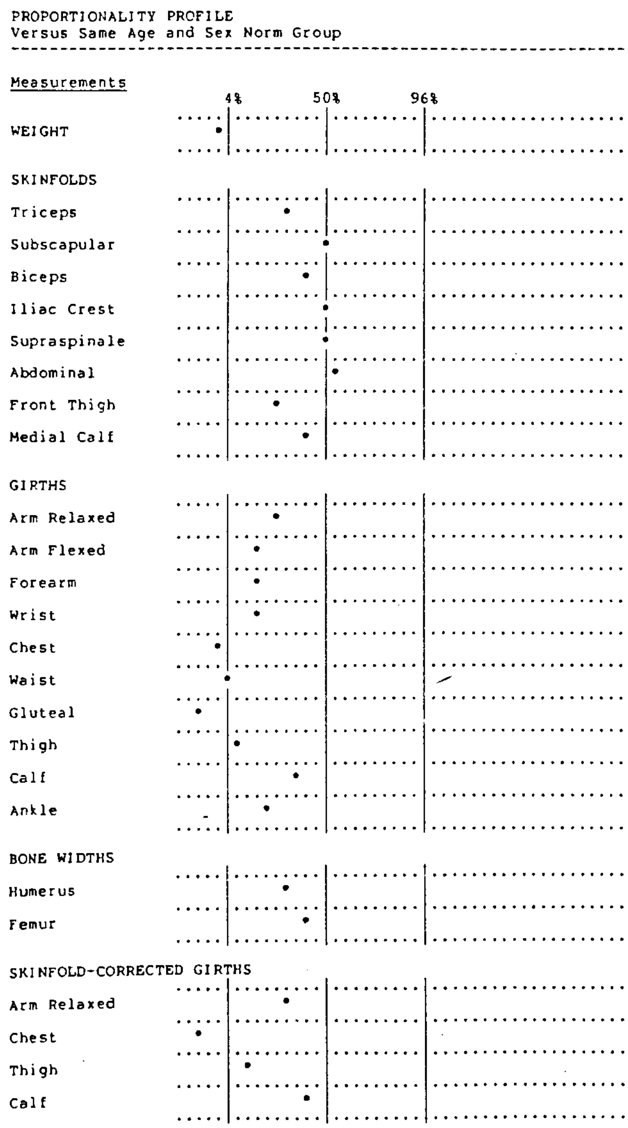
Weight = 54.0 kg

Proportional Weight = 53.0 kg

Sum of 6 Skinfolds = 92.5 mm

Prop. Sum Skinfolds = 91.9 mm





Alternative Assessments

In addition to the O-SCALE analyses, analyses were carried out on the selected CANAD individuals using the Heath-Carter Somatotype, Body Mass Index and three predictions of percentage body fat. The results of these analyses were reported in Table CII.1. The somatotype analyses showed all three males with balanced physiques to be endomesomorphs along with female subject E being a mesoendomorph. Subject F was a mesopene. The individuals with weight dominant physiques all showed more extreme mesomorphic physiques as would be expected from the differential in their O-SCALE A and W-ratings. The somatotype analyses were in total accord with expectations based on the A and W ratings and their proportionality profile analysis. The BMI analysis presented a confusing pattern. BMI has been associated with "fatness", however in these few examples it was seen that for a given BMI there was considerable difference in physique. For instance Balanced Physique D, Weight dominant Physique E and Adiposity dominant Physique E were females with BMI's of 21.2, 21.6 and 21.5 respectively. However percent fat was predicted to be 18.4%, 14.9% and 21.5% respectively using the Yuhasz formula and 18.7%, 17.4% and 25.3% using the Sloan equation. Thus there was considerable difference in percentage body fat. Being a combination of weight and height alone the BMI was unable to truly differentiate physique as indicated by the difference in proportionality profiles of these individuals.

There was a consistently higher prediction of percentage body fat using the Durnin and Womersley equations. This was expected and had been previously reported in the literature. There was a tendency for the Sloan equations to predict higher than the Yuhasz equations however, in three of the subjects the Sloan equation predicted the smaller value. These differences were purely a feature of differences in skinfold patterning. Since the Sloan equations use only two skinfolds, they are particularly susceptible to variations in patterning.

Table CII.1: Comparison of Physique Assessments for randomly selected individuals with Balanced, Weight Dominant and Adiposity Dominant Physiques. Assessments included Heath-Carter Somatotype, Body Mass Index, Percentage Body Fat predicted using three sets of equations; Yuhasz (YZ), Sloan (SL), Durnin and Womersly (DW), and O-SCALE A and W-ratings.

		HEATH-CARTER					O-SCALE	
ID	SEX	SOMATOTYPE	BMI	YZ	SL	DW	A	W
BALANCED TYPE								
A	M	2.9-3.7-2.4	24.5	9.4	13.2	16.8	5	5
B	M	2.5-4.5-2.5	24.2	9.9	11.5	14.9	5	5
C	M	3.2-4.2-1.9	25.3	10.8	12.2	20.0	5	5
D	F	3.8-4.1-2.7	21.2	18.4	18.7	25.4	5	5
E	F	5.6-4.0-1.4	25.9	23.9	22.5	34.0	7	7
F	F	3.1-2.6-3.9	18.9	14.7	17.4	21.4	3	3
WEIGHT DOMINANT								
A	M	2.2-5.6-2.6	24.1	7.6	8.5	13.4	3	5
B	M	1.9-7.0-1.5	26.5	7.2	9.2	12.4	2	7
C	M	1.5-5.5-3.3	21.2	7.2	8.7	12.1	3	6
D	F	3.0-4.2-2.7	20.8	13.0	17.1	21.2	1	5
E	F	3.3-5.4-1.8	21.6	14.9	17.4	21.6	3	7
F	F	2.8-4.4-2.1	23.5	15.2	17.4	22.1	2	6
ADIPOSITY DOMINANT								
A	M	4.5-4.4-2.5	22.8	12.6	13.8	20.9	7	5
B	M	3.6-4.3-2.5	21.4	11.2	12.6	18.1	6	4
C	M	4.4-3.8-3.0	23.4	12.1	10.2	19.6	6	4
D	F	3.6-3.8-3.0	18.3	19.0	18.4	22.5	5	3
E	F	5.8-3.3-2.5	21.5	25.8	25.3	31.3	8	6
F	F	4.0-2.9-4.6	18.4	17.9	19.4	26.0	4	2

SPORT SPECIFICITY

Rowers

Three types of athletes were selected for analysis from the Montreal Olympic Games (MOGAP) data set. They were rowers, cyclists and weightlifters. Figure CII.7 showed the O-SCALE analyses resulting from the average anthropometric dimensions of the male and female rowers in the MOGAP data assembly, being analysed as if they were individuals. It should be noted that all profiles are plotted relative to the appropriate age and sex norms from the O-SCALE normative set. similarity between profiles, however it must be borne in mind that the males and females were each compared to their own sex and age specific norm group. Figure CII.8 showed the profiles for three male rowers randomly selected using the random numbers table from the same group of male Olympic rowers. Figure CII.9 showed the three O-SCALE analyses for three female rowers similarly selected. Subject A, a 31.43 year old male, 194.3 cm in stature, and 91.8 kg in body weight, had a sum of six skinfolds of 38.0 mm. His proportional weight was 61.7 kg and his proportional sum of skinfolds was 33.3 mm, giving rise to an **A-rating** of 1 and a **W-rating** of 4. Subject B, having an **A-rating** of 1 and **W-rating** of 8, was 24.30 year old male, 182.0 cm tall with a weight of 91.7 kg. His sum of six skinfolds was 33.4 mm, his proportional weight was 75.0 kg and his proportional sum of skinfolds was 31.2 mm. Subject C was a 23.19 year old male, 179.2 cm in stature and 82.6 kg in body weight. His proportional weight was 70.6 kg and sum of skinfolds was 48.6 mm with the proportional sum of skinfolds being 46.1 mm. This lead to an adiposity rating of 3 and a proportional weight rating of 7. Despite the differences in height and weight, there were striking similarities profiles of the three individuals in comparison to the average profile for male rowers. For instance, in each the humerus width received a considerably higher rating than the femur width. Also the corrected calf girth had the highest rating of the corrected girths, with the corrected arm girth in subjects A and C receiving the lowest rating. In comparison to the average profile for male rowers in Figure CII.7 there was remarkable commonality in the three profiles. Figure CII.9 showed the three female Olympic rowers selected for analysis, subjects D, E and F. Subject D was a 22.27 year old female, 172.8 cm tall and weighing 65.8 kg. Her proportional weight was 62.9 kg and her sum of six skinfolds 69.7 mm, and proportional sum of skinfolds was 68.6 mm. She had an **A-rating** of 2 and a **W-rating** of 5. Subject E was a 26.74 year old female 172.4 cm tall and with a body weight of 59.4 kg. Her proportional weight was 57.1 kg, her sum of six skinfolds was 52.2 mm and her proportional sum of skinfolds was 49.7 mm. This gave rise to an **A-rating** of 1 and a **W-rating** of 3. Subject F was a 25.12 year old female, 174.4 cm tal with a body weight of 65.7 kg. Her proportional weight was 61.0 kg, her sum of six skinfolds was 60.1 mm and her proportional sum of skinfolds was 58.6 mm. She had an **A-rating** of 1 and a **W-rating** of 5. In the female rower profiles there were the same striking resemblances to the male profiles in that the humerus and femur width receive very disparate ratings with the humerus being rated much higher than the femur, and the corrected calf girth being the highest rated girth, although tied with corrected chest girth in subject D. In comparison to the female average profile each of the three individuals exhibit a remarkable similarity despite the differences in height and weight and adiposity level. From consideration of the male and female average profiles and the six individual profiles it appeared that there was a physique pattern in relation to their same age and sex norms distinctive to the Olympic Rowers. This consisted mainly of similarities in the bone widths and girths. The humerus was consistently higher rated than the femur. The forearm and wrist girths were consistently higher rated than the other girths, with the calf girth being the highest rated of the skinfold corrected girths. The A and **W-ratings** showed the weight dominant pattern typical of athletes in that the **A-rating** was less than the **W-rating** reflecting the disproportionate development of the muscular component.

Figure CII.7a: O-SCALE Analysis for average values of anthropometric items for Male Olympic Rowers

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MALE 24.247 years of age

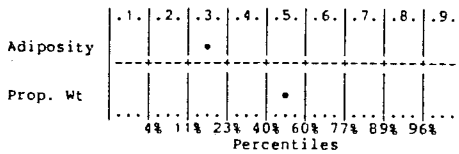
Height = 191.4 cm

Weight = 90.0 kg

Proportional Weight = 63.3 kg

Sum of 6 Skinfolds = 49.4 mm

Prop. Sum Skinfolds = 43.9 mm



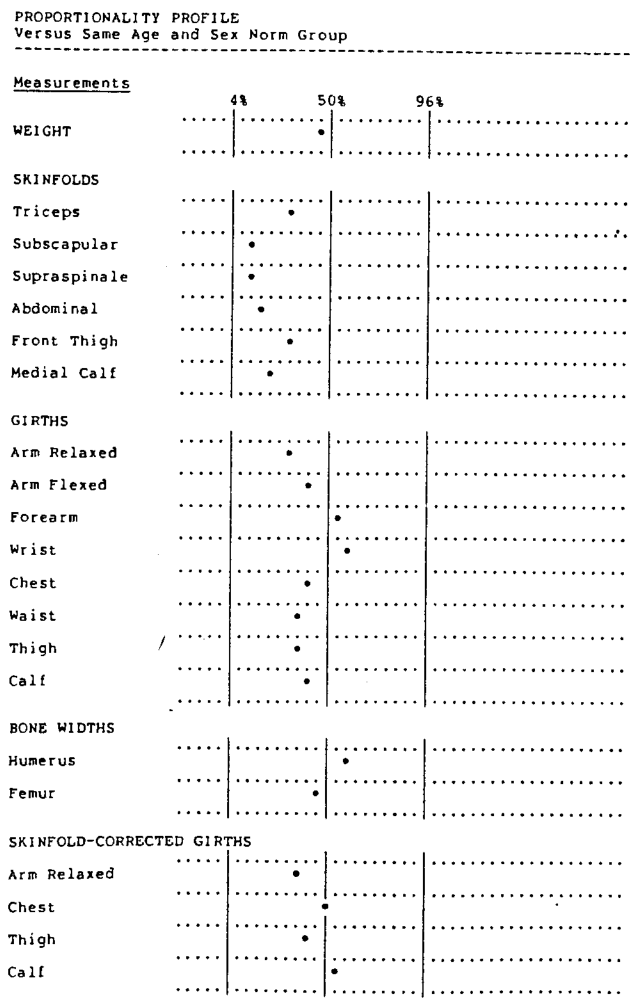


Figure CII.7b: O-SCALE Analysis for average values of anthropometric items for Female Olympic Rowers

FEMALE 23.784 years of age

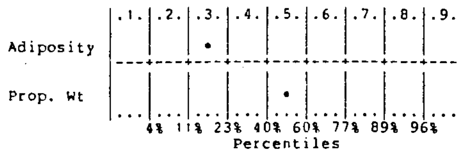
Height = 174.3 cm

Weight = 67.4 kg

Proportional Weight = 75.2 kg

Sum of 6 Skinfolds = 75.2 mm

Prop. Sum Skinfolds = 73.4 mm



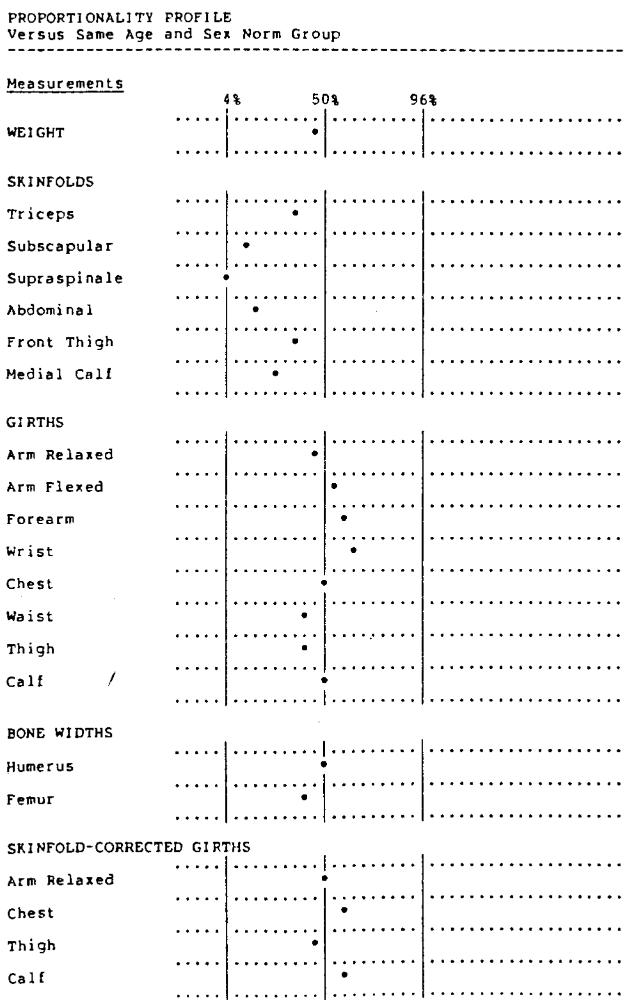


Figure CII.8a: O-SCALE Analysis for male Olympic Rower A

MALE 31.43 years of age

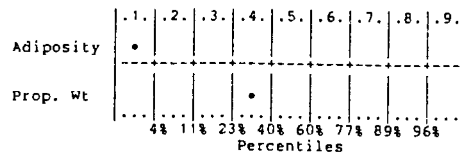
Height = 194.3 cm

Weight = 91.8 kg

Proportional Weight = 61.7 kg

Sum of 6 Skinfolds = 38.0 mm

Prop. Sum Skinfolds = 33.3 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

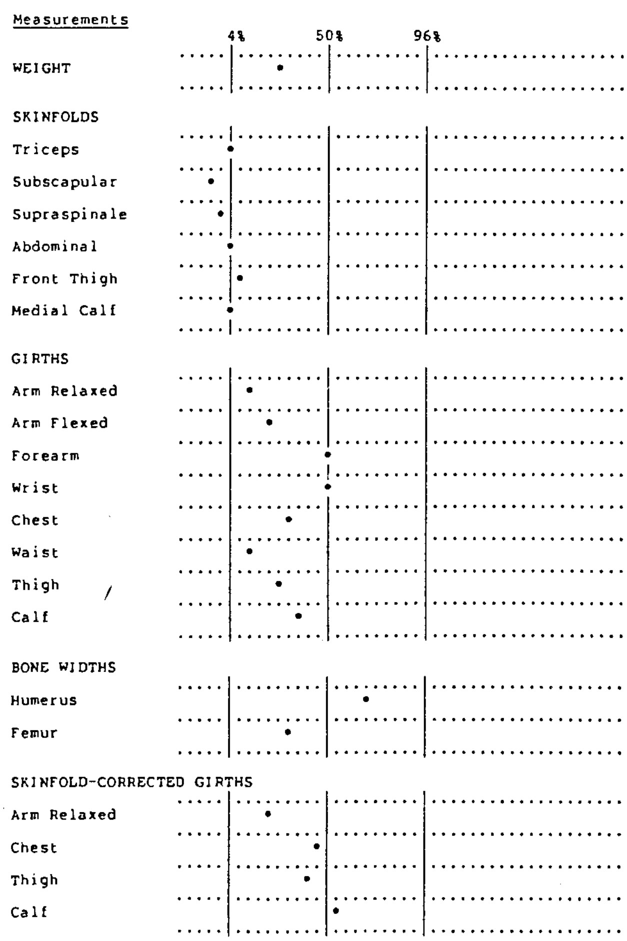


Figure CII.8b: O-SCALE Analysis for male Olympic Rower B

MALE 24.30 years of age

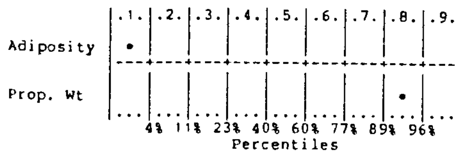
Height = 182.0 cm

Weight = 91.7 kg

Proportional Weight = 75.0 kg

Sum of 6 Skinfolds = 33.4 mm

Prop. Sum Skinfolds = 31.2 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

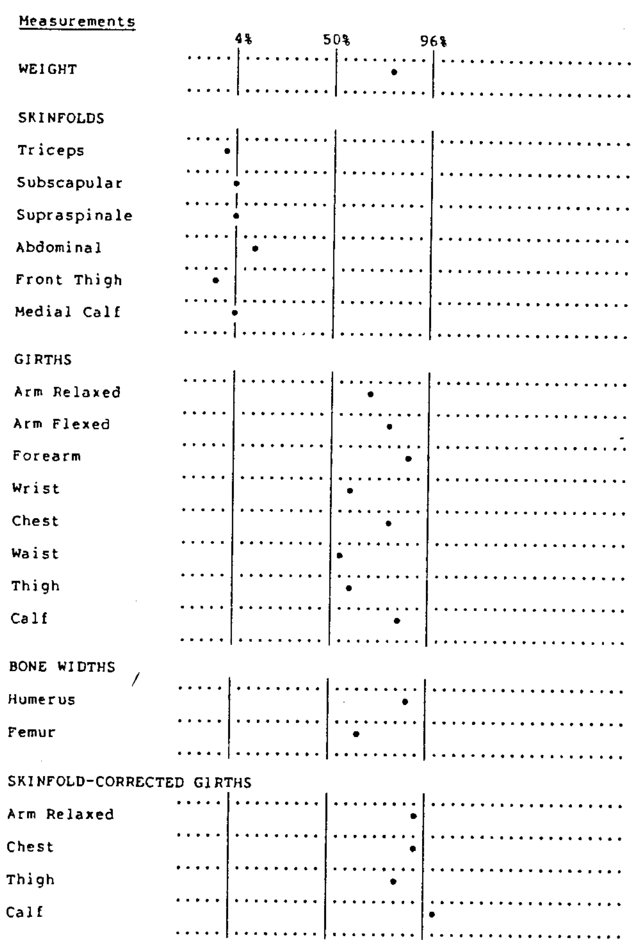


Figure CII.8c: O-SCALE Analysis for male Olympic Rower C

MALE 23.19 years of age

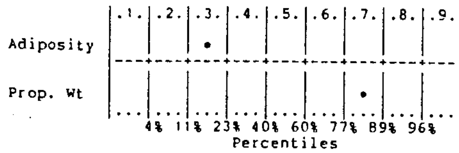
Height = 179.3 cm

Weight = 82.6 kg

Proportional Weight = 70.6 kg

Sum of 6 Skinfolds = 48.6 mm

Prop. Sum Skinfolds = 46.1 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

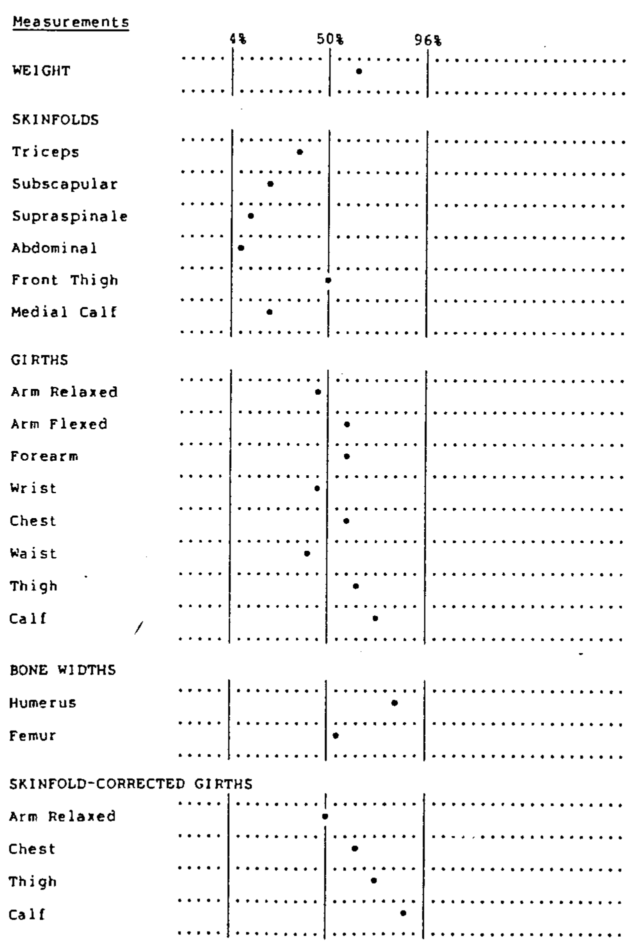


Figure CII.9a: O-SCALE Analysis for female Olympic Rower D

FEMALE 22.27 years of age

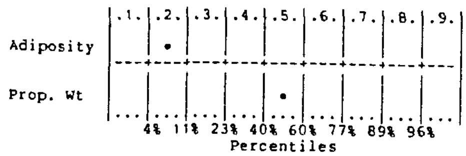
Height = 172.8 cm

Weight = 65.8 kg

Proportional Weight = 62.9 kg

Sum of 6 Skinfolds = 69.7 mm

Prop. Sum Skinfolds = 68.6 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

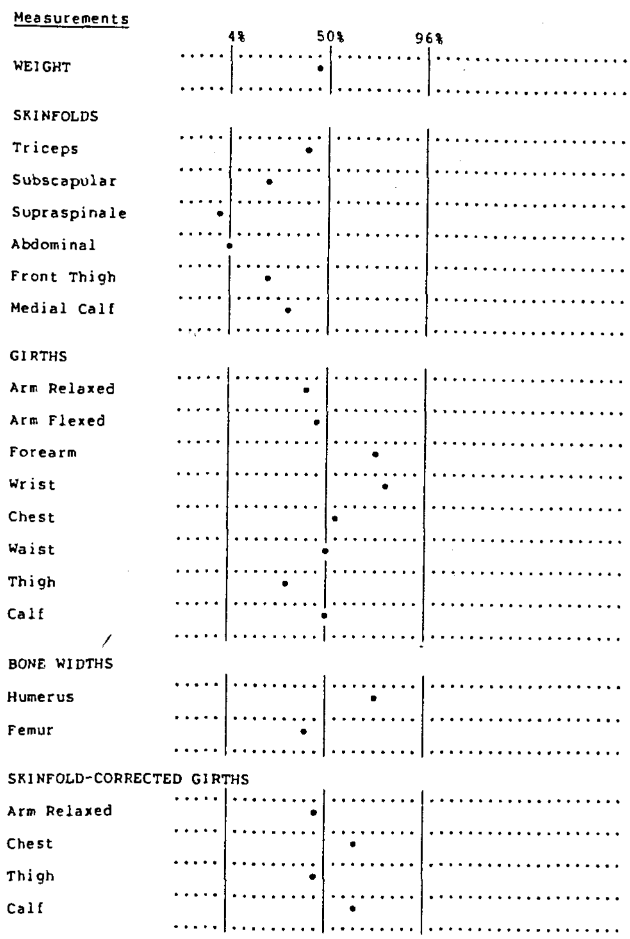


Figure CII.9b: O-SCALE Analysis for female Olympic Rower E

FEMALE 26.74 years of age

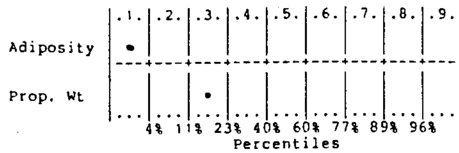
Height = 172.4 cm

Weight = 59.4 kg

Proportional Weight = 57.1 kg

Sum of 6 Skinfolds = 50.3 mm

Prop. Sum Skinfolds = 49.7 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

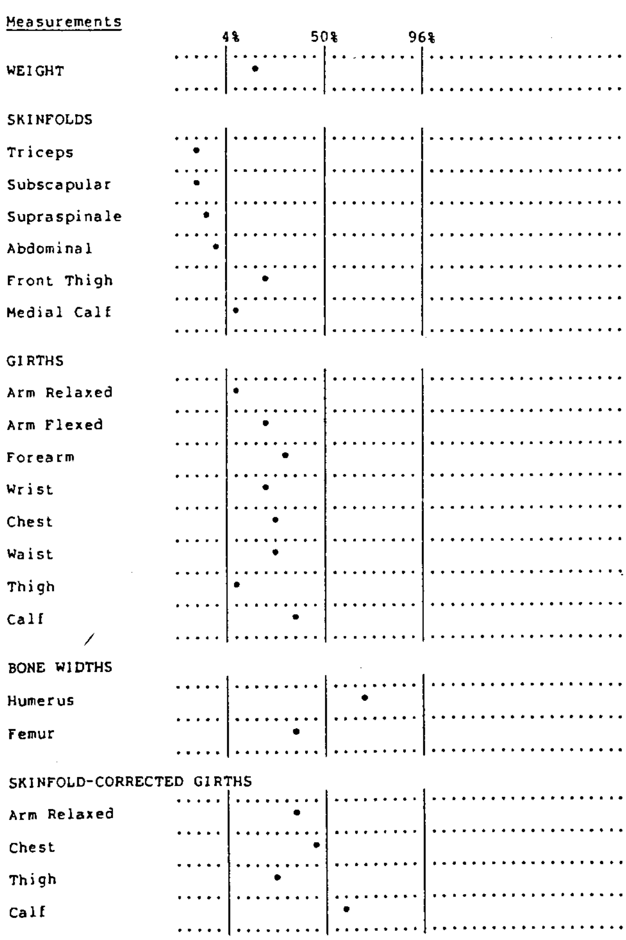


Figure CII.9c: O–SCALE Analysis for female Olympic Rower F

FEMALE 25.12 years of age

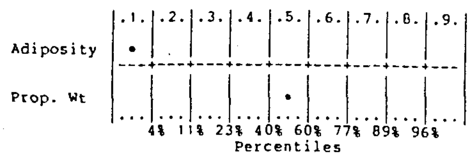
Height = 174.4 cm

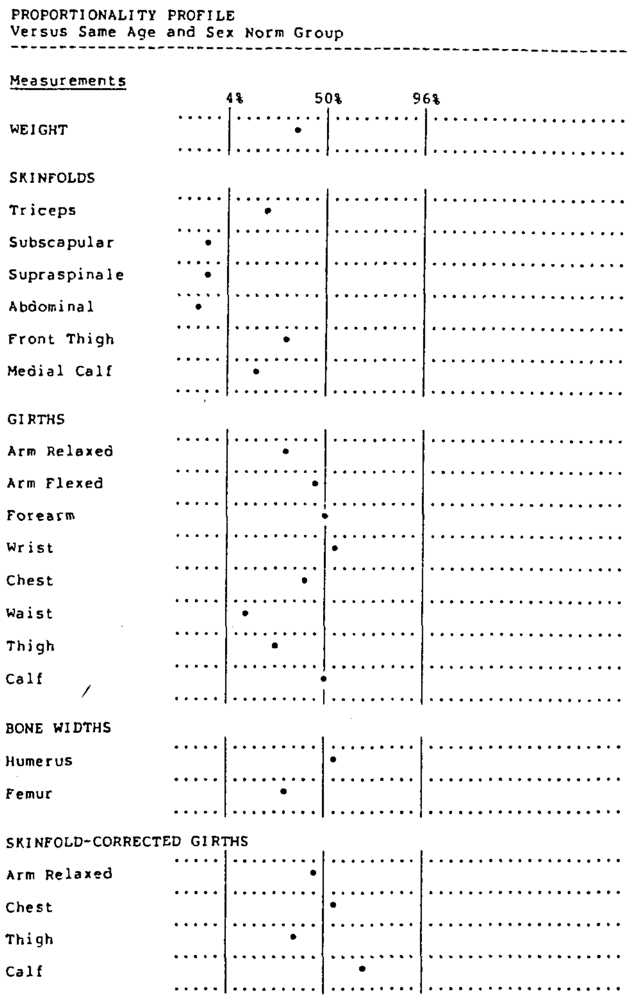
weight = 65.7 kg

Proportional Weight = 61.0 kg

Sum of 6 Skinfolds = 60.1 mm

Prop. Sum Skinfolds = 58.6 mm





Cyclists

Figure CII.10 showed the average profile for male Olympic cyclists (N=18). The average height was 177.1 with a weight of 69.6. Their proportional weight was 61.8 kg, their sum of skinfolds was 39.3 and their proportional sum of skinfolds was 37.8. This gave rise to an **A-rating** of 2 and a **W-rating** of 4. The girths showed an interesting pattern whereby the wrist and forearm were higher rated than the upper arm girths and the calf was higher rated than the thigh and in turn the chest and relaxed arm. The proportionality profile showed a lower body dominance in skinfold-corrected girths with the calf girth being the most highly rated. Figure CII.11 showed the O-SCALE analyses for the three subjects randomly selected from the Cyclist group, subjects A, B and C. Subject A was a 23.65 year old male, 184.8 cm tall, 77.2 kg in body weight with a proportional body weight of 60.3 kg. His sum of six skinfolds was 40.8 mm, with the proportional sum being 37.6 mm. This gave rise to an **A-rating** of 2 and a **W-rating** of 4. Subject B was a 22.13 year old male 175.9 cm tal, weighing 71.0 kg with a proportional weight of 64.3 kg. His sum of six skinfolds was 39.2 mm and his proportional sum of skinfolds was 37.9 mm. His resultant A rating was 2 and his **W-rating** was 5. Subject C was a 20.34 year old male with a height of 177.0 cm and a body weight of 67.6 kg. His proportional weight was 60.1 kg , his sum of six skinfolds was 38.6 mm and his proportional sum of skinfolds was 37.1 mm. As with the rowers there were distinct similarities between the profiles for the individual athletes and the average profile for their sport. Each of the three cyclists exhibited higher ratings for the forearm and wrist girth relative to the upper arm, and for the calf in relation to thigh, waist and chest. In the skinfold corrected girths there was again the pattern of lower body dominance.

Figure CII.10: O-SCALE Analysis for average values of anthropometric items for Male Olympic Cyclists

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MALE 22.952 years of age

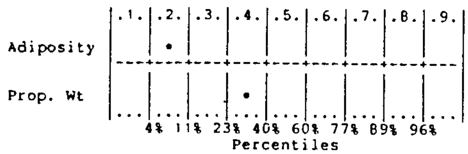
Height = 177.1 cm

Weight = 69.6 kg

Proportional Weight = 61.8 kg

Sum of 6 Skinfolds = 39.3 mm

Prop. Sum Skinfolds = 37.8 mm



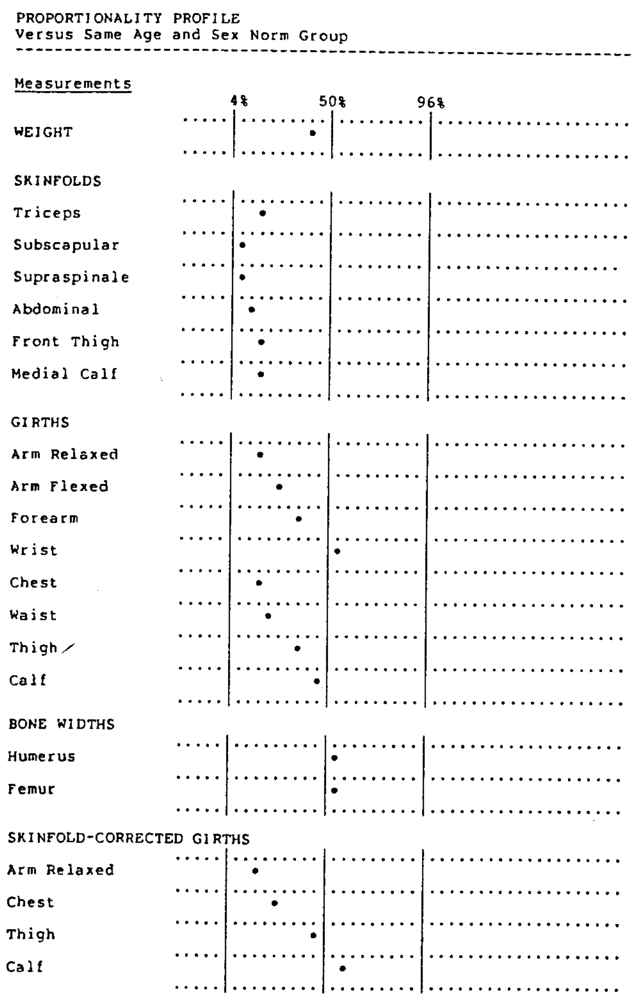


Figure CII.11a: O-SCALE Analysis for male Olympic Cyclist A

MALE 23.65 years of age

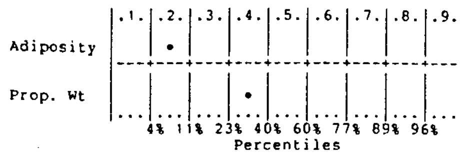
Height = 184.8 cm

Weight = 77.2 kg

Proportional Weight = 60.3 kg

Sum of 6 Skinfolds = 40.8 mm

Prop. Sum Skinfolds = 37.6 mm.



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

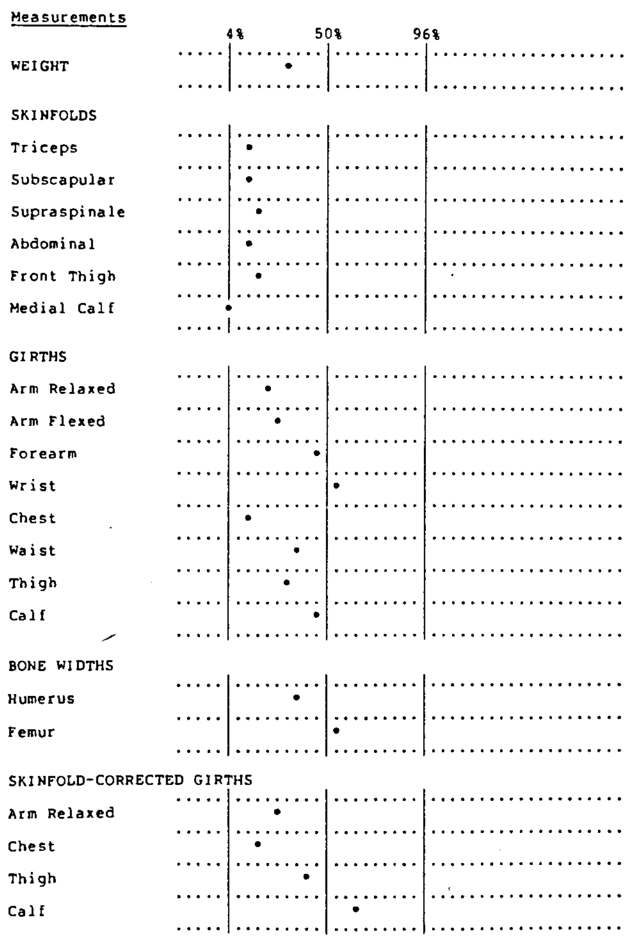


Figure CII.11b: O-SCALE Analysis for male Olympic Cyclist B

MALE 22.13 years of age

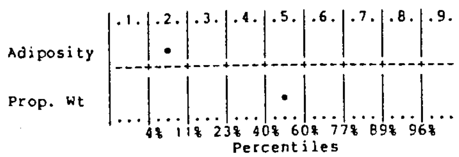
Height = 175.9 cm

Weight = 71.0 kg

Proportional Weight = 64.3 kg

Sum of 6 Skinfolds = 39.2 mm

Prop. Sum Skinfolds = 37.9 mm



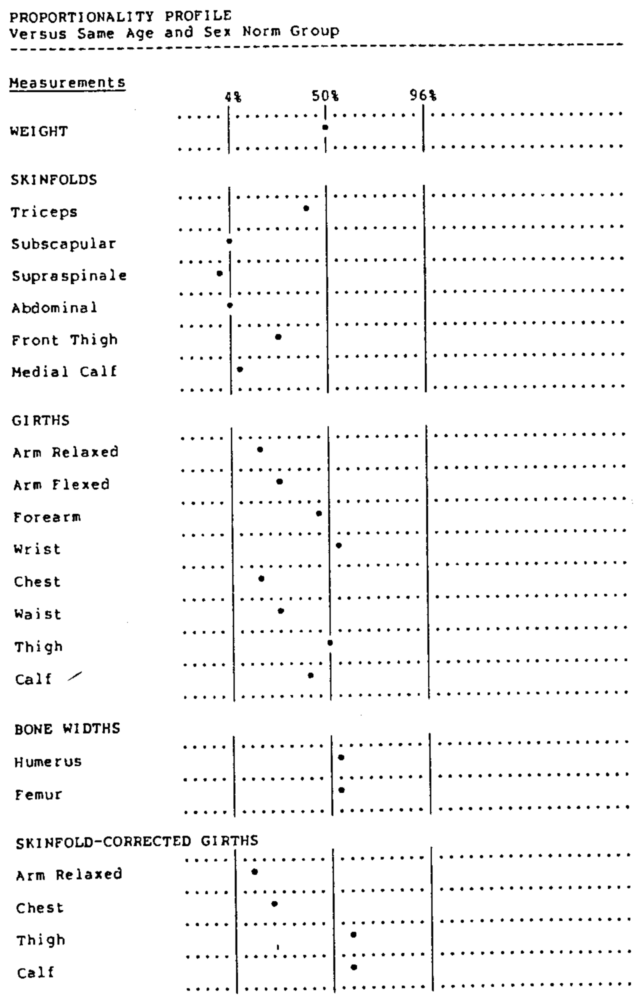


Figure CII.11c: O-SCALE Analysis for male Olympic Cyclist C

MALE 20.34 years of age

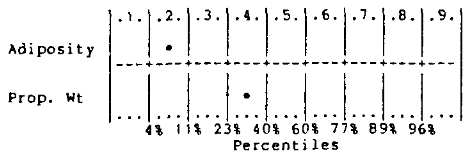
Height = 177.0 cm

Weight = 67.6 kg

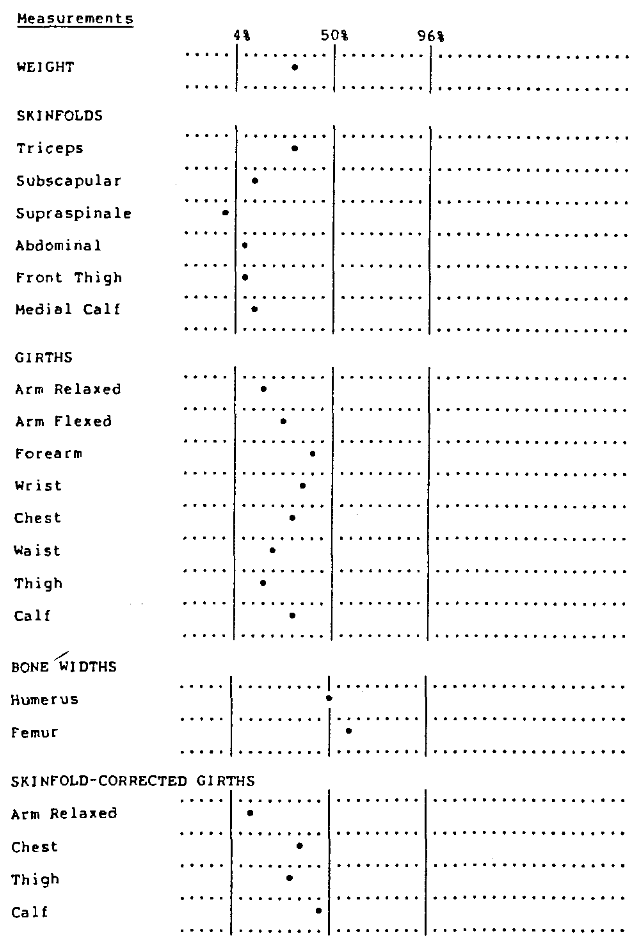
Proportional Weight = 60.1 kg

Sum of 6 Skinfolds = 38.6 mm

Prop. Sum Skinfolds = 37.1 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group



Weightlifters

Figure CII.12 showed the O-SCALE analysis for the average of the Olympic Weightlifters (N=11). They averaged 170.5 cm tall with a body weight of 86.9 kg. Their proportional weight was 86.4 kg, their sum of six skinfolds was 52.3 mm and the proportional sum of skinfolds was 52.2 mm. The resultant **A-rating** was 3 with a **W-rating** of 9. The average profile exhibited an upper body dominance in girths which was reflected in the muscularity estimates of the skinfold-corrected girths. The O-SCALE analyses for the three weightlifters randomly selected from the group were shown in Figure CII.13 as Subjects A, B and C. Subject A was a 34.91 year old male, 158.8 cm tall with a body weight of 60.9 kg. His proportional weight was 75.0 kg, his sum of six skinfolds was 28.1 and his proportional sum of skinfolds was 30.1. This lead to an **A-rating** of 1 and a **W-rating** of 7. Subject B was a 28.65 year old male, 160.2 cm tall, with a weight of 78.0 kg. His proportional weight was 93.5 kg, with a sum of six skinfolds of 39.9 mm and a proportional sum of skinfolds of 42.4, giving an **A-rating** of 2 and a **W-rating** of 9. Subject C was a 29.50 year old male with a stature of 170.8 cm, a weight of 82.9 kg and consequently a proportional weight of 82.0 kg. His sum of six skinfolds was 45.7 mm and his proportional sum of 45.5 mm with the **A-rating** therefore being 3 and the **W-rating** being 8. The weightlifters were characterised by massive proportional weight that was not reflected in the skinfold thicknesses. As expected the great difference in A and **W-ratings** was explained by the massive muscularity as indicated by the girths and the skinfold-corrected girths. Each of the subjects A to C showed extreme development in the skinfold corrected relaxed arm girth, as did the profile for the average of the group. In subjects A and C there was a lot of similarity between profiles and the average profile. A was lower in skinfolds than C or the average profile, however the girths showed a similar pattern other than displacement to the left reflecting partially the lower skinfold measures. Subject B differred in that foreram and wrist girth received the highest ratings and the calf and then thigh received the highest rating of the skinfold-corrected girths.

Figure CII.12: O-SCALE Analysis for average values of anthropometric items for Male Olympic Weightlifters

MALE 28.354 years of age

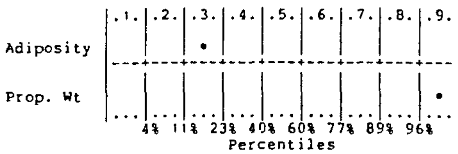
Height = 170.5 cm

Weight = 86.9 kg

Proportional Weight = 86.4 kg

Sum of 6 Skinfolds = 52.3 mm

Prop. Sum Skinfolds = 52.2 mm



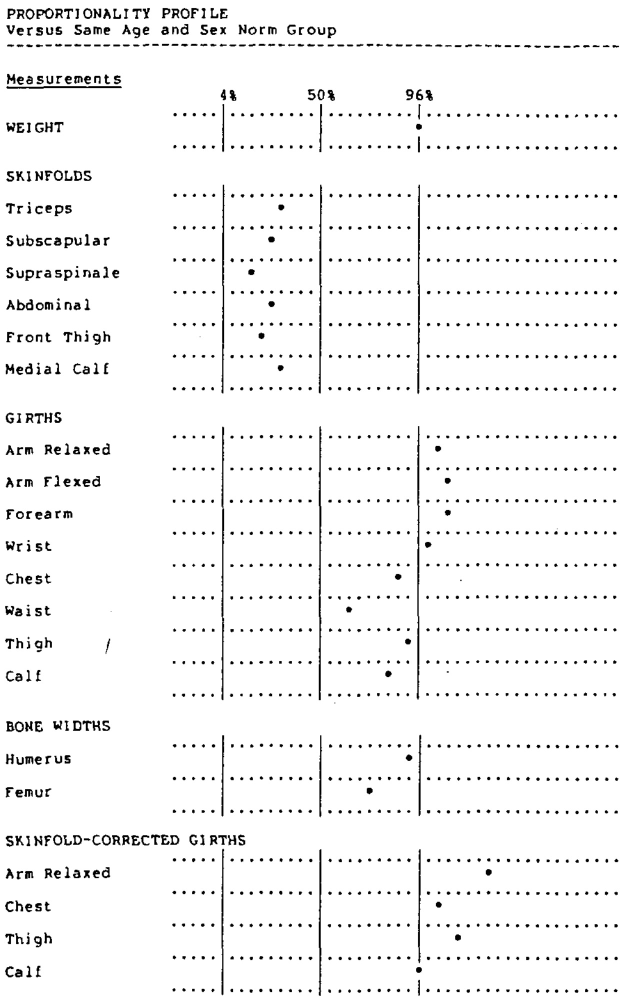


Figure CII.13a: O-SCALE Analysis for male Olympic Weightlifter A

MALE 34.91 years of age

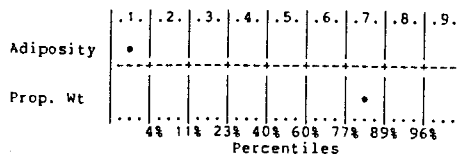
Height = 158.8 cm

Weight = 60.9 kg

Proportional Weight = 75.0 kg

Sum of 6 Skinfolds = 28.1 mm

Prop. Sum Skinfolds = 30.1 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

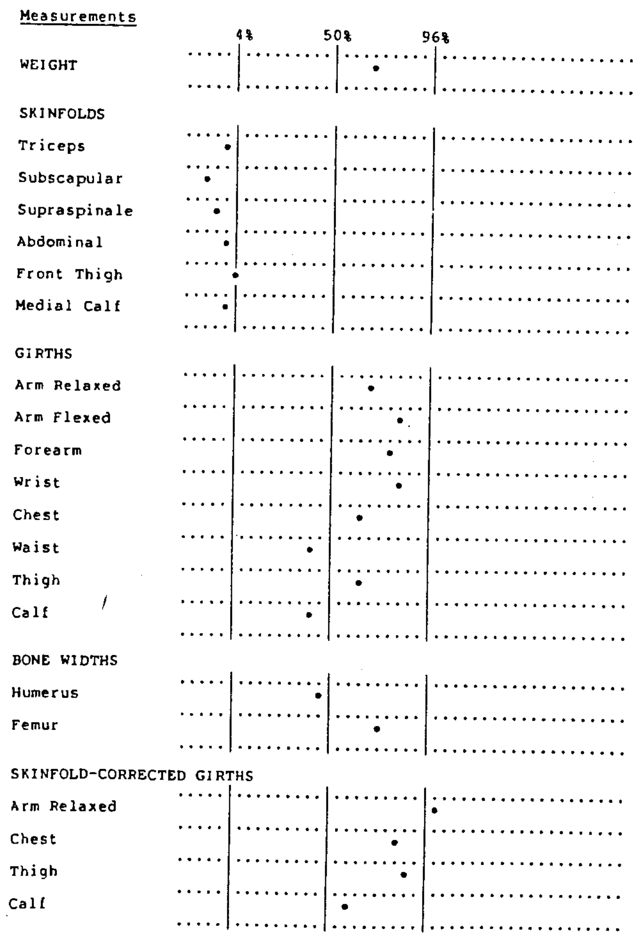


Figure CII.13b: O-SCALE Analysis for male Olympic Weightlifter B

MALE 28.65 years of age

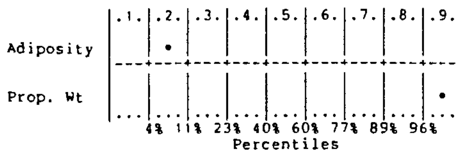
Height = 160.2 cm

Weight = 78.0 kg

Proportional Weight = 93.5 kg

Sum of 6 Skinfolds = 39.9 mm

Prop. Sum Skinfolds = 42.4 mm



PROPORTIONALITY PROFILE
Versus Same Age and Sex Norm Group

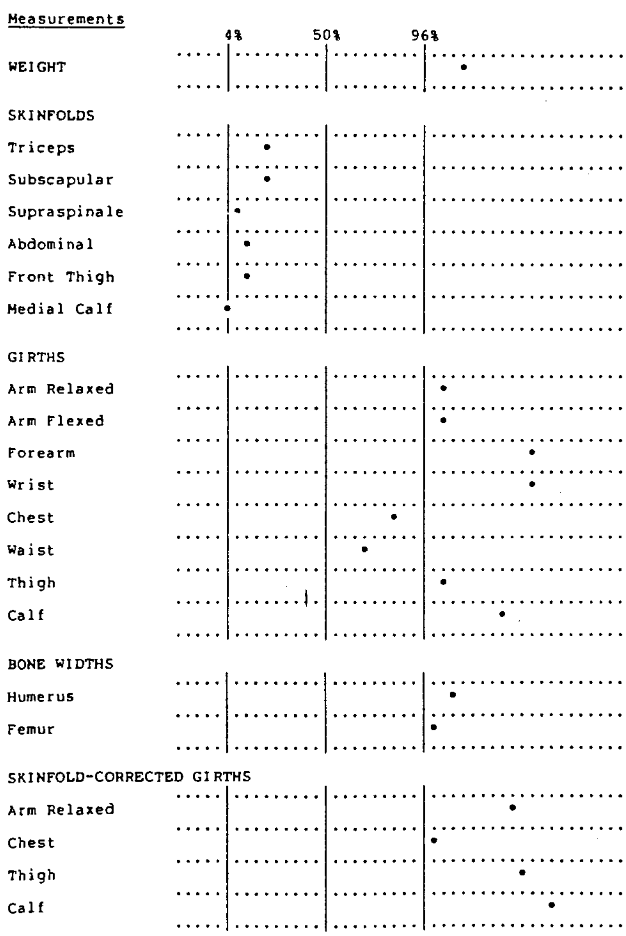


Figure CII.13c: O-SCALE Analysis for male Olympic Weightlifter C

MALE 29.50 years of age

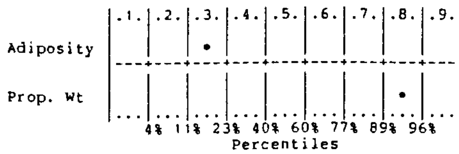
Height = 170.8 cm

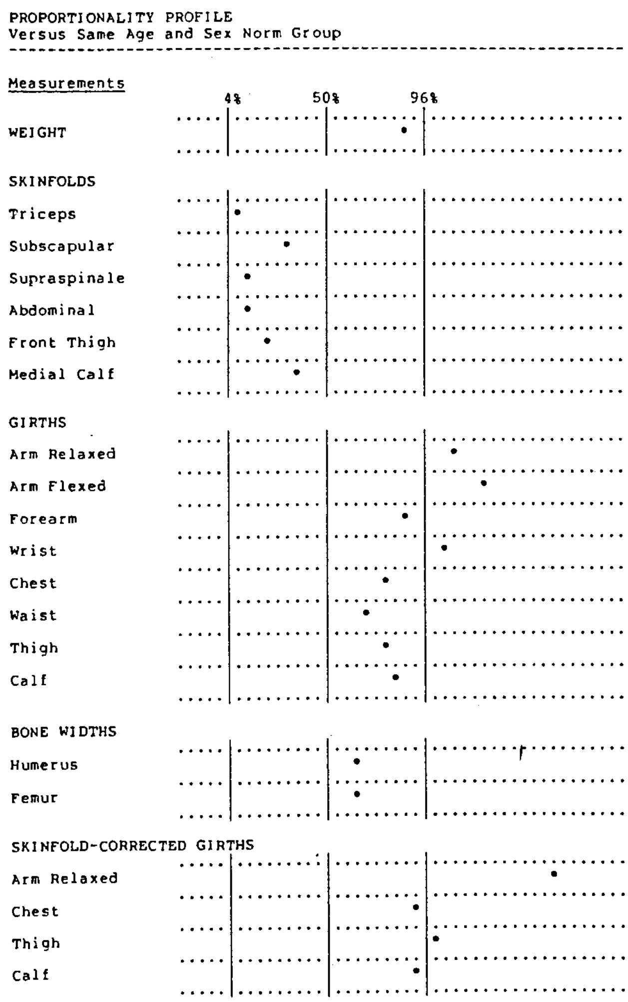
Weight = 82.9 kg

Proportional Weight = 82.0 kg

Sum of 6 Skinfolds = 45.7 mm

Prop. Sum Skinfolds = 45.5 mm





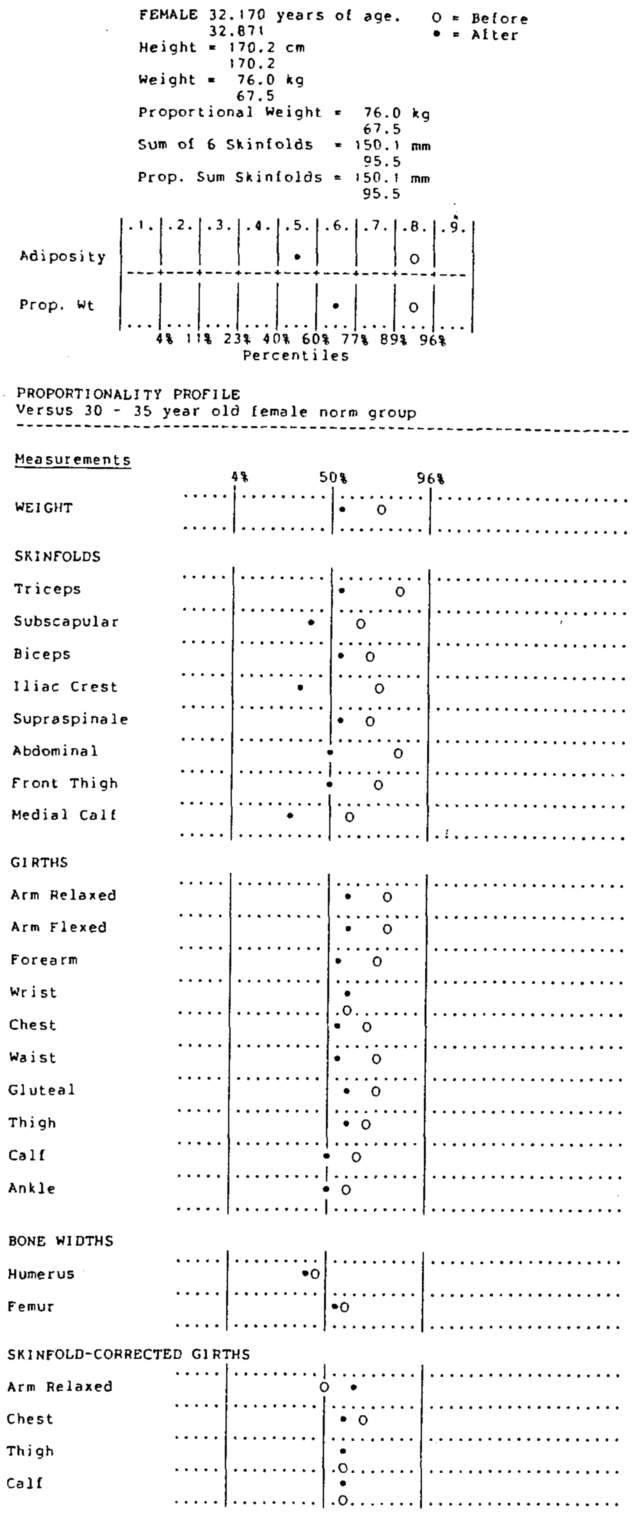
REPEATED ASSESSMENT BEFORE AND AFTER A CHANGE IN BODY WEIGHT

1) Female Before and After Dietary and Exercise Modification:

(A8–W8 to A5–W6)

The subject whose analysis is displayed in Figure CII.1 was typical of the clients who many health and fitness professionals will be asked to measure frequently. She was a 30 year old female who, dissatisfied with her appearance, began a modification of her diet and an increase in her daily activity. Neither were drastic changes, nor did she follow any stringent guidelines for diet or exercise regimen. When she was first measured she weighed 76.0kg (165.7lbs) and was rated an A=8 and W=8, placing her between the 89th and 96th percentiles. Her heaviness in comparison to her norm, was in accord with her adiposity rating. Just over six months later upon remeasurement she weighed 67.5 kg (147.2 lbs) (a loss of 8.5 kg (18.5 lbs)), and was rated as A=5 and W=6. The proportionality profile in Figure CII.1 clearly showed the changes that occurred. The open circles represent her initial values and the closed circles represent the values on the second measurement occasion. All of the proportional skinfolds decreased relative to the norm, with the biggest changes occuring at the iliac crest and abdominal sites. All girths, except for the wrist decreased. As could be expected, the two bone widths showed little reduction. The skinfold-corrected girths showed a mixed pattern with the thigh and calf girths remaining the same, the chest girth decreasing and the relaxed arm girth actually increasing. The overall conclusion that can be drawn from these profiles was that this woman lost adiposity as was desired, but also maintained relative muscularity as indicated by the skinfold-corrected girths. The O-SCALE system was therefore able to monitor the changing physique of this woman as she carried out sensible weight loss via modification of diet and physical activity.

Figure CII.14: O-SCALE Analysis of Female Before and After Dietary and Exercise Modification



2) Male Monitored during 75 day Walk from Brussels to Nice, France:

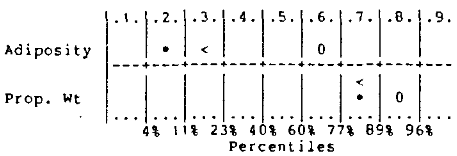
(A6–W8 to A3–W7 to A2–W7)

As part of an intensive thesis investigation of body morphology changes with lifestyle (Van Den Bogaerde 1986), a 22 year old male was routinely each morning as he walked from Brussels to Nice. Considerable changes in body composition were observed over the 77 day period. Figure CII.15 shows his O–SCALE ratings and proportionality profile derived from measurements taken on the first, thirty–eighth and seventy–seventh days.

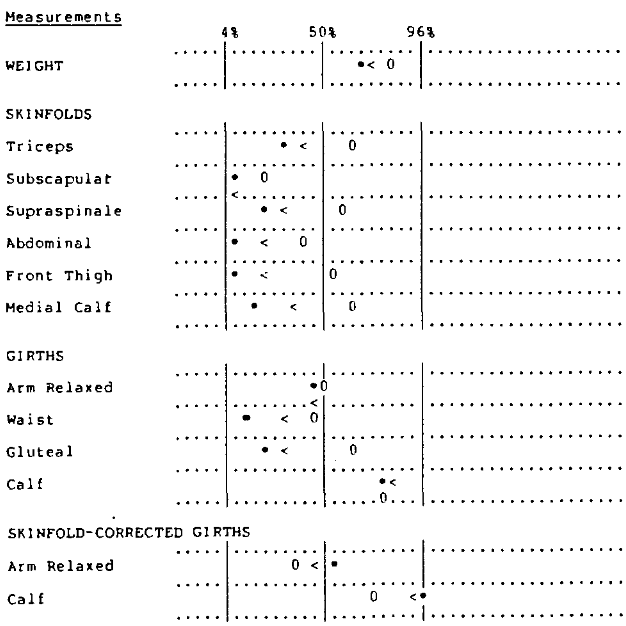
The A and **W-ratings** showed a dramatic loss in adiposity from A=6 to A=2 over the 77 day period; whereas for proportional weight only a slight drop from W=8 to W=7 was observed. The proportionality profile was most revealing about the changes in his physique. All of the skinfolds showed a considerable proportional reduction. The trunk girths also showed a considerable reduction, whereas there was little difference in either arm or calf girths over the time period. As could be anticipated with gain in muscularity, the skinfold–corrected girths increased in the arm and calf sites over the 77 days. The walker was a fairly short man (165 cm, 5' 5"), one would therefore have to take into account in interpretation of his profile, the expected proportions of a short person. That is, the relative ponderosity associated with shortness. The walker certainly was a squat, although athletic individual.

Figure CII.15: O-SCALE Analysis of Male Monitored during 75 day Walk from Brussels to Nice, France.

```
MALE 22.315 years of age.    0 = Day 1
                             < = Day 38
                             • = Day 77

Height = 165.0 cm
         165.1
         165.0

Weight =  70.5 kg
          67.0
          65.0

Proportional Weight =  77.4 kg
                       73.5
                       65.0

Sum of 6 Skinfolds  =  69.4 mm
                       46.0
                       37.2

Prop. Sum Skinfolds =  71.6 mm
                       47.4
                       38.4
```



PROPORTIONALITY PROFILE
Versus 20-25 year old male norm group



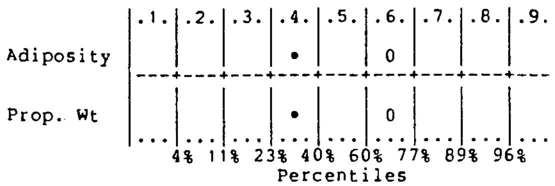
3) Working Male after 1 year of dietary control.

(A6-W6 to A4-W4)

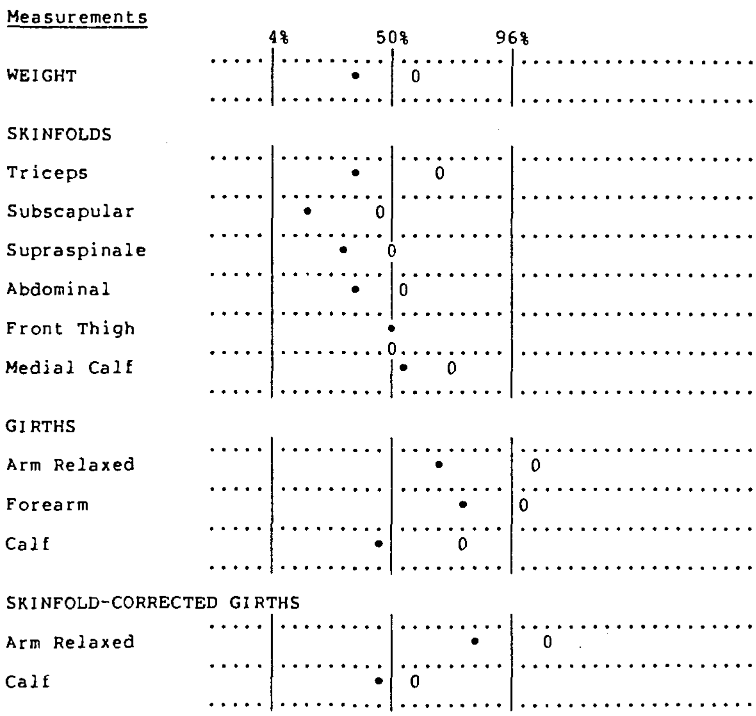
Figure CII.16 shows the change in assessments over approximately a one year period for a 32 year old civic employee. He decided to lose weight by dieting but did not change his habitual activity level at all from its normal sedentary state. His job mainly entailed driving. The **A-rating** dropped from a value of 6 to 4 and was mirrored by the the same change in the **W-rating**. The proportionality profile exhibited the same consistent pattern. All measures, skinfolds, girths and skinfold-corrected girths were consistently reduced as might be expected with weight loss. This is in contrast to the patterns of the young female and the walker shown earlier who either maintained or increased muscularity. The O-SCALE has shown itself here to be sensitive to the types of changes that are occurring in body composition with dietary or activity modifications. It can therefore be used wherever information is sought on such changes.

Figure CII.16: O-SCALE Analysis of Working Male after 1 year of dietary control

```
MALE 32.236 years of age.        0 = Before
     33.115                      • = After
Height = 176.0 cm
         175.9
Weight =  80.2 kg
          71.2
Proportional Weight =  72.5 kg
                       64.5
Sum of 6 Skinfolds  =  96.5 mm
                       72.0
Prop. Sum Skinfolds =  93.3 mm
                       69.7
```



PROPORTIONALITY PROFILE
Versus 30-35 year old male norm group



4) Male Body Builder 9 days before and at time of Competition.

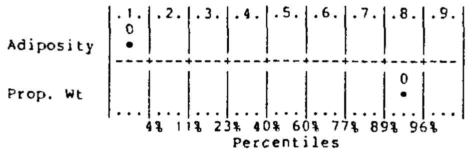
(A1-W8 to A1-W8)

In the sport of body building one of the more extreme practices is the adoption of drastic dietary modifications that occur in the two weeks prior to a contest. All water, salt and most caloric intake is avoided in order to achieve an onion-skin like covering over their sharply defined musculature. A local competitive body builder consented to being measured during such a precontest endeavor. He was measured 9 days before competition at the start of the rigorous diet and on the day before competition. The superimposed profiles are shown in Figure CII.17. On the 9th day before competition the body builder weighed 81 kg (176.6 lbs) and was rated as an A=1, W=8. His proportionality profile was typical of that for top class body builders. On the day before competition he weighed 78.6 kg (171.3 lbs), a loss of 2.4 kg (5.3 lbs), but was still rated as an A=1, W=8. The proportionality profile does reveal some differences however. All the minimal skinfolds were reduced even further. The wrist and trunk girths showed no changes, but the limb girths all showed decreases. The bone widths showed little change, and the skinfold-corrected girths showed sizeable decreases in relaxed arm and thigh girths. It would appear from this profile comparison that the body builder has not only reduced his subcutaneous adiposity with his extreme dietary restrictions but also had showed a reduction in limb muscularity. When this was pointed out to the body builder, he was not surprised. Many body builders feel that they actually lose muscle size while gaining definition in the week before contest. It appears that the O-SCALE profile is sensitive to quite small changes that are approaching the precision of replicability of the measurements. If the assessment of change is being attempted using the O-SCALE system then the measurer has to be very confident in the accuracy of their anthropometric techniques. Any errors in measurement will mask any possible small changes.

Figure CII.17: O-SCALE Analysis of Body Builder 9 Days Before and At Time of Competition

MALE 28.368 years of age.
28.400
Height = 170.7 cm
170.7
Weight = 81.0 kg
78.6
Proportional Weight = 80.3 kg
77.9
Sum of 6 Skinfolds = 32.2 mm
26.4
Prop. Sum Skinfolds = 32.1 mm
26.3

0 = Before
• = At Time



PROPORTIONALITY PROFILE
Versus 25-30 year old male norm group

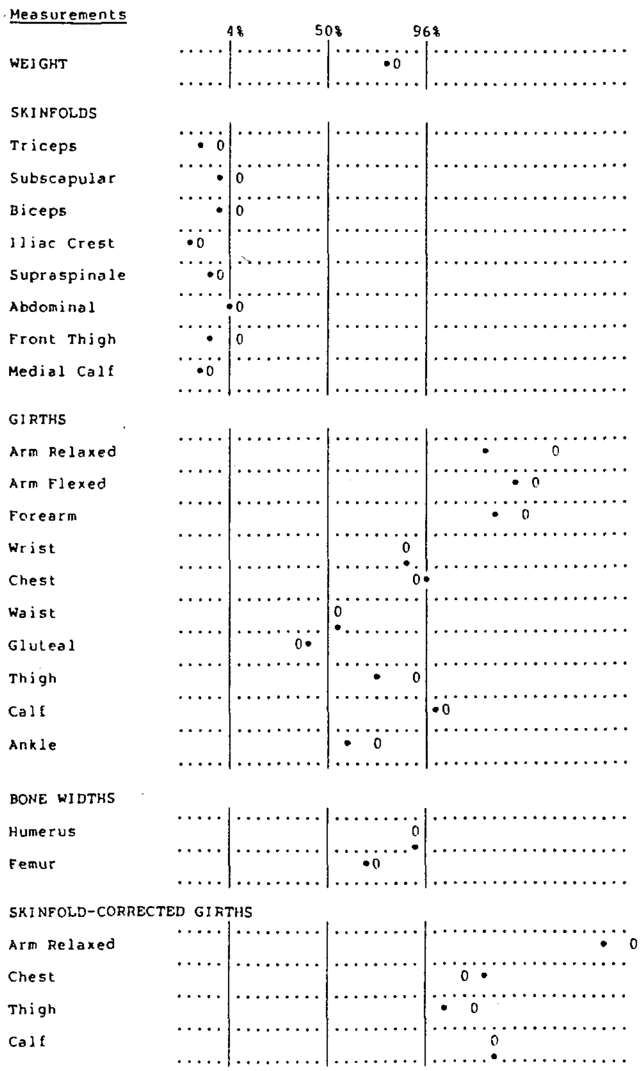


Table CII.2: Frequency distribution of A and W-ratings for CANAD males (N=233).

ADIPOSITY RATING	PROPORTIONAL WEIGHT RATING 1	2	3	4	5	6	7	8	9	%
1	3	4	8	6	3	2	2			11.7
2		3	5	9	2	5	2	1		11.3
3	2	1	3	4	13	7	1	2		13.8
4		4	4	8	17	7	4	1		18.8
5		2	6	7	15	5	5	3		18.4
6			1	4	8	9	4	3	1	12.6
7				2	4	4	5	2	2	7.9
8					1	1	1	2		2.1
9					1		3	4		3.3
%	2.1	5.9	11.3	16.7	26.8	16.7	10.0	7.1	3.3	

Tables CII.2 and CII.3 showed crosstabulated frequency distributions of A and **W-ratings** for the CANAD male and female samples respectively. The median rating of the CANAD males in Table CII.2 was A=4 and W=5. This indicated the general trend for the CANAD males to be leaner than the same aged O-SCALE norm. The distribution showed some combinations of A and **W-ratings** that did not occur. Specifically, high adiposity associated with low proportional weight and to a lesser extent high proportional weight with low adiposity ratings. The contingency coefficient between A and **W-ratings** was 0.582 for females and 0.632 for the males, showing a strong positive relationship between the two scores.

Table CII.3: Frequency distribution of A and W-ratings for CANAD females (N=199).

ADIPOSITY RATING	PROPORTIONAL WEIGHT RATING 1	2	3	4	5	6	7	8	9	%
1	3	3	4	5			1			7.8
2		2	4	4	5	3	1	1		9.7
3	1	2	5	8	8	3	2			14.1
4	2	2	5	7	10	7	4			18.0
5	1	1	3	7	4	11	5	1	1	16.5
6		2	4	4	9	5	6	2		15.5
7				3	1	5	6	3	1	9.2
8	1				3	2	3	3	1	6.3
9					1		4		1	2.9
%	2.1	5.9	11.3	16.7	26.8	16.7	10.0	7.1	3.3	

In Table CII.3 the CANAD females reflected similar patterns to those shown in the CANAD males, with a median rating of A=4 and W=5. The extremes of high adiposity and high proportional weight, and vice versa were again not present, other than a female who had an **A-rating** of 8 and a **W-rating** of 1.

Table CII.4 Frequency distribution of A and W-ratings for MOGAP males (N=309).

ADIPOSITY RATING	PROPORTIONAL WEIGHT RATING 1	2	3	4	5	6	7	8	9	%
1	1	12	21	21	25	10	6	1		31.4
2		3	11	13	16	8	10	1	2	20.7
3		1	3	10	18	11	13	6		20.1
4		2	2	9	11	13	10	2	1	16.2
5				2	8	9	3	2	2	8.4
6					1		2	2	1	1.9
7						1	2			1.0
8									1	0.3
9										
%	0.3	5.8	12.0	17.8	25.6	16.8	14.9	4.5	2.3	

Table CII.4 showed a distorted distribution in comparison to the CANAD groups. This Table displayed the distribution of the MOGAP males. From this distribution it was seen that in only 9 (2.9%) individuals were **A-ratings** higher than **W-ratings**. In 274 individuals (88.7%) the **A-rating** was lower than the **W-rating**. The relatively higher muscularity in these individuals was evidenced by the higher rating for ponderosity than adiposity. In 36 individuals (11.6%) the adiposity rating was 5 or greater. These "fat" athletes included open weight class boxers, wrestlers and weightlifters, along with throwers of the track and field disciplines.

Table CII.5: Frequency distribution of A and W-ratings for MOGAP females (N=148).

ADIPOSITY RATING	PROPORTIONAL WEIGHT RATING 1	2	3	4	5	6	7	8	9	%
1	4	4	12	17	10	5	3			37.2
2			3	8	13	5	3			21.6
3				3	12	5	2			14.9
4			1	3	7	7	5			15.5
5				1	2	3	2	1		6.1
6			1	1				1		2.0
7						1	1	1	1	2.7
8										
9										
%	2.7	2.7	11.5	22.3	29.7	17.6	10.8	2.0	0.7	

Table CII.5 showed the distribution of the female athletes to be similar to the distortion apparent in the MOGAP males. Only 5 individuals (3.4%) had **A-ratings** higher than their **W-ratings**. 133 individuals (89.9%) had **W-ratings** higher than their **A-ratings**, and 16 individuals (10.8%) had **A-ratings** of 5 or higher.

Table CII.6: Frequency distribution of A and W-ratings for CANAD males (N=233) and females (N=199). Significance between group distribution and and O-SCALE Norm distribution tested by Chi-Square ($p<0.05$, d.f.=8) indicated by *.

A RATING	1	2	3	4	5	6	7	8	9	Sig
	4.0	7.0	12.0	17.0	20.0	17.0	12.0	7.0	4.0	
Canad Males	11.7	11.3	13.8	18.8	18.4	12.6	7.9	2.1	3.3	*
Canad Females	7.8	9.7	14.1	18.0	16.5	15.5	9.2	6.3	2.9	*
Mogap Males	31.4	20.7	20.1	16.2	8.4	1.9	1.0	0.3	0	*
Mogap Females	37.2	21.6	14.9	15.5	6.1	2.0	2.7	0	0	*
W RATING	1	2	3	4	5	6	7	8	9	
	4.0	7.0	12.0	17.0	20.0	17.0	12.0	7.0	4.0	
Canad Males	2.1	5.9	11.3	16.7	26.8	16.7	10.0	7.1	3.3	*
Canad Females	3.9	5.8	12.1	18.4	19.9	17.5	15.5	4.9	1.9	*
Mogap Males	0.3	5.8	12.0	17.8	25.6	16.8	14.9	4.5	2.3	*
Mogap Females	2.7	2.7	11.5	22.3	29.7	17.6	10.8	2.0	0.7	*

Differences between A and **W-ratings** and the O-SCALE norm distibutions for the scores respectively were tested using Chi-Square tests using the O-SCALE norm distribution percentages as the expected frequencies. All four groups showed A and **W-rating** distributions that were significantly different than the O-SCALE norm distributions ($p<0.05$). Same sex comparisons between CANAD and MOGAP groups also showed significant differences between distributions of A and **W-ratings** using the Chi-Square test ($p<0.05$).

CHAPTER III

DISCUSSION 2: APPLICATION OF THE O-SCALE SYSTEM

Comprehensive Analysis

Upon application of the O-SCALE system two levels of description of physique were made available. The first was the general description of physique facilitated by the A and **W-ratings**. As with the three components of somatotype they provided a reduction of the chaos of a lot of data into a brief, quickly understood description of physique. Unlike the somatotype components this provided a comparison to a same age and sex normative group. As such the A and **W-ratings** provided a useful system for categorizing physique. Through the individual profiles presented here it was apparent that the relative A and **W-ratings** gave information on the relative musculo-skeletal development. For instance, 88.7% (274 out of 309) of male and 94.0% (137 out of 148) of female athletes in the MOGAP sample had **W-ratings** higher than their **A-ratings**, indicative of their musculo-skeletal development.

Further evidence of this was provided by the second level of description of the O-SCALE system, which consisted of the listing of the individual item measurements in comparson to their norms for the same age and sex group, along with the proportionality profile of z-values again in comparison to the similarly scaled same age and sex norm group. This second level provided the detailed description of physique to substantiate the inferrences derived by the A and **W-ratings**. For the system to be deemed valid the second level of description had to be shown to be consistent with the A and **W-ratings**, and to explain any differences in A and **W-ratings**. This was clearly shown to be the case, in all of the profiles selected for inclusion in the thesis. It should be borne in mind that all of the eighteen profiles for balanced, weight and adiposity dominant physiques were randomly selected from the CANAD data set, and in every one there was agreement between the A and **W-ratings** and the distribution of the proportionality profile. In the six subjects with balanced physiques the skinfold, girth and skinfold-corrected girths were seen to have ratings in a distribution around the position of the weight rating. In the individuals with weight dominant physiques it was seen that although the skinfolds received lower ratings than body weight, that this was offset by the higher ratings than body weight of the skinfold-corrected girths. The uncorrected girths rated in a distribution around that of the weight rating. This pattern was also observed in the twelve Olympic athlete profiles, who also were weight dominant individuals. At the opposite extreme, the adiposity dominant individuals were seen to have their low rating for weight in relation to adiposity explained by low rated skinfold-corrected girths. Thus, they were typified as individuals with low levels of muscularity.

The system was intended to be able to depict the individuality of physique. This it achieved, as illustrated by the variety of skinfold and girth patterns exhibited by the relatively few individual profiles included in this thesis. With ageing and between the sexes there are considerable differences in skinfold patterning. With ageing there tends to be a predisposition for preferential deposition of trunk adiposity, whereas between the sexes females tend to have predominantly more deposition of adiposity on the limbs. Since the O-SCALE system utilised 5 year age and sex specific norm groups, these general trends were accounted for. Thus, the patterning that was observed on the profile was the individuals own pattern independent of the age or sex specific trends. The question then remained, was this a genetic trait or the result of environmental influence? Certainly, the patterns were specific to the individual, however, in the Olympic athlete analysis there were certain commonalities of physique that appeared to be a consequence of training specific to the sport. For instance, among both male and female Rowers in comparison to their same sex norms, the forearm and wrist girths, humerus width and skinfold-corrected calf girth showed disproportionate development unlike any pattern seen in the other athletes or among those individuals selected from the CANAD data set. In the cyclists there was commonality of girth development, just as there was in the weightlifters, but with a dissimilar pattern..

Comparison to Alternative Procedures

The comparisons to other valid anthropometric assessment systems were limited to three types of physique assessment methods which were based on anthropometric variables common to the O-SCALE system, as follows:

a) Heath-Carter Somatotype

b) Body Mass Index

c) Percentage Body Fat predicted from three sets of anthropometrically based equations.

Somatotype was the anthropometrically derived version with a correction for stature in endomorphy. The height correction for endomorphy (170.18/Height x sum of triceps, subscapular and supraspinale skinfolds) had the same dimensional adjustment as the **A-rating** in the O-SCALE system which also included the abdominal skinfold and lower limb skinfolds at front thigh and medial calf sites. The mesomorphic component in the Heath-Carter somatotype was a height adjusted measure of relative skinfold corrected arm and calf girths and humerus and femur breadth. It was a composite of musculo-skeletal tissues unlike the O-SCALE which treated girths, bone breadths and corrected girths as separate entities. The third component of the Heath-Carter system was based on a geometrical ratio of height and weight, the reciprocal of the ponderal index. Mathematically, the ectomorphic component could be obtained from the O-SCALE proportional weight which was the basis of the **W-rating**; except for the direction, they were identical. The somatotype expressed the ratio categorically as units of ectomorphy, whereas the O-SCALE system expressed ponderosity categorically as the **W-rating** but also carried the weight z-value on the proportionality profile thus providing greater resolution in assessments.

Not surprisingly, the results of the somatotype analyses were in agreement with the A and **W-ratings** in all the individual profiles considered. The somatotype had the advantage of reducing the complexity of human physique to a three component rating which could be displayed and analysed as a point on a two or three dimensional grid. The A and **W-ratings** achieved the same goal but differed in that they were specific to the age and sex specific norms. The somatotype may be described as being the best single descriptor of human morphology, however, what it gained in the reduction of data to a rating it lost in detail for individual assessments. The strength of the O-SCALE system was providing the general description in the A and **W-rating**, but in addition providing the detailed description in the proportionality profile.

The **W-rating** of the O-SCALE, unlike the BMI (Body Mass Index), did not ascribe cause for its departure from expectancy or presume it was an indicator of adiposity. It's interpretation relied wholly on its relationship to the **A-rating** and the relative departures of skinfolds, skinfold-corrected girths and bone measurements from one another, with respect to the appropriate age and sex norm. The **W-rating** was an indicator of ponderosity, not obesity or "fatness", and as such all the other anthropometric variables served to explain it's status.

Three sets of equations were used to predict the percentage body fat of the individuals. They were selected because of common use in Canada and commonality of anthropometric variables to the O-SCALE proforma. The initial striking result was that the three sets of equations gave different predictions for the individuals. This was an expected result. It was not the purpose of this thesis to determine the best equation for the prediction of percentage body fat. The equations were used to highlight some of the problems associated with the prediction of percentage body fat from skinfold formulae. The equations are specific to the originating sample. This in itself lead to disparate predictions of percent fat from the different equations. For example, the Durnin and Womersley equations gave consistent high evaluations; this may have been related to the fact that they were developed on British rather than North American subjects. When carrying out individual assessments the potential for error in prediction was intolerably high having as Lohman (1986) stated a standard error of estimate of 3.7% of body fat. The O-SCALE system did not commit itself to any assumptions of constant densities of tissues or make predictions of masses. Even if the prediction of percentage body fat were perfect, the information contained is limited. There was no information of regional deposition of adiposity or musculo-skeletal development. The O-SCALE system provided the **A-rating** as an equivalent to percentage body fat compared to a normative base, but in addition provided the **W-rating** to further describe the general physique, with the proportionality profile adding greater detail. An interesting note on the use of the percent fat prediction formulae was that they only contained skinfold measures. Thus it was the skinfold thicknesses alone that determined the percentage body fat. Any changes in body weight with no change in skinfolds would not be reflected in a change in percent fat.

The variation in skinfold patterning was a problem to the assessment of body fat, for the O-SCALE system it presented another feature that could be described. Individual patterns were identified, over and above those general patterns associated with age and sex specificity. For the weight loss case studies it was interesting to note that despite the reduction in adiposity the pattern of skinfolds remain relatively constant. In the prediction formulae for body fat the equations with the least number of skinfolds included would be more prone to error due to deviations in skinfold patterning. Thus, the Sloan equations with only two skinfolds would be more prone to problems than the Yuhasz equations which use the sum of six skinfolds. The resiliency of a sum was demonstrated earlier with respect to the selection of the sum of skinfolds as a basis of the **A-rating**.

Monitoring Change

The majority of people wanting to be tested, do so because they are expecting some change to occur, normally due to a modification of diet or habitual activity level. The O–SCALE system was ideally suited to this role. It provided an objective assessment of physique status and subsequent assessments could be used to objectify change. It provided an indispensible quantification of muscularity as inferred from the skinfold–corrected girths, which was useful in determining the quality of weight loss. In the female who lost 18.2 lbs it was seen that there was maintainance of the muscularity as the individual reduced in adiposity. She had increased her physical activity level, whereas the male worker who had only restricted his diet and made no modification to habitual physical activity, showed a uniform loss in all the measurements, thus infering loss of lean tissue as well as adiposity. The O–SCALE system has shown itself to be capable of the task of monitoring not only adiposity but also musculo–skeletal status.

PART D

CONCLUSIONS AND SUMMARY

CHAPTER I

CONCLUSION

The basic hypothesis addressed in this thesis was that:

A comprehensive anthropometric battery yielding individual item and geometrically scaled ratings in comparison to age and sex appropriate norms could be used as an *effective* method for individual physique assessment.

Apart from extensive field testing and testimonial evidence of hundreds of analyses being carried out successfully by many practitioners, with no complaints of the O–SCALE system ever giving misleading information, the case for affirmation of the hypothesis was based on whether the system fulfilled five basic criteria of effectiveness:

1) **Efficiency of data resolution into interpretable results.**
2) **Reliability of anthropometric techniques.**
3) **Ease of interpretation of the analysis.**
4) **Consistency with results among other validated anthropometric methods based on common data.**
5) **Explanation of the changes in body composition experienced during changes in body weight.**

Efficiency of Data Resolution

The measurement protocol and data entry by a trained anthropometrist and an assistant can be completed in about thirty minutes. A microcomputer programme with access to an augmented data base for 26 variables based on over 19,467 subjects is the most comprehensive, efficient microcomputer based anthropometric data assembly, resolution and report system known to the author. The essential microcomputer software written for IBM compatible machines using GWBASIC was listed in Appendix 1, provided a four page print-out of the A and **W-ratings** and the more detailed analysis including the proportionality profile.

Reliability of Anthropometry

Any system is only as good as the anthropometrists and the quality of the data being entered into it. It is axiomatic that the measures must be made by a trained anthropometrist following the standardised procedures. If this is done it was shown that the reliability of the measures was amply good enough to provide meaningful interpretation. The **A-rating** was shown to be very resilient to imposed error due to its basis on a sum of skinfolds. The proportionality profile was more susceptible to error. However, it was shown that the resolution of one space on the profile was greater than or equal to the technical error of the measurements. Thus assuming precise measures probably a change in one, and certainly change in two spaces on the profile could be regarded as true change rather than measurement error.

Ease of Interpretation

The O-SCALE system, having evolved through many versions represented a compromise between quantificative precision and comprehension. The ratings, listing of obtained values and proportionality profiles were easily interpreted as illustrated in the previous chapter and by various profiles shown later in this chapter. The claim was that due to the power of the iconometrographic approach the print-outs could be "read at a glance". All items were visually displayed whilst none of the raw data was obscured in the process. If a subject had both A and **W-ratings** of 5, the first impression would be that he had adiposity and other tissue masses which were average for their age and sex when scaled to the standard stature. If the A value was greater than the **W-rating** the impression was that there was greater subcutaneous adiposity at some sites than expected for the **W-rating** or that bone and muscle tissue masses were smaller than expected. If on the other hand the subject's A value was less than the W value, the indication would have been that the profile plots for girths or bone breadths would have been displaced to the right relative to the skinfold plots. Because each item was scaled to proportionality z-values they could be compared directly. The intepretation was, if the subject was geometrically scaled to the standard stature in all dimensions, each point on the profile would have showed his or her proportional size of the particular item relative to the norm group.

Earlier versions of the profile were displayed on gradated grids, however, it was apparent that no more than three reference points at the 4th, 50th and 96th percentiles were necessary and small differences in plots were easily perceived. Since the technical error of measurement was generally less than the distance between plot gradations, a horizontal difference in adjacent plotting points could be considered as a function of true change.

Consistency with results among other validated anthropometric methods

The O-SCALE system was seen to agree with analyses of the three other methodologies. Indeed it was seen to explain some discrepancies in results. A problem in prediction of percentage fat being the variability in skinfold patterning was amply demonstrated by the O-SCALE system. Also the reliance on skinfolds alone for prediction of percent fat, without a consideration for differences in body weight was shown to be a problem, with explanation coming from the O-SCALE system. It was also shown to be consistent with the Heath-Carter somatotype analyses.

ACCEPTANCE OF HYPOTHESIS

The stated hypothesis tested in this thesis related to the *effectiveness* of the system in physique assessment. Effectiveness was judged by the five criteria discussed above. Based on the overwhelming evidence of performance of the system it was decided to accept the hypothesis that the O–SCALE system could be used as an effective physique assessment system to augment existing methodologies.

The O–SCALE system was designed for assessment of status and monitoring of change in physique to be utilized by health, fitness and lifestyle enhancement professionals. The O–SCALE does not neccessarily enable the professional to make appropriate decisions in regard to counselling of clients. It only provides objective evidence of physique status at any measurement occasion. Advice given in regard to exercise, nutrition and lifestyle enhancement are an individual matter, made more objective and purposeful by measurement and procedures that do not distort reality. The O–SCALE system gave assessments in individual application that were always in accord with expectations. Percentage body fat when used in individual assessments was often seen to give discordant results. Percent body fat predictions have been seen to have so much error because the desired simplicity forced assumptions which were not appropriate in all individuals. Percent body fat predictions may be appropriate in group analyses but at present the O–SCALE system was shown to be superior and more informative. However, the O–SCALE system cannot replace percentage body fat prediction. It merely provides another assessment tool for the Health and Fitness Professional. There are many applications were the O–SCALE system would be inappropriate. There is a need for accurate prediction of fractional masses of the body, such as for drug dosages or considerations in underwater physiology. The O–SCALE system cannot provide these. The O–SCALE system was designed for a specific purpose and that was to provide individual description of physique status. It has achieved this goal.

There are no ideal A and W–ratings. In reference to the concept of ideal Garn (1986) stated:

> "...in the present state of knowledge we can not honestly assign an ideal or optimum weight of fat for anyone."

The variety of human physique is too great to be able to ascribe one ideal rating. A healthy, elite athlete such as an Olympic High Jumper could have both A and **W-ratings** of 1. Such ratings could also be associated with with emmaciation associated with anorexia nervosa. The A and **W-ratings** must be interpreted within the context of the individual. The proportionality profile can help in this regard particularly in quantifying muscularity, but it is not the whole answer. The Health and Fitness professional must use his or her own judgement, based on experience, along with information from other tests, to provide appropriate counsel to the individual.

CHAPTER II

SUMMARY

The purpose of this thesis was to design a fully integrated system of data assembly, resolution and report, for the assessment of individual physique status or for monitoring change. The new system provided for input of date of birth, date of measurement occasion, height, weight, and for Slim Guide or Harpenden skinfold caliper thicknesses at eight sites (triceps, biceps, subscapular, iliac crest, iliospinale, abdominal, front thigh and medial calf), ten girths (relaxed arm, flexed arm, forearm, wrist, chest, waist, gluteal, thigh, calf and ankle) and two bone breadths (humerus and femur).

The new O-SCALE system provided A (Adiposity) and W (Proportional Weight) ratings for 24 geometrically scaled normative groupings, ages 16 and 17; 18 and 19, and in five year increments thereafter until age 70 years. Adiposity was assessed by a proportional sum of six skinfolds (triceps, subscapular, supraspinale, abdominal, front thigh and medial calf). The proportional values were obtained by geometric scaling to a standard stature of 170.18 cm. A and **W-ratings** were achieved using a nine category percentile transformed stanine scale. An IBM Compatible GWBASIC microcomputer programme was developed to facilitate calculation of the A and **W-ratings**. This also permitted calculation of Phantom z-values for all individual measurements and four skinfold-corrected girths. These values were displayed as a proportionality profile on a simple 4%ile, 50%ile, 96%ile grid, relative to the appropriate norm for age and sex of the subject.

The normative database included assembly of a set of comprehensive anthropometric variables on 12,504 males and 7,143 females aged 16 to 70 years. These were produced from three data sets. Firstly, from a comprehensive anthropometric data assembly on children aged 6 to 18 years of age (Coquitlam Growth Study - COGRO); and secondly, measurements of height, weight, five skinfold, two girth and two bone width measurements (part of Y.M.C.A.

Lifestyle Inventory and Fitness Evaluation project - LIFESTYLE) on 12,204 male and 6,580 female Canadians, aged 20 to 70 years of age. Finally, a data set of comprehensive anthropometry on 233 male and 199 female university students (CANAD). A separate PREDICTOR sample of 103 males and 110 females aged 18 to 70 years was used to develop new distributions in the LIFESTYLE data for 3 derived skinfold variables and 8 derived girths, based on known relationships. A technique for correcting for the shrinkage of variance in regressed data, by adding a random error term to predicted values, was tested by prediction of known variables. The O-SCALE norms were compared to Canadian national standards and shown to be leaner, yet similar in muscularity.

Application of the O-SCALE system was shown to yield rational explanations for physique status in comparison to results obtained by contemporary methods on a variety of individuals. Analyses were shown for randomly selected individuals with balanced, adiposity and weight dominant physiques.

Although primarily developed for individual assessment, the O-SCALE system was also used to evaluate group characteristics of Olympic athletes randomly selected from the sports of Rowing, Cycling and Weightlifting. Nearly identical deviations in proportionality patterns from their own age and sex norm were demonstrated between male and female Olympic rowers.

The O-SCALE system was also shown to be valuable in describing the change in physique of: a female increasing habitual activity level along with dietary modification; a young male before and after a 77 day walk down the length of France; a male worker before and after a one year period of dietary control with no increase in activity level; and a body builder 9 days prior to and the day before competition.

While the O-SCALE system was primarily a normative-descriptive method in the Quetelet tradition, it had some distinct advantages over other methods. It was based on non-invasive, inexpensive and demonstrably precise and accurate measures which were related to appropriate age and sex norms. The measures sampled different regions of the body and reflected the underlying tissues and structures. It made use of contemporary microcomputer technology to bring order to the chaos of numbers by presenting both raw score summaries and proportionality profiles where attention to the salient characteristics of an individual's physique is focussed by the relationship between a rating of adiposity and ponderosity.

The purpose of the O-SCALE system was to provide a systematic way of assessing individual physique status and monitoring change accompanying growth, ageing, exercise and nutritional changes. Thus while it did not replace methods purporting to quantify tissue masses, it showed the unique physique characteristics of individuals which explain some of the discrepancies of different methods. In this respect, in addition to it's application by professionals in medicine, health, fitness, nutrition and lifestyle enhancement programmes, the O-SCALE system may help in the development of other methods and new technologies, or perhaps set limits for their applicability.

APPENDIX 1: O-SCALE GWBASIC MICROCOMPUTER PROGRAMME LISTING

```
5 WIDTH "SCRN:",40
10 CLS
12 PRINT "*************************************"
13 PRINT "*                                   *"
14 PRINT "*    O - S C A L E   S Y S T E M    *"
15 PRINT "*                                   *"
16 PRINT "*          P H Y S I Q U E          *"
17 PRINT "*                                   *"
18 PRINT "*        A S S E S S M E N T        *"
19 PRINT "*                                   *"
20 PRINT "* ----------------------------------*"
21 PRINT "*                                   *"
22 PRINT "*    by:  Richard Ward  M.Sc.       *"
23 PRINT "*                                   *"
24 PRINT "*         Shool of Kinesiology      *"
25 PRINT "*         SIMON FRASER UNIVERSITY   *"
26 PRINT "*************************************"
30 A=1000
31 A=A-1
32 IF A>0 THEN GOTO 31
36 DIM ZMES(26), DZB(26), ZSC(26), ZZE(26),ZTB(26),MES(26),LAB$(26),MIN(26),MAX(
26),ZAX(26),ZLO(26),P(26),S(26),WG(386),OGCP(386),M50(26),Z50(26)
37 DIM MES$(26),MIN$(26),MAX$(26),M50$(26)
40 CLS
59 PRINT ":-------------------------------------:"
60 PRINT ":  O-SCALE SYSTEM PHYSIQUE ANALYSIS   :"
61 PRINT ":-------------------------------------:
62 PRINT ":                                     :"
63 PRINT ":  Name =                             :"
64 PRINT ":                                     :"
65 PRINT ":  Sex (M/F) =                        :"
66 PRINT ":                                     :"
67 PRINT ":  Date of Birth (dec. yrs) =         :"
68 PRINT ":                                     :"
69 PRINT ":  Date of Test  (dec. yrs) =         :"
70 PRINT ":                                     :"
71 PRINT ":                                     :"
72 PRINT ":-------------------------------------:"
75 LOCATE   5,11:INPUT NM$
76 LOCATE   7,16:INPUT SEX$
77 LOCATE   9,31:INPUT BDAY
78 LOCATE   11,31:INPUT DATE
79 AGE=DATE-BDAY
80 CLS
82 IF SEX$="M" OR SEX$="m" THEN SEX$="MALE"
83 IF SEX$="F" OR SEX$="f" THEN SEX$="FEMALE"
85 PRINT:PRINT:PRINT NM$; "is a ";AGE;" year old ";SEX$
87 PRINT:PRINT:INPUT "Is this correct? (Y or N) : ";C$
88 CLS:IF C$="N" OR C$="n" THEN GOTO 59
90 WIDTH "SCRN:",80
150 OPEN "I",#1,"LABELS"
154 FOR I=1 TO 26
155 INPUT #1,LAB$(I)
156 NEXT I
160 CLOSE
170 CLS
180 IF SEX$="MALE" THEN SX$="M"
181 IF SEX$="FEMALE" THEN SX$="F"
185 NAGE=((INT((AGE*2)/10))*10)/2
187 AG$=STR$(NAGE)
189 NF$=SX$+AG$:NF$="M20"
255 CLS
260 GOSUB 1100
262 LOCATE 5,1
263 PRINT " Enter the Measurements for ";ID$
```

```
265 LOCATE 7,1
266 FOR I=1 TO 11: PRINT LAB$(I): LOCATE (7+I),1: NEXT I
270 LOCATE 7,41
273 FOR I=12 TO 22:PRINT LAB$(I): LOCATE (7+I-11),41: NEXT I
275 LOCATE 7,25
278 FOR I=1 TO 11: INPUT MES(I): LOCATE (7+I),25:NEXT I
280 LOCATE 7,65
283 FOR I=12 TO 22: INPUT MES(I): LOCATE (7+I-11),65:NEXT I
290 LOCATE 20,4
291 INPUT "Do you want to make any changes? (Y or N)";YN$
293 IF YN$="Y" OR YN$="y" THEN GOSUB 4000
295 IF YN$="N" OR YN$="n" THEN GOTO 300
297 GOTO 290
299 '***** GET NORMS FROM APPROPRIATE AGE AND SEX FILE
300 OPEN NF$ FOR INPUT AS #1
305 FOR I=1 TO 8
307 INPUT #1, OGCP(I)
309 NEXT I
310 FOR I=1 TO 8
312 INPUT #1, WG(I)
313 NEXT I
314 FOR I=1 TO 26:INPUT #1, MIN(I):NEXT I
315 FOR I=1 TO 26:INPUT #1, M50(I):NEXT I
316 FOR I=1 TO 26:INPUT #1, MAX(I):NEXT I
317 FOR I=1 TO 26:INPUT #1, ZLO(I):NEXT I
318 FOR I=1 TO 26:INPUT #1, Z50(I):NEXT I
319 FOR I=1 TO 26:INPUT #1, ZAX(I):NEXT I
320 CLOSE
349 '
350 '***** GET ROSS/WILSON PHANTOM VALUES FROM FILE
351 '
355 OPEN "I",#3,"PHANTOM"
360 FOR I=1 TO 26
365 INPUT #3, P(I)
366 INPUT #3, S(I)
367 NEXT I
368 CLOSE
379 '
380 '***** CALCULATE HEIGHT RATIOS
381 '
382 RHT=170.18/MES(2)
384 WRHT=RHT^3
389 '
390 '***** CALCULATE SKINFOLD CORRECTED GIRTHS
391 '
392 MES(23)=MES(11)-(3.14*(MES(3)/10))
394 MES(24)=MES(15)-(3.14*(MES(4)/10))
395 MES(25)=MES(18)-(3.14*(MES(9)/10))
396 MES(26)=MES(19)-(3.14*(MES(10)/10))
399 '
400 '***** CALCULATE PHANTOM Z-VALUES
401 '
405 ZMES(1)=((MES(1)*WRHT)-P(1))/S(1)
408 FOR I=3 TO 26
410 ZMES(I)=((MES(I)*RHT)-P(I))/S(I)
412 NEXT I
420 '
421 '***** CALCULATE PLOTTING POINTS ON PROFILE
422 '
425 FOR I = 1 TO 26
427 IF ZMES(I)<=Z50(I) THEN DZB(I)=Z50(I)-ZLO(I)
428 IF ZMES(I)>Z50(I) THEN DZB(I)=ZAX(I)-Z50(I)
430 IF DZB(I)=0 THEN DZB(I)=99
432 ZSC(I)=DZB(I)/10
435 IF ZMES(I)<=Z50(I) THEN ZZE(I)=ZMES(I)-ZLO(I)
436 IF ZMES(I)>Z50(I) THEN ZZE(I)=ZMES(I)-Z50(I)
```

```
438 IF ZMES(I)<=Z50(I) THEN ZTB(I)=INT(23+(ZZE(I)/ZSC(I)))
439 IF ZMES(I)>Z50(I) THEN ZTB(I)=INT(33+(ZZE(I)/ZSC(I)))
440 NEXT I
460 '
461 '***** CALCULATE PROPORTIONAL SUM OF SKINFOLDS AND PROP. WEIGHT
462 '
465 S6SF=MES(3)+MES(4)+MES(7)+MES(8)+MES(9)+MES(10)
467 PS6SF=(INT((S6SF*RHT)*10))/10
469 PWT=MES(1)*WRHT
475 '
476 '***** CALCULATE A AND W RATINGS
477 '
480 AR=1: WR=1
485 FOR I=1 TO 8
490 IF PS6SF>=OGCP(I) THEN AR=I+1
495 IF PWT >=WG(I) THEN WR=I+1
497 NEXT I
500 '
501 '***** SEND OUTPUT TO PRINTER
502 '***** FIRST PAGE
503 '
520 LPRINT " ";TAB(20);"----------------------------------------"
521 LPRINT " ";TAB(20);"O-SCALE RATING FOR ";NM$
522 LPRINT " ";TAB(20);"----------------------------------------"
525 LPRINT
527 LPRINT " ";TAB(20);SEX$;" ";AGE;" YEARS OF AGE."
528 LPRINT
529 LPRINT " ";TAB(20);"Height = ";MES(2);"cm.    Weight = ";MES(1);"kg."
530 LPRINT
531 LPRINT " ";TAB(20);"Proportional Weight = ";PWT;"kg."
532 LPRINT
533 LPRINT " ";TAB(20);"Sum of Skinfolds = ";S6SF;"mm."
534 LPRINT
536 LPRINT " ";TAB(20);"Proportional Sum of Skinfolds = ";PS6SF;"mm."
537 LPRINT
550 '
551 '***** A AND W RATING GRAPHIC
552 '
560 LPRINT " ";TAB(20);"I...I...I...I...I...I...I...I...I...I"
562 LPRINT " ";TAB(20);"I.1.I.2.I.3.I.4.I.5.I.6.I.7.I.8.I.9.I"
564 OV=AR+.5
566 OVP=(((INT((OV*4)))/4)*4)-3
568 WV=WR+.5
570 WVP=(((INT((WV*4)))/4)*4)-3
575 LPRINT:LPRINT " ";TAB(20);"A";TAB(20+OVP);"*"
577 LPRINT:LPRINT " ";TAB(20);"W";TAB(20+WVP);"*"
579 LPRINT " ";TAB(20);"I...I...I...I...I...I...I...I...I...I"
580 LPRINT " ";TAB(20);"    4%.11%.23%.40%.60%.77%.89%.96%    "
585 LPRINT CHR$(12)
600 '
601 '***** SECOND PAGE
602 '
610 LPRINT "SIZE - This is a listing of your measurements. To the right of your"
612 LPRINT "measurements are shown the 4th, 50th and 96th percentiles for your"
614 LPRINT "own age and sex norm"
616 LPRINT:LPRINT
618 LPRINT " ";TAB(44);"Norm Percentiles"
620 LPRINT " ";TAB(42);"4%";TAB(50);"50%";TAB(59);"96%"
622 LPRINT "------------------------------------------------------------------"
625 FOR I=1 TO 20:GOSUB 25100:NEXT I
626 FOR I=21 TO 22:GOSUB 25200:NEXT I
627 FOR I=23 TO 26:GOSUB 25100:NEXT I
640 I=1:GOSUB 24000:LPRINT:I=2:GOSUB 24000:LPRINT
645 LPRINT :LPRINT "SKINFOLDS":LPRINT:FOR I=3 TO 10:GOSUB 24000:NEXT I:LPRINT:LP
RINT
646 LPRINT "GIRTHS" :LPRINT:FOR I=11 TO 20:GOSUB 24000:NEXT I:LPRINT:LPRINT
```

```
647 LPRINT "BONE WIDTHS":LPRINT:FOR I=21 TO 22:GOSUB 24000:NEXT I:LPRINT:LPRINT
648 LPRINT :LPRINT "SKINFOLD-CORRECTED GIRTHS (Muscularity)":LPRINT:FOR I=21 TO
22:GOSUB 24000:NEXT I:LPRINT:LPRINT
655 LPRINT "-----------------------------------------------------------"
690 LPRINT CHR$(12)
700 '
701 '***** THIRD PAGE
702 '
710 LPRINT CHR$(27)+"W"+CHR$(1)
712 LPRINT "           PROPORTIONALITY PROFILE"
714 LPRINT:LPRINT
716 LPRINT CHR$(27)+"W"+CHR$(0)
720 LPRINT "Your measurements are scaled to a common stature and then plotted"
725 LPRINT "relative to your similarly scaled same age and sex norm."
730 LPRINT:LPRINT
735 LPRINT " ";TAB(23);"4%";TAB(32);"50%";TAB(42);"96%"
740 LPRINT "-----------------------------------------------------------------
----"
745 LPRINT " ";TAB(18);".....I........I.........I.........................."
747 IF ZTB(I)<16 THEN PRINT LAB$(I);TAB(16);"<---"
748 IF ZTB(I)>69 THEN PRINT LAB$(I);TAB(66);"--->"
750 IF ZTB(I) >=16 AND ZTB(I) <= 69 THEN LPRINT LAB$(1);TAB(ZTB(1));"*"
755 LPRINT " ";TAB(18);".....I........I.........I.........................."
760 FOR I=3 TO 26
761 IF ZTB(I)<16 THEN PRINT LAB$(I);TAB(16);"<---"
762 IF ZTB(I)>69 THEN PRINT LAB$(I);TAB(66);"--->"
763 IF ZTB(I) >=16 AND ZTB(I) <= 69 THEN LPRINT LAB$(I);TAB(ZTB(I));"*"
765 LPRINT " ";TAB(18);".....I........I.........I.........................."
770 NEXT I
775 LPRINT "-----------------------------------------------------------------
----"
780 LPRINT CHR$(12)
800 '
801 '***** FOURTH PAGE
802 '
820 '***** PERCENTAGE BODY FAT CALCULATIONS
825 '***** YUHASZ
830 IF SEX$="M" THEN FT(1)=(.1051*(MES(3)+MES(4)+MES(7)+MES(8)+MES(9)+MES(10)))+
2.585
831 IF SEX$="F" THEN FT(1)=(.1548*(MES(3)+MES(4)+MES(7)+MES(8)+MES(9)+MES(10)))+
3.58
840 '***** SLOAN
841 IF SEX$ = "F" THEN FT(2)=1.0764-(.00081*MES(6))-(.00088*MES(3))
845 IF SEX$ = "F" THEN FT(2)=100*((4.57/FT(2))-4.142)
846 IF SES$ = "M" THEN FT(2)=100*((4.57/(1.1043-(.001327*MES(9))-(.00131*MES(4))
))-4.142)
850 '***** DURNIN AND WOMERSLEY'
855 DW=(LOG(MES(3)+MES(4)+MES(5)+MES(6)))/LOG(10)
856 IF SEX$="M" AND AGE>=17 AND AGE<20 THEN FT(3)=1.162-(.063*DW)
857 IF SEX$="F" AND AGE>=16 AND AGE<20 THEN FT(3)=1.1549-(.0678*DW)
858 IF SEX$="M" AND AGE>=20 AND AGE<30 THEN FT(3)=1.1631-(.0632*DW)
859 IF SEX$="F" AND AGE>=20 AND AGE<30 THEN FT(3)=1.1599-(.0717*DW)
860 IF SEX$="F" AND AGE>=30 AND AGE<40 THEN FT(3)=1.1423-(.0632*DW)
861 IF SEX$="M" AND AGE>=40 AND AGE<50 THEN FT(3)=1.162-(.07*DW)
862 IF SEX$="F" AND AGE>=40 AND AGE<50 THEN FT(3)=1.1333-(.0612*DW)
863 IF SEX$="M" AND AGE>=50 THEN FT(3)=1.1715-(.0779*DW)
864 IF SEX$="F" AND AGE>=50 THEN FT(3)=1.1339-(.0645*DW)
865 IF FT(3)>0 THEN FT(3)=((4.95/FT(3))-4.5)*100
870 GOSUB 40000
872 FE$(1)="YUHASZ":FE$(2)="SLOAN":FE$(3)="DURNIN AND WOMERSLEY"
875 FOR I=1 TO 5:LPRINT:NEXT I
877 LPRINT "                      PERCENTAGE BODY FAT PREDICTIONS"
878 LPRINT "                     -----------------------------------"
880 LPRINT:FOR I=1 TO 3
882 LPRINT "                     ";FE$(I);TAB(50);FT(I);"%":LPRINT
883 NEXT I
```

```
885 LPRINT CHR$(12)
1000 END
1100 FOR I=1 TO 26: VN$=STR$(I):NEXT I
1105 RETURN
4000 INPUT "     Which # Variable? : ";NI
4010 INPUT "     Enter the new value : ";MES(NI)
4020 IF NI < 12  THEN GOTO 4025
4021 IF NI > 11 THEN GOTO 4030
4025 LOCATE (7+NI),25: PRINT "?";MES(NI);"    "
4026 IF NI < 12 THEN GOTO 4032
4030 LOCATE (7+NI-11),65: PRINT "?";MES(NI);"  "
4032 PRINT "III"
4050 RETURN
22000 PRINT "O-SCALE SYSTEM: HUMAN PHYSIQUE ANALYSIS"
22005 PRINT "***************************************"
22010 FOR I=1 TO 18
22015 PRINT "*                                     *"
22020 NEXT I
22030 PRINT "***************************************"
22050 RETURN
24000 LPRINT LAB$(I);TAB(25);MES$(I);TAB(40);MIN$(I);"     ";M50$(I);"     ";MAX$(
I)
24010 RETURN
25100 MES$(I)=STR$(MES(I))
25101 MIN$(I)=STR$(MIN(I))
25102 M50$(I)=STR$(M50(I))
25103 MAX$(I)=STR$(MAX(I))
25110 IF LEN(MES$(I))=1 THEN MES$(I)= "  "+MES$(I)
25111 IF LEN(MIN$(I))=1 THEN MIN$(I)= "  "+MIN$(I)
25112 IF LEN(M50$(I))=1 THEN M50$(I)= "  "+M50$(I)
25113 IF LEN(MAX$(I))=1 THEN MAX$(I)= "  "+MAX$(I)
25120 IF MID$(MES$(I),LEN(MES$(I))-1,1)<>"."THEN MES$(I)=MES$(I)+".0"
25121 IF MID$(MIN$(I),LEN(MIN$(I))-1,1)<>"."THEN MIN$(I)=MIN$(I)+".0"
25122 IF MID$(M50$(I),LEN(M50$(I))-1,1)<>"."THEN M50$(I)=M50$(I)+".0"
25123 IF MID$(MAX$(I),LEN(MAX$(I))-1,1)<>"."THEN MAX$(I)=MAX$(I)+".0"
25130 IF LEN(MES$(I))=3 THEN MES$(I)="  "+MES$(I)
25131 IF LEN(MIN$(I))=3 THEN MIN$(I)="  "+MIN$(I)
25132 IF LEN(M50$(I))=3 THEN M50$(I)="  "+M50$(I)
25133 IF LEN(MAX$(I))=3 THEN MAX$(I)="  "+MAX$(I)
25140  IF LEN (MES$(I))=4 THEN MES$(I)=" "+MES$(I)
25141  IF LEN (MIN$(I))=4 THEN MIN$(I)=" "+MIN$(I)
25142  IF LEN (M50$(I))=4 THEN M50$(I)=" "+M50$(I)
25143  IF LEN (MAX$(I))=4 THEN MAX$(I)=" "+MAX$(I)
25170 RETURN
25200 MES$(I)=STR$(MES(I))
25201 MIN$(I)=STR$(MIN(I))
25202 M50$(I)=STR$(M50(I))
25203 MAX$(I)=STR$(MAX(I))
25220 IF MID$(MES$(I),LEN(MES$(I))-1,1)= "."THEN MES$(I)=MES$(I)+"0"
25221 IF MID$(MIN$(I),LEN(MIN$(I))-1,1)= "."THEN MIN$(I)=MIN$(I)+"0"
25222 IF MID$(M50$(I),LEN(M50$(I))-1,1)= "."THEN M50$(I)=M50$(I)+"0"
25223 IF MID$(MAX$(I),LEN(MAX$(I))-1,1)= "."THEN MAX$(I)=MAX$(I)+"0"
25240  IF LEN (MES$(I))=4 THEN MES$(I)=" "+MES$(I)
25241  IF LEN (MIN$(I))=4 THEN MIN$(I)=" "+MIN$(I)
25242  IF LEN (M50$(I))=4 THEN M50$(I)=" "+M50$(I)
25243  IF LEN (MAX$(I))=4 THEN MAX$(I)=" "+MAX$(I)
25250 RETURN
```

```
40000 '***** FOURTH PAGE TEXT
40010 LPRINT "                         PERCENTAGE BODY FAT"
40020 LPRINT:LPRINT "     The O-SCALE SYSTEM is an alternative to the traditiona
l prediction of"
40030 LPRINT:LPRINT "     percentage body fat, which has on many occasions given
 dubious results"
40040 LPRINT:LPRINT "     in individual assessments. As an illustration of the p
roblem of using"
40050 LPRINT:LPRINT "     percentage body fat prediction formulae, the following
 are predictions"
40060 LPRINT:LPRINT "     using only three of many published prediction equation
s. They are not"
40070 LPRINT:LPRINT "     selected as being the best or worst, merely as typical
 of results"
40080 LPRINT:LPRINT "     that might be achieved using the data of this subject
and percent fat"
40090 LPRINT:LPRINT "     prediction equations. As can be seen, all three predic
tions are"
40100 LPRINT:LPRINT "     different. Which is the right answer? There are many f
actors that"
40110 LPRINT:LPRINT "     contribute to the different predictions. The justifica
tion for the"
40120 LPRINT:LPRINT "     production of the O-SCALE SYSTEM is that this problem
exists for"
40130 LPRINT:LPRINT "     individual assessments. The O-SCALE therefore, does no
t predict "
40140 LPRINT:LPRINT "     percent fat, but does give information not only on fat
ness, but "
40150 LPRINT:LPRINT "     also on muscularity and body proportions."
40200 RETURN
```

APPENDIX 2: O-SCALE ABSOLUTE AND Z-VALUE NORMS

MALES 16 - 17.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	47.1	64.8	82.4	-1.8	-.8	1.1
Height (cm)	158.5	175.8	191.0	.0	.0	.0
Triceps SF (mm)	4.6	7.9	19.3	-2.4	-1.5	.9
Subscapular SF	5.5	8.2	20.6	-2.3	-1.9	0.7
Supraspinale SF	3.5	6.3	22.0	-2.5	-2.1	1.1
Abdominal SF	4.6	9.4	37.4	-2.6	-2.1	.7
Front Thigh SF	6.6	11.0	26.8	-2.4	-1.9	-.2
Medial Calf SF	4.6	8.2	17.5	-2.4	-1.7	.6
Relaxed Arm G	23.2	27.5	32.7	-1.6	.0	2.1
Flexed Arm G	25.8	30.3	35.1	-1.5	-.1	2.2
Forearm G	23.2	26.3	29.5	-.4	1.0	4.2
Wrist G	15.1	16.9	18.7	-1.7	.1	2.9
Chest G	77.8	89.3	100.5	-1.8	-.2	1.6
Waist G	64.3	72.3	84.4	-1.5	-.6	3.8
Thigh G	45.5	52.6	63.3	-0.8	-.6	1.5
Calf G	30.6	35.2	41.0	-2.0	-.3	1.8
Ankle G	20.1	22.6	25.0	-1.4	.3	2.3
Humerus B	6.4	7.1	7.8	-.2	1.4	3.5
Femur B	8.9	9.8	10.6	-1.5	.0	1.9
Cor. Relaxed Arm G	21.0	25.0	28.4	-.7	1.1	3.2
Cor. Chest G	76.2	86.8	96.9	-1.2	.4	2.2
Cor. Thigh G	41.7	48.7	57.4	-1.3	.1	2.5
Cor. Calf G	27.8	32.5	36.9	-1.1	.8	2.8

MALES 18 - 19.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	56.9	71.5	92.0	-1.9	-.3	1.0
Height (cm)	165.4	179.7	191.3	.0	.0	.0
Triceps SF (mm)	4.6	8.8	19.0	-2.3	-1.6	.4
Subscapular SF	6.0	9.4	22.2	-2.2	-1.7	-.8
Supraspinale SF	3.6	6.2	12.3	-2.6	-2.1	-.8
Abdominal SF	5.1	9.8	21.1	-2.6	-2.0	-.6
Front Thigh SF	6.3	11.2	24.9	-2.4	-1.9	-.5
Medial Calf SF	3.7	8.2	16.3	-2.7	-1.7	.0
Relaxed Arm G	24.5	29.6	33.8	-1.3	.7	2.0
Flexed Arm G	27.1	31.8	35.9	-1.3	.7	1.9
Forearm G	24.4	27.2	30.0	-.4	1.1	3.2
Wrist G	15.5	17.1	18.5	-2.2	-.1	1.6
Chest G	82.3	93.3	103.4	-1.7	.2	2.3
Waist G	67.7	76.5	84.7	-.8	1.0	4.2
Thigh G	48.3	55.1	61.8	-1.2	-.8	2.1
Calf G	33.4	36.7	41.3	-1.8	-.1	1.7
Ankle G	20.1	22.4	24.8	-1.8	-.3	1.6
Humerus B	6.4	7.2	7.8	-.5	1.0	2.9
Femur B	8.9	9.9	10.6	-1.6	-.3	1.1
Cor. Relaxed Arm G	22.1	26.6	30.6	-.2	1.8	3.6
Cor. Chest G	80.2	90.4	99.8	-1.2	.8	2.9
Cor. Thigh G	45.6	51.4	58.2	-1.0	.4	2.1
Cor. Calf G	30.5	33.7	37.9	-.5	1.1	3.1

FEMALES 16 - 17.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	45.2	55.2	68.8	-1.6	-.5	1.5
Height (cm)	156.8	164.9	175.1	.0	.0	.0
Triceps SF (mm)	8.3	15.4	25.8	-1.6	.2	2.4
Subscapular SF	5.8	10.2	22.1	-2.0	-1.2	1.6
Supraspinale SF	6.0	10.8	20.2	-2.0	-.9	1.2
Abdominal SF	6.8	14.8	29.4	-2.3	-1.3	.7
Front Thigh SF	12.7	24.6	39.1	-1.6	-.1	1.5
Medial Calf SF	7.4	15.1	26.6	-1.7	-.1	2.4
Relaxed Arm G	21.2	25.7	29.9	-2.2	-.1	1.9
Flexed Arm G	23.1	26.9	31.1	-2.5	-.5	1.5
Forearm G	21.5	23.6	26.1	-1.8	-.5	1.7
Wrist G	14.1	15.3	16.9	-3.1	-.6	2.0
Chest G	75.0	82.3	90.3	-2.2	-.4	1.3
Waist G	58.3	65.5	77.0	-2.0	-.1	3.6
Thigh G	46.8	54.3	63.6	-1.6	-.6	3.5
Calf G	30.4	34.3	39.5	-1.8	.2	2.5
Ankle G	19.3	21.3	23.6	-1.4	.3	2.3
Humerus B	5.7	6.2	6.8	-1.5	.0	1.9
Femur B	8.2	8.9	9.9	-2.1	-.6	1.4
Cor. Relaxed Arm G	17.9	21.0	23.9	-1.7	-.2	1.8
Cor. Chest G	71.5	79.0	85.2	-1.8	-.1	1.4
Cor. Thigh G	40.7	46.3	53.3	-1.3	.2	2.3
Cor. Calf G	26.0	29.8	33.2	-1.5	.2	2.3

FEMALES 18 - 19.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	47.7	59.2	77.1	-1.3	-.2	1.8
Height (cm)	155.5	166.6	177.5	.0	.0	.0
Triceps SF (mm)	10.1	16.9	29.4	-1.1	.6	3.2
Subscapular SF	7.1	11.1	21.6	-1.9	-1.1	1.0
Supraspinale SF	5.1	9.9	19.9	-2.1	-1.1	1.2
Abdominal SF	7.7	16.0	27.5	-2.2	-1.1	.3
Front Thigh SF	14.6	25.4	45.1	-1.3	.0	2.3
Medial Calf SF	8.7	15.8	31.3	-1.5	.0	3.6
Relaxed Arm G	23.5	26.2	30.0	-1.4	.2	2.1
Flexed Arm G	24.3	27.1	31.1	-2.1	-.5	1.4
Forearm G	21.6	24.0	25.9	-1.9	.2	2.5
Wrist G	13.8	14.9	16.5	-3.0	-1.3	.6
Chest G	77.4	84.4	95.2	-1.8	-.2	2.4
Waist G	61.1	68.0	77.9	-1.6	-0.5	2.9
Thigh G	51.2	56.1	63.3	-1.6	.0	2.3
Calf G	31.4	35.0	39.6	-1.1	.3	2.5
Ankle G	19.3	21.0	23.6	-1.4	.0	1.9
Humerus B	5.7	6.3	6.9	-1.7	-.1	1.7
Femur B	8.2	9.0	9.7	-2.0	-.6	1.2
Cor. Relaxed Arm G	17.9	20.9	25.0	-2.1	-.3	2.0
Cor. Chest G	74.1	80.1	88.7	-1.4	.1	2.3
Cor. Thigh G	40.9	47.5	53.9	-1.3	.6	2.3
Cor. Calf G	24.5	30.0	34.6	-2.4	.5	2.4

MALES 20 - 24.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	59.0	75.0	97.5	-1.4	-.1	2.0
Height (cm)	166.9	179.7	191.5	.0	.0	.0
Triceps SF (mm)	4.6	8.9	18.9	-2.4	-1.5	.6
Subscapular SF	6.9	11.4	25.6	-2.1	-1.2	1.5
Biceps Sf	2.8	4.4	10.4	-2.6	-1.9	1.0
Iliac Crest SF	6.6	13.7	34.4	-2.3	-1.3	1.6
Supraspinale SF	4.1	9.0	25.6	-2.5	-1.5	2.1
Abdominal SF	3.8	15.2	42.5	-2.7	-1.3	1.9
Front Thigh SF	5.7	12.5	25.8	-2.6	-1.8	-.2
Medial Calf SF	4.0	8.2	18.5	-2.6	-1.7	.4
Relaxed Arm G	25.9	31.3	36.5	-.9	1.2	3.3
Flexed Arm G	28.2	33.1	38.2	-1.0	.9	3.1
Forearm G	25.4	28.0	31.3	-.6	1.0	3.1
Wrist G	15.3	16.6	19.6	-2.3	-.6	2.4
Chest G	88.6	97.6	114.2	-.4	1.1	3.5
Waist G	70.5	80.9	100.5	-.8	1.1	5.2
Gluteal G	88.5	97.6	110.3	-1.8	-.3	1.7
Thigh G	51.0	58.4	66.3	-1.6	-.2	1.6
Calf G	33.0	37.0	42.5	-1.8	.1	2.1
Ankle G	18.2	22.1	26.6	-3.2	-.5	2.5
Humerus B	6.2	7.1	8.0	-1.3	.7	2.8
Femur B	8.6	9.7	10.9	-2.6	-.5	1.6
Cor. Relaxed Arm G	24.5	28.6	32.0	.7	2.5	4.4
Cor. Chest G	85.0	94.7	107.2	.1	1.5	3.5
Cor. Thigh G	46.4	54.3	60.7	-.6	1.1	2.6
Cor. Calf G	29.9	34.4	39.2	-.8	1.2	3.4

MALES 25 - 29.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	60.9	76.4	101.0	-1.3	.2	2.4
Height (cm)	167.3	179.7	191.7	.0	.0	.0
Triceps SF (mm)	4.8	9.8	20.0	-2.4	-1.3	.8
Subscapular SF	7.4	13.3	28.2	-2.0	-.8	1.8
Biceps Sf	2.7	5.0	11.7	-2.7	-1.6	1.5
Iliac Crest SF	7.5	16.5	38.1	-2.1	-.9	2.0
Supraspinale SF	4.6	11.4	27.2	-2.4	-1.0	2.4
Abdominal SF	4.3	19.0	46.3	-2.7	-.9	2.5
Front Thigh SF	5.4	13.4	27.2	-2.6	-1.7	-.1
Medial Calf SF	4.0	8.9	19.1	-2.6	-1.6	.5
Relaxed Arm G	26.2	31.5	36.9	-1.0	1.4	3.4
Flexed Arm G	28.5	33.3	38.5	-1.1	1.0	3.1
Forearm G	25.7	28.0	31.5	-.5	1.1	3.2
Wrist G	15.4	16.6	19.4	-2.4	-.5	2.6
Chest G	89.7	98.4	116.1	-.3	1.3	4.0
Waist G	72.2	83.5	105.7	-.6	1.7	6.1
Gluteal G	89.2	98.7	112.2	-1.6	-.1	2.0
Thigh G	51.0	58.9	67.1	-1.6	-.1	1.7
Calf G	33.2	37.3	42.5	-1.7	.1	2.2
Ankle G	18.6	22.2	26.6	-3.1	-.4	2.5
Humerus B	6.2	7.1	7.8	-1.6	.7	2.6
Femur B	8.7	9.7	10.9	-2.6	-.5	1.6
Cor. Relaxed Arm G	24.5	28.6	32.1	.6	2.6	4.4
Cor. Chest G	86.3	94.9	108.1	.0	1.6	3.7
Cor. Thigh G	46.9	54.3	61.0	-.6	1.1	2.7
Cor. Calf G	30.3	34.3	39.0	-.7	1.2	3.5

MALES 30 - 34.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	61.9	78.1	100.9	-1.2	.3	2.4
Height (cm)	167.9	179.7	191.0	.0	.0	.0
Triceps SF (mm)	5.0	10.1	19.7	-2.3	-1.2	.8
Subscapular SF	7.8	14.4	28.7	-1.9	-.6	2.1
Biceps Sf	3.0	5.4	11.7	-2.6	-1.4	1.6
Iliac Crest SF	8.6	17.8	37.1	-2.1	-.7	1.9
Supraspinale SF	5.2	12.6	26.9	-2.3	-.7	2.4
Abdominal SF	5.6	20.9	46.7	-2.6	-.6	2.4
Front Thigh SF	5.8	13.9	25.9	-2.5	-1.6	-.2
Medial Calf SF	4.2	9.0	18.0	-2.5	-1.5	.3
Relaxed Arm G	26.3	31.8	36.9	-.7	1.4	3.4
Flexed Arm G	29.1	33.6	38.5	-.8	1.1	3.1
Forearm G	25.7	28.1	31.4	-.4	1.2	3.2
Wrist G	15.5	16.8	19.3	-2.2	-.3	2.7
Chest G	90.4	99.2	115.5	-.2	1.5	3.9
Waist G	73.9	85.5	106.3	-.2	2.2	6.4
Gluteal G	89.6	99.5	112.3	-1.5	.0	2.1
Thigh G	51.2	58.8	66.7	-1.6	-.1	1.7
Calf G	33.1	37.5	42.4	-1.6	.3	2.1
Ankle G	18.7	22.4	26.5	-3.0	-.3	2.5
Humerus B	6.3	7.1	7.9	-1.3	.8	2.8
Femur B	8.7	9.8	10.9	-2.5	-.4	1.8
Cor. Relaxed Arm G	24.7	28.7	32.1	.8	2.6	4.3
Cor. Chest G	86.2	95.6	107.9	.2	1.8	3.8
Cor. Thigh G	46.7	54.3	61.0	-.6	1.1	2.7
Cor. Calf G	30.2	34.6	38.9	-.7	1.4	3.4

MALES 35 - 39.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	63.6	79.1	102.3	-1.0	.5	2.7
Height (cm)	166.9	179.5	191.2	.0	.0	.0
Triceps SF (mm)	5.4	10.2	19.2	-2.3	-1.2	.7
Subscapular SF	8.3	15.4	28.7	-1.8	-.5	2.2
Biceps Sf	3.0	5.7	11.7	-2.5	-1.2	1.6
Iliac Crest SF	10.1	18.8	39.2	-1.9	-.5	2.2
Supraspinale SF	5.5	13.1	28.3	-2.2	-.6	2.7
Abdominal SF	7.3	22.7	47.6	-2.4	-.4	2.5
Front Thigh SF	6.2	13.8	26.0	-2.5	-1.6	-.2
Medial Calf SF	4.2	8.8	18.2	-2.5	-1.6	.3
Relaxed Arm G	26.7	31.9	36.9	-.6	1.5	3.6
Flexed Arm G	29.4	33.8	38.9	-.6	1.1	3.4
Forearm G	25.8	28.2	31.5	-.4	1.2	3.5
Wrist G	15.5	16.8	19.6	-2.0	-.3	2.9
Chest G	91.1	99.9	116.9	.0	1.6	4.2
Waist G	75.9	87.3	108.7	.2	2.5	6.9
Gluteal G	90.7	100.3	113.5	-1.4	.1	2.3
Thigh G	51.1	58.6	66.4	-1.6	-.1	1.7
Calf G	33.3	37.5	42.5	-1.6	.2	2.3
Ankle G	18.7	22.4	26.5	-3.0	-.3	2.8
Humerus B	6.3	7.1	7.9	-1.4	.9	3.1
Femur B	8.7	9.8	10.9	-2.5	-.4	1.9
Cor. Relaxed Arm G	24.8	28.7	32.3	.8	2.6	4.6
Cor. Chest G	86.8	95.9	108.7	.4	1.8	4.0
Cor. Thigh G	46.6	54.2	61.1	-.6	1.0	2.8
Cor. Calf G	30.5	34.6	39.3	-.7	1.4	3.7

MALES 40 - 44.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	64.1	79.8	104.6	-1.0	.5	2.6
Height (cm)	168.2	179.7	190.6	.0	.0	.0
Triceps SF (mm)	5.5	10.2	19.4	-2.2	-1.2	.7
Subscapular SF	8.6	15.6	28.7	-1.8	-.4	2.1
Biceps Sf	3.1	5.8	11.7	-2.5	-1.2	1.5
Iliac Crest SF	10.5	19.0	39.8	-1.7	-.5	2.1
Supraspinale SF	5.6	13.4	28.4	-2.2	-.6	2.6
Abdominal SF	8.1	23.0	48.6	-2.2	-.4	2.7
Front Thigh SF	6.3	13.4	24.9	-2.5	-1.7	-.3
Medial Calf SF	4.2	8.5	17.0	-2.5	-1.7	.1
Relaxed Arm G	26.6	31.7	36.6	-.6	1.4	3.3
Flexed Arm G	29.5	33.6	38.6	-.5	1.1	3.3
Forearm G	25.8	28.2	31.7	-.3	1.1	3.4
Wrist G	15.6	16.9	19.9	-2.1	-.2	2.9
Chest G	91.5	100.3	118.1	-.1	1.7	4.3
Waist G	77.0	88.4	109.3	.4	2.8	6.9
Gluteal G	90.8	100.4	113.4	-1.3	.2	2.2
Thigh G	50.7	58.3	66.0	-1.7	-.2	1.4
Calf G	33.5	37.5	42.5	-1.5	.2	2.2
Ankle G	19.0	22.4	26.8	-2.8	-.3	2.6
Humerus B	6.3	7.2	8.1	-1.1	.9	3.1
Femur B	8.8	9.8	10.9	-2.5	-.3	1.7
Cor. Relaxed Arm G	24.7	28.6	32.2	.9	2.5	4.5
Cor. Chest G	86.9	96.3	109.8	.3	1.9	4.0
Cor. Thigh G	46.0	53.8	60.6	-.9	1.0	2.6
Cor. Calf G	30.6	34.7	39.3	-.5	1.4	3.6

MALES 45 - 49.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	63.5	80.2	103.0	-.9	.6	2.6
Height (cm)	167.5	179.2	190.5	.0	.0	.0
Triceps SF (mm)	5.4	10.2	18.9	-2.3	-1.2	.6
Subscapular SF	9.0	16.4	31.0	-1.7	-.3	2.6
Biceps Sf	3.2	6.0	11.7	-2.5	-1.1	1.6
Iliac Crest SF	10.6	19.5	40.0	-1.8	-.4	2.2
Supraspinale SF	6.0	13.4	29.1	-2.1	-.5	2.8
Abdominal SF	8.7	23.6	49.6	-2.1	-.3	2.7
Front Thigh SF	6.2	13.7	24.9	-2.5	-1.6	-.4
Medial Calf SF	4.2	8.7	17.8	-2.5	-1.6	.2
Relaxed Arm G	26.5	31.6	36.5	-.6	1.4	3.4
Flexed Arm G	29.5	33.8	38.6	-.5	1.2	3.2
Forearm G	25.6	28.2	31.5	-.4	1.2	3.4
Wrist G	15.5	16.9	19.7	-2.0	-.1	3.0
Chest G	91.0	100.4	117.9	-.1	1.8	4.4
Waist G	77.1	89.4	110.9	.6	3.1	7.4
Gluteal G	90.3	100.5	113.3	-1.3	.2	2.2
Thigh G	50.0	57.8	65.6	-1.7	-.3	1.4
Calf G	33.0	37.3	42.0	-1.6	.2	2.1
Ankle G	18.5	22.4	26.7	-3.0	-.3	2.5
Humerus B	6.3	7.2	8.0	-1.3	1.0	3.2
Femur B	8.8	9.8	11.0	-2.3	-.2	1.9
Cor. Relaxed Arm G	24.6	28.6	31.9	.7	2.6	4.3
Cor. Chest G	87.0	96.1	108.8	.5	1.9	3.9
Cor. Thigh G	45.2	53.3	59.9	-.8	.9	2.5
Cor. Calf G	30.4	34.5	38.8	-.7	1.4	3.5

MALES 50 - 54.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	63.5	79.5	100.5	-.9	.6	2.6
Height (cm)	166.9	178.4	190.0	.0	.0	.0
Triceps SF (mm)	5.5	10.2	18.4	-2.2	-1.2	.5
Subscapular SF	8.8	16.7	28.7	-1.7	-.2	2.2
Biceps Sf	3.2	6.0	11.7	-2.5	-1.0	1.5
Iliac Crest SF	11.3	19.5	37.4	-1.6	-.4	1.9
Supraspinale SF	5.8	13.0	26.6	-2.1	-.6	2.4
Abdominal SF	9.7	23.7	46.3	-2.0	-.3	2.3
Front Thigh SF	6.6	13.2	23.7	-2.5	-1.7	-.5
Medial Calf SF	4.2	8.2	17.0	-2.5	-1.7	.1
Relaxed Arm G	26.4	31.3	35.7	-.7	1.3	3.1
Flexed Arm G	29.0	33.5	38.0	-.7	1.1	3.0
Forearm G	25.6	28.0	31.1	-.4	1.1	3.1
Wrist G	15.6	16.9	19.4	-2.0	-.1	2.9
Chest G	90.8	100.3	115.9	.0	1.8	4.1
Waist G	78.1	90.1	108.9	.8	3.2	6.9
Gluteal G	90.4	100.1	111.8	-1.3	.2	2.1
Thigh G	49.3	57.3	64.0	-1.9	-.4	1.2
Calf G	33.0	37.0	42.0	-1.5	.1	2.1
Ankle G	18.8	22.2	26.3	-2.8	-.3	2.5
Humerus B	6.4	7.2	8.0	-1.0	1.1	3.2
Femur B	8.7	9.8	10.8	-2.4	-.2	1.8
Cor. Relaxed Arm G	24.2	28.2	31.3	.6	2.4	4.1
Cor. Chest G	86.6	95.8	107.4	.3	1.9	4.0
Cor. Thigh G	44.8	52.7	58.4	-1.1	.8	2.3
Cor. Calf G	30.5	34.3	38.8	-.6	1.3	3.6

MALES 55 - 59.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	64.1	79.1	99.5	-.8	.6	2.9
Height (cm)	164.5	177.7	188.7	.0	.0	.0
Triceps SF (mm)	5.8	10.4	18.1	-2.2	-1.2	.5
Subscapular SF	8.8	16.8	28.7	-1.7	-.1	2.2
Biceps Sf	3.2	6.2	11.7	-2.4	-1.0	1.6
Iliac Crest SF	11.3	19.5	38.5	-1.6	-.4	2.0
Supraspinale SF	5.4	13.0	26.0	-2.2	-.6	2.4
Abdominal SF	9.5	24.0	47.4	-2.0	-.3	2.6
Front Thigh SF	6.8	12.6	23.4	-2.5	-1.7	-.5
Medial Calf SF	4.2	7.6	15.9	-2.5	-1.8	-.1
Relaxed Arm G	26.2	31.0	35.6	-.6	1.2	3.0
Flexed Arm G	29.5	33.2	38.0	-.5	1.1	3.1
Forearm G	25.5	27.8	31.0	-.4	1.1	3.2
Wrist G	15.6	16.9	19.6	-1.8	.0	3.4
Chest G	91.6	100.1	115.1	.2	1.7	4.2
Waist G	78.8	90.4	107.9	1.0	3.4	7.2
Gluteal G	90.3	99.6	111.0	-1.3	.2	2.2
Thigh G	49.0	56.1	62.9	-2.0	-.5	1.1
Calf G	32.9	37.0	41.6	-1.6	.1	2.1
Ankle G	18.5	22.2	26.3	-3.0	-.3	2.8
Humerus B	6.4	7.2	8.1	-.8	1.3	3.7
Femur B	8.7	9.9	11.1	-2.3	.0	2.3
Cor. Relaxed Arm G	24.2	27.9	31.2	.7	2.4	4.0
Cor. Chest G	86.4	95.4	107.3	.5	1.9	4.1
Cor. Thigh G	44.0	52.0	58.2	-1.1	.6	2.2
Cor. Calf G	30.2	34.4	38.6	-.6	1.5	3.6

MALES 60 - 64.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	61.2	77.5	95.5	-.9	.5	2.8
Height (cm)	165.1	176.9	187.8	.0	.0	.0
Triceps SF (mm)	5.2	10.0	17.4	-2.3	-1.3	.5
Subscapular SF	8.5	16.2	28.7	-1.7	-.3	2.1
Biceps Sf	3.3	6.0	11.7	-2.3	-1.1	1.7
Iliac Crest SF	11.6	19.3	37.6	-1.5	-.4	2.0
Supraspinale SF	5.9	12.2	26.6	-2.1	-.8	2.3
Abdominal SF	10.1	23.3	45.7	-1.9	-.3	2.5
Front Thigh SF	6.2	12.5	23.1	-2.4	-1.8	-.6
Medial Calf SF	3.7	7.4	16.0	-2.6	-1.8	-.2
Relaxed Arm G	25.1	30.3	34.6	-.7	1.0	3.0
Flexed Arm G	28.5	32.7	38.0	-.6	.9	3.2
Forearm G	25.2	27.5	30.4	-.3	.9	3.2
Wrist G	15.7	16.8	19.3	-1.9	.0	3.0
Chest G	90.7	99.1	113.2	.2	1.7	4.2
Waist G	77.7	90.5	105.9	1.2	3.4	7.1
Gluteal G	88.8	98.9	108.1	-1.2	.1	1.9
Thigh G	47.6	55.3	60.2	-2.1	-.7	.9
Calf G	31.5	36.5	40.7	-1.9	.0	1.9
Ankle G	18.0	22.0	26.0	-3.1	-.4	2.5
Humerus B	6.4	7.2	8.1	-.6	1.4	3.7
Femur B	8.7	9.8	10.8	-2.4	.0	2.2
Cor. Relaxed Arm G	23.6	27.4	30.5	.6	2.1	3.9
Cor. Chest G	85.6	95.0	106.4	.4	1.9	3.7
Cor. Thigh G	43.0	51.2	55.9	-1.3	.4	1.9
Cor. Calf G	29.5	33.8	38.6	-.9	1.3	3.7

MALES 65 - 69.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	60.9	75.0	94.1	-1.1	.4	2.2
Height (cm)	166.8	175.9	187.2	.0	.0	.0
Triceps SF (mm)	5.5	9.2	16.0	-2.2	-1.4	.0
Subscapular SF	7.4	16.0	27.3	-2.0	-.3	1.9
Biceps Sf	3.0	5.5	9.8	-2.5	-1.3	.9
Iliac Crest SF	11.0	19.3	34.2	-1.7	-.4	1.5
Supraspinale SF	5.3	13.4	26.4	-2.2	-.5	2.5
Abdominal SF	9.0	23.7	44.3	-2.0	-.3	2.3
Front Thigh SF	5.9	11.7	19.5	-2.4	-1.8	-.9
Medial Calf SF	3.6	7.0	13.0	-2.7	-1.9	-.6
Relaxed Arm G	24.2	29.4	33.1	-1.5	.7	2.1
Flexed Arm G	27.0	31.8	36.0	-1.3	.6	2.5
Forearm G	24.8	26.9	30.0	-1.0	.7	2.6
Wrist G	15.2	16.6	19.4	-2.6	-.2	2.9
Chest G	89.4	98.1	111.1	-.4	1.6	3.5
Waist G	77.9	90.1	105.0	1.0	3.5	6.9
Gluteal G	88.6	98.2	107.8	-1.5	.0	1.6
Thigh G	47.4	54.0	59.2	-2.3	-.9	.2
Calf G	32.4	35.7	40.5	-1.8	-.2	1.7
Ankle G	18.0	21.6	25.7	-3.3	-.5	2.1
Humerus B	6.2	7.1	8.2	-1.3	1.3	4.5
Femur B	8.2	9.8	10.7	-2.7	-.2	1.9
Cor. Relaxed Arm G	22.5	26.6	29.4	-.1	1.8	3.5
Cor. Chest G	85.9	93.8	105.1	.1	1.7	3.3
Cor. Thigh G	43.0	50.4	55.3	-1.4	.2	1.6
Cor. Calf G	30.2	33.6	37.7	-.7	1.1	3.3

FEMALES 20 - 24.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	47.5	58.2	74.3	-1.3	-.1	2.0
Height (cm)	154.2	165.5	176.4	.0	.0	.0
Triceps SF (mm)	8.4	15.3	27.0	-1.5	.1	2.9
Subscapular SF	7.2	12.2	25.4	-1.9	-.9	1.9
Biceps Sf	3.8	7.3	15.2	-2.0	-.2	3.9
Iliac Crest SF	6.8	11.4	26.0	-2.2	-1.4	.6
Supraspinale SF	5.5	11.0	24.2	-2.1	-.8	2.3
Abdominal SF	6.8	15.5	32.7	-2.3	-1.1	1.2
Front Thigh SF	11.0	22.4	39.2	-1.8	-.4	1.7
Medial Calf SF	7.6	15.2	28.0	-1.7	.0	2.7
Relaxed Arm G	22.2	26.7	31.5	-1.8	.3	2.6
Flexed Arm G	23.5	27.1	32.0	-2.3	-.6	1.6
Forearm G	21.3	23.3	26.5	-2.3	-.8	1.4
Wrist G	13.6	14.5	16.3	-3.3	-1.9	.8
Chest G	78.4	83.8	96.0	-1.5	-.1	2.5
Waist G	61.0	67.9	81.7	-2.0	-.4	2.9
Gluteal G	84.8	93.7	106.2	-1.1	.3	2.6
Thigh G	47.8	55.9	63.8	-1.4	.3	2.4
Calf G	30.6	34.8	39.7	-1.5	.3	2.6
Ankle G	18.5	20.8	23.9	-2.1	-.2	2.4
Humerus B	5.3	6.0	6.8	-2.8	-.6	1.5
Femur B	7.9	8.9	10.0	-2.8	-.7	1.9
Cor. Relaxed Arm G	18.3	22.0	25.4	-1.6	.2	2.1
Cor. Chest G	75.4	80.6	88.7	-1.1	.2	1.9
Cor. Thigh G	40.6	48.6	55.1	-1.2	.7	2.5
Cor. Calf G	25.7	29.9	34.5	-1.8	.3	2.7

FEMALES 25 - 29.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	46.5	57.8	75.0	-1.3	-.1	2.2
Height (cm)	154.5	165.3	176.9	.0	.0	.0
Triceps SF (mm)	8.7	15.6	27.0	-1.4	.2	2.8
Subscapular SF	7.4	13.0	26.0	-1.9	-.7	2.0
Biceps Sf	3.8	7.4	17.0	-2.0	-.1	4.6
Iliac Crest SF	6.5	11.5	27.0	-2.2	-1.4	.9
Supraspinale SF	5.3	11.2	25.0	-2.2	-.8	2.4
Abdominal SF	7.2	16.2	34.1	-2.3	-1.0	1.2
Front Thigh SF	10.9	22.4	38.5	-1.9	-.4	1.6
Medial Calf SF	7.0	15.0	27.2	-1.8	-.1	2.6
Relaxed Arm G	22.5	26.8	32.1	-1.7	.4	2.7
Flexed Arm G	23.4	27.2	33.0	-2.2	-.5	1.9
Forearm G	21.3	23.3	26.5	-2.2	-.8	1.7
Wrist G	13.6	14.6	16.5	-3.2	-1.8	1.0
Chest G	78.2	84.0	97.0	-1.4	.0	2.6
Waist G	61.0	68.3	83.3	-1.9	-.3	3.5
Gluteal G	84.4	93.5	106.3	-1.1	.3	2.7
Thigh G	47.7	55.6	64.1	-1.4	.3	2.4
Calf G	30.5	34.5	39.5	-1.6	.2	2.4
Ankle G	18.5	20.7	23.7	-2.0	-.3	2.3
Humerus B	5.3	6.1	6.8	-2.9	-.6	1.6
Femur B	7.9	8.9	10.2	-3.0	-.7	2.2
Cor. Relaxed Arm G	18.5	22.1	25.6	-1.5	.3	2.2
Cor. Chest G	75.2	80.6	89.1	-1.1	.2	2.2
Cor. Thigh G	40.2	48.5	55.3	-1.3	.6	2.5
Cor. Calf G	25.6	29.7	34.3	-1.8	.2	2.6

FEMALES 30 - 34.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	46.8	58.2	77.3	-1.3	-.1	2.5
Height (cm)	153.9	165.3	175.6	.0	.0	.0
Triceps SF (mm)	8.9	16.2	27.6	-1.3	.3	3.0
Subscapular SF	7.0	13.0	26.3	-1.9	-.7	2.0
Biceps Sf	3.7	7.7	17.0	-2.1	.0	4.6
Iliac Crest SF	6.2	11.5	28.8	-2.3	-1.4	1.0
Supraspinale SF	5.0	11.4	26.8	-2.3	-.8	2.8
Abdominal SF	7.2	16.8	36.8	-2.3	-1.0	1.6
Front Thigh SF	11.0	22.4	39.3	-1.8	-.4	1.6
Medial Calf SF	6.0	15.2	28.0	-2.0	.0	2.8
Relaxed Arm G	22.7	27.0	32.6	-1.6	.4	3.0
Flexed Arm G	24.0	27.5	33.0	-2.0	-.4	2.3
Forearm G	21.3	23.4	26.8	-2.1	-.7	1.8
Wrist G	13.7	14.6	16.7	-3.1	-1.7	1.3
Chest G	78.5	84.2	98.7	-1.5	.0	2.9
Waist G	61.6	69.1	85.2	-1.8	-.1	3.9
Gluteal G	84.5	93.9	107.9	-1.1	.4	3.1
Thigh G	47.9	55.8	64.8	-1.2	.3	2.7
Calf G	30.5	34.5	39.7	-1.6	.2	2.7
Ankle G	18.5	20.7	24.1	-2.0	-.3	2.6
Humerus B	5.3	6.1	6.9	-2.6	-.5	1.7
Femur B	7.9	8.9	10.2	-3.0	-.6	2.2
Cor. Relaxed Arm G	18.7	22.1	25.8	-1.3	.3	2.6
Cor. Chest G	75.3	80.8	89.5	-1.0	.2	2.4
Cor. Thigh G	40.5	48.6	55.8	-1.2	.7	2.8
Cor. Calf G	25.3	29.8	34.6	-2.0	.3	2.8

FEMALES 35 - 39.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	48.1	58.7	79.6	-1.2	.1	2.6
Height (cm)	154.0	164.5	175.8	.0	.0	.0
Triceps SF (mm)	8.4	16.4	28.0	-1.5	.4	3.1
Subscapular SF	7.2	13.2	28.8	-1.9	-.6	2.6
Biceps Sf	3.8	8.2	17.1	-1.9	.3	4.9
Iliac Crest SF	5.9	11.5	31.1	-2.3	-1.4	1.4
Supraspinale SF	5.0	11.8	29.8	-2.3	-.6	3.5
Abdominal SF	7.1	17.6	39.3	-2.3	-.9	2.0
Front Thigh SF	10.8	23.1	40.4	-1.9	-.3	1.8
Medial Calf SF	7.3	15.8	27.8	-1.8	.1	2.8
Relaxed Arm G	22.9	27.4	33.5	-1.6	.6	3.3
Flexed Arm G	24.2	27.8	34.0	-2.0	-.2	2.4
Forearm G	21.6	23.5	27.3	-2.0	-.5	2.0
Wrist G	13.7	14.7	16.9	-3.0	-1.5	1.8
Chest G	79.0	84.4	100.7	-1.4	.2	3.1
Waist G	62.3	69.9	88.3	-1.7	.2	4.6
Gluteal G	85.5	94.3	108.9	-1.0	.6	3.2
Thigh G	48.8	56.0	65.3	-1.1	.4	2.6
Calf G	30.6	34.6	40.0	-1.4	.4	2.5
Ankle G	18.5	20.7	24.1	-2.1	-.2	2.6
Humerus B	5.4	6.1	6.9	-2.4	-.4	1.9
Femur B	8.0	9.0	10.1	-2.6	-.5	2.2
Cor. Relaxed Arm G	19.0	22.4	26.5	-1.3	.6	2.9
Cor. Chest G	75.9	81.1	90.8	-1.0	.4	2.5
Cor. Thigh G	40.4	48.8	56.2	-1.3	.8	2.9
Cor. Calf G	25.9	29.8	34.0	-1.8	.3	2.6

FEMALES 40 - 44.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	49.1	60.8	81.6	-1.1	.2	3.1
Height (cm)	154.2	165.3	176.8	.0	.0	.0
Triceps SF (mm)	9.4	17.2	29.0	-1.2	.6	3.3
Subscapular SF	7.5	14.3	29.5	-1.8	-.4	2.8
Biceps Sf	4.0	8.8	19.5	-1.8	.7	6.3
Iliac Crest SF	6.0	12.8	31.1	-2.3	-1.3	1.5
Supraspinale SF	5.2	13.2	29.9	-2.2	-.3	3.6
Abdominal SF	7.8	19.5	42.4	-2.2	-.6	2.3
Front Thigh SF	11.2	23.9	42.7	-1.9	-.2	2.2
Medial Calf SF	7.0	15.9	28.8	-1.8	.1	3.1
Relaxed Arm G	23.2	27.9	34.5	-1.3	.8	3.5
Flexed Arm G	24.5	28.3	35.0	-1.7	.0	2.7
Forearm G	21.8	23.9	27.6	-1.9	-.4	2.5
Wrist G	14.0	14.8	17.3	-2.8	-1.3	2.0
Chest G	79.5	85.5	101.7	-1.2	.3	3.5
Waist G	63.4	71.7	90.1	-1.3	.5	4.8
Gluteal G	86.2	95.8	110.6	-.9	.7	3.4
Thigh G	48.5	56.7	67.0	-1.3	.5	2.9
Calf G	30.2	35.0	40.0	-1.6	.3	2.8
Ankle G	18.4	20.9	24.3	-2.3	-.1	2.7
Humerus B	5.5	6.2	7.0	-2.3	-.1	2.5
Femur B	7.8	9.0	10.5	-2.8	-.5	2.4
Cor. Relaxed Arm G	18.9	22.5	27.0	-1.4	.6	3.2
Cor. Chest G	76.2	82.0	92.6	-1.0	.4	2.6
Cor. Thigh G	39.9	49.1	57.2	-1.3	.8	3.0
Cor. Calf G	25.4	29.8	34.5	-1.8	.3	2.7

FEMALES 45 - 49.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	49.5	62.3	83.6	-1.0	.4	3.3
Height (cm)	153.9	164.3	175.6	.0	.0	.0
Triceps SF (mm)	9.2	18.2	31.0	-1.3	.8	3.9
Subscapular SF	8.0	15.1	30.1	-1.8	-.2	2.8
Biceps Sf	4.5	9.6	18.0	-1.6	1.0	5.6
Iliac Crest SF	6.4	13.2	31.5	-2.2	-1.2	1.6
Supraspinale SF	5.6	14.2	29.9	-2.1	.0	3.6
Abdominal SF	8.5	21.2	42.9	-2.2	-.3	2.5
Front Thigh SF	11.2	24.9	43.6	-1.8	-.1	2.4
Medial Calf SF	6.0	16.6	29.9	-2.0	.3	3.0
Relaxed Arm G	23.4	28.5	34.5	-1.0	1.1	3.7
Flexed Arm G	25.0	29.0	35.1	-1.5	.3	2.9
Forearm G	22.0	24.2	28.1	-1.7	-.1	2.9
Wrist G	14.1	14.9	17.2	-2.5	-1.0	2.3
Chest G	80.2	86.4	102.8	-1.0	.5	3.8
Waist G	65.0	73.4	92.0	-1.0	.9	5.7
Gluteal G	86.8	96.6	112.9	-.7	.9	4.1
Thigh G	48.7	57.3	68.2	-1.1	.6	3.4
Calf G	30.9	35.0	41.0	-1.4	.4	3.2
Ankle G	18.6	20.9	24.9	-1.9	.0	3.1
Humerus B	5.5	6.3	7.1	-2.2	.1	2.6
Femur B	7.8	9.0	10.4	-2.9	-.3	2.8
Cor. Relaxed Arm G	19.1	22.9	27.2	-1.1	.7	3.2
Cor. Chest G	76.3	82.5	92.9	-.7	.6	2.8
Cor. Thigh G	40.6	49.0	57.7	-1.1	.8	3.3
Cor. Calf G	25.8	29.6	34.9	-1.6	.3	3.1

FEMALES 50 - 54.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	49.4	61.8	82.8	-1.0	.5	3.3
Height (cm)	153.9	164.1	175.6	.0	.0	.0
Triceps SF (mm)	9.3	18.8	32.0	-1.2	1.0	4.0
Subscapular SF	8.0	16.6	29.3	-1.7	.1	2.8
Biceps Sf	4.4	10.0	19.4	-1.7	1.2	6.1
Iliac Crest SF	6.1	14.3	30.2	-2.3	-1.0	1.5
Supraspinale SF	5.9	15.8	31.7	-2.0	.3	4.0
Abdominal SF	9.1	23.0	45.0	-2.1	-.1	2.8
Front Thigh SF	12.2	25.2	42.8	-1.7	-.1	2.3
Medial Calf SF	7.2	16.0	28.7	-1.8	.2	3.0
Relaxed Arm G	23.7	28.6	34.7	-1.3	1.2	4.0
Flexed Arm G	25.0	29.0	35.1	-1.6	.4	3.3
Forearm G	22.0	24.1	27.9	-1.7	-.1	2.7
Wrist G	14.0	14.9	17.2	-2.6	-.9	2.6
Chest G	79.8	87.0	101.8	-1.2	.6	3.9
Waist G	65.1	74.5	92.9	-1.1	1.3	5.7
Gluteal G	86.3	96.8	112.7	-.8	1.0	4.0
Thigh G	48.5	57.0	66.8	-1.2	.7	3.3
Calf G	30.5	34.5	40.0	-1.6	.3	2.9
Ankle G	18.5	20.8	24.6	-2.0	.0	2.8
Humerus B	5.4	6.3	7.2	-2.4	.2	2.9
Femur B	8.0	9.0	10.4	-2.6	-.3	2.7
Cor. Relaxed Arm G	18.7	22.9	26.5	-1.4	.8	3.1
Cor. Chest G	76.6	82.5	92.5	-.9	.7	3.0
Cor. Thigh G	40.0	49.0	56.2	-1.2	.9	3.1
Cor. Calf G	25.5	29.3	34.1	-1.6	.2	2.8

FEMALES 55 - 59.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	47.7	62.3	81.9	-1.0	.6	3.7
Height (cm)	151.8	164.0	174.5	.0	.0	.0
Triceps SF (mm)	8.8	19.2	30.6	-1.4	1.1	3.8
Subscapular SF	8.0	15.9	30.9	-1.7	.0	3.0
Biceps Sf	5.0	10.4	19.0	-1.5	1.5	6.1
Iliac Crest SF	6.1	14.5	31.1	-2.3	-.9	1.6
Supraspinale SF	6.3	16.8	31.2	-1.9	.5	3.9
Abdominal SF	9.1	24.8	45.7	-2.0	.2	3.0
Front Thigh SF	12.3	25.0	41.9	-1.7	-.1	2.1
Medial Calf SF	6.1	16.0	28.4	-2.0	.2	2.8
Relaxed Arm G	23.5	28.8	35.0	-1.1	1.4	4.1
Flexed Arm G	25.1	29.4	35.8	-1.3	.4	3.4
Forearm G	21.9	24.2	27.8	-1.5	.1	3.2
Wrist G	14.1	15.0	17.5	-2.2	-.6	2.3
Chest G	79.3	87.1	102.3	-.8	.7	3.9
Waist G	65.1	75.7	92.2	-.9	1.5	5.7
Gluteal G	85.6	97.1	112.3	-.8	1.1	4.0
Thigh G	47.5	57.2	66.8	-1.3	.7	3.4
Calf G	30.0	34.8	40.1	-1.5	.4	2.9
Ankle G	18.2	20.9	24.4	-2.0	.0	3.0
Humerus B	5.4	6.3	7.2	-2.1	.3	3.0
Femur B	7.8	9.0	10.5	-2.7	-.1	3.1
Cor. Relaxed Arm G	19.1	22.8	27.3	-1.1	.8	3.3
Cor. Chest G	76.1	82.6	93.0	-.6	.8	3.3
Cor. Thigh G	39.6	49.2	56.6	-1.3	.9	3.3
Cor. Calf G	25.5	29.5	35.2	-1.8	.2	3.5

FEMALES 60 - 64.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	48.4	62.7	82.5	-.8	.7	3.6
Height (cm)	153.4	162.5	174.3	.0	.0	.0
Triceps SF (mm)	9.0	18.6	29.5	-1.2	1.0	3.7
Subscapular SF	8.0	16.8	32.8	-1.7	.1	3.5
Biceps Sf	4.5	10.0	19.7	-1.5	1.3	6.2
Iliac Crest SF	5.7	15.5	31.4	-2.4	-.8	1.7
Supraspinale SF	6.3	18.0	33.1	-1.9	.8	4.5
Abdominal SF	10.3	26.3	45.5	-1.9	.4	3.2
Front Thigh SF	11.0	24.6	41.7	-1.7	-.2	2.3
Medial Calf SF	5.8	15.0	25.6	-2.1	-.1	2.5
Relaxed Arm G	22.9	28.6	34.7	-1.0	1.2	4.2
Flexed Arm G	24.8	29.0	35.1	-1.5	.4	3.4
Forearm G	21.6	24.1	27.6	-1.6	.1	2.9
Wrist G	14.2	15.1	17.7	-2.4	-.6	2.9
Chest G	79.1	87.3	101.9	-1.0	.8	3.8
Waist G	65.2	76.7	93.0	-.7	1.8	5.8
Gluteal G	85.4	97.7	112.2	-.6	1.2	4.2
Thigh G	47.0	57.1	66.3	-1.1	.7	3.3
Calf G	29.8	34.1	39.1	-1.7	.3	2.9
Ankle G	18.0	20.8	24.1	-2.0	.0	3.0
Humerus B	5.3	6.4	7.3	-2.7	.5	2.7
Femur B	7.6	9.1	10.5	-2.9	.1	3.3
Cor. Relaxed Arm G	18.8	22.9	27.5	-1.4	.9	3.5
Cor. Chest G	76.1	82.4	92.5	-.7	.8	3.1
Cor. Thigh G	40.4	49.0	58.3	-1.2	1.0	3.5
Cor. Calf G	25.3	29.2	34.6	-1.7	.2	3.3

FEMALES 65 - 69.999 YEARS

	P4	P50	P96	Z4	Z50	Z96
Weight (kg)	48.4	61.4	79.6	-1.3	1.1	3.8
Height (cm)	151.4	160.8	176.6	.0	.0	.0
Triceps SF (mm)	10.9	19.8	30.5	-.8	1.3	3.5
Subscapular SF	7.9	17.1	29.2	-1.7	.3	2.7
Biceps Sf	3.8	9.3	19.8	-1.9	.9	5.8
Iliac Crest SF	5.2	13.9	28.6	-2.4	-.9	1.2
Supraspinale SF	5.8	15.7	28.4	-2.0	.3	3.4
Abdominal SF	10.8	24.9	39.0	-1.9	.3	2.2
Front Thigh SF	9.7	25.2	38.1	-2.0	.1	1.6
Medial Calf SF	6.1	16.3	28.3	-2.0	.3	3.0
Relaxed Arm G	23.1	28.7	34.0	-.8	1.5	4.0
Flexed Arm G	24.5	29.5	35.2	-1.1	.6	3.6
Forearm G	21.9	24.3	27.2	-1.8	.3	3.1
Wrist G	14.2	15.3	17.0	-2.0	-.3	3.3
Chest G	78.9	87.0	100.0	-1.2	1.1	3.6
Waist G	64.4	75.1	90.3	-.9	1.8	4.9
Gluteal G	85.3	96.6	108.7	-1.2	1.5	3.7
Thigh G	47.5	56.8	64.0	-1.6	1.1	2.4
Calf G	29.0	34.2	38.4	-1.9	.5	2.5
Ankle G	18.1	20.9	23.3	-2.4	.3	2.5
Humerus B	5.5	6.4	7.1	-2.0	.7	3.5
Femur B	7.3	9.1	10.5	-3.3	.1	3.8
Cor. Relaxed Arm G	18.7	22.9	28.3	-1.1	.9	4.5
Cor. Chest G	75.9	82.1	91.0	-.8	1.0	3.4
Cor. Thigh G	40.4	48.4	56.0	-1.8	1.0	2.9
Cor. Calf G	24.6	29.4	34.5	-2.0	.3	3.0

APPENDIX 3: PREDICTOR MULTIPLE REGRESSION EQUATIONS

Prediction of Stretch Stature

Using the Mexico City Olympic games data set (de Garay, 1974) multiple regression analysis was carried out to predict stretch stature from all other anthropometric variables. Equations were produced for both males and females. In each analysis free standing stature was the first selected variable with no other variable being able to significantly reduce the error variance. The resultant equations for the prediction of stretch stature were therefore merely simple linear regressions based on free standing stature. The equations were:

MALES

Stretch Stature = 1.01(Free Standing Stature) + 0.074

r = 0.994   S.E.E. = 1.00 cm

FEMALES

Stretch Stature = 1.01(Free Standing Stature) + 0.345

r = 0.993   S.E.E. = 0.98 cm

PREDICTOR multiple regression equations

The following are the multiple regression equations produced on the entire PREDICTOR data set, as used in Chapter BI.

TABLE AP5.4: PREDICTOR regression equations for female "UNKNOWN" variables.

```
ILSF = (0.55*SISF)+(0.137*WT)+(0.254*SSSF)-(0.046*AGE)-4.24
       r = 0.87      S.E.E. = 2.57mm

ABSF = (0.98*SISF)+(0.075*AGE)+(0.396*TPSF)-(0.253*MCSF)+0.83
       r = 0.86      S.E.E. = 4.13mm

THSF = (0.0656*TPSF)+(0.537*MCSF)+(0.64*CAG)-(0.149*HT)+6.54
       r = 0.81      S.E.E. = 4.33mm

AGR  = (0.91*AGF)-(1.016*HUM)+(0.078*BISF)+(0.031*WT)+5.73
       r = 0.97      S.E.E. = 0.59cm

FAG  = (0.047*WT)+(0.247*AGF)+(0.151*CAG)+(0.804*HUM)+3.73
       r = 0.91      S.E.E. = 0.64cm

WRG  = (0.92*HUM)+(0.008*AGE)+(0.035*WT)+6.77
       r = 0.78      S.E.E. = 0.52cm

CHG  = (0.267*WT)+(0.236*SSSF)+(0.59*AGF)+50.08
       r = 0.83      S.E.E. = 2.74cm

WAG  = (0.327*WT)+(0.411*SISF)+(0.082*AGE)+(0.537*AGF)+27.84
       r = 0.87      S.E.E. = 3.45cm

GLG  = (0.514*CAG)+(0.022*AGE)+(0.131*SISF)+(0.529*WT)+43.05
       r = 0.88      S.E.E. = 3.09cm

THG  = (0.355*WT)+(0.45*CAG)+(0.303*AGF)-(2.56*HUM)+26.23
       r = 0.85      S.E.E. = 2.28cm

ANG  = (0.24*CAG)+(0.016*MCSF)-(0.0018*AGE)+(0.048*WT)+9.39
       r = 0.72      S.E.E. = 0.86cm
```

TABLE AP5.4: PREDICTOR regression equations for female "KNOWN" variables.

```
TPSF = (0.66*BISF)+(0.27*MCSF)+(0.06*AGE)+(0.177*SISF)+3.97
       r = 0.83      S.E.E. = 2.90mm

SSSF = (0.636*SISF)-(4*FEM)+(0.15*WT)+32.09
       r = 0.79      S.E.E. = 3.12mm

BISF = (0.22*SISF)+(0.183*TPSF)+(0.28*AGF)-6.21
       r = 0.83      S.E.E. = 1.68mm

SISF = (0.61*SSSF)+(0.23*TPSF)+(0.25*MCSF)+(0.048*AGE)-4.87
       r = 0.88      S.E.E. = 2.68mm

MCSF = (0.42*TPSF)+(0.60*CAG)+(0.21*SISF)-16.30
       r = 0.70      S.E.E. = 3.63mm

AGF  = (0.12*WT)+(0.27*BISF)+(0.029*AGE)+(0.23*CAG)+10.05
       r = 0.84      S.E.E. = 1.73cm

CAG  = (0.166*WT)-(0.04*AGE)+(1.55*FEM)-(0.057*HT)+22.1
       r = 0.75      S.E.E. = 1.47cm
```

TABLE AP5.3: PREDICTOR regression equations for male "UNKNOWN" variables.

```
ILSF = (0.583*SISF)+(0.062*AGE)+(0.155*WT)+(0.729TPSF)-10.8
       r = 0.82          S.E.E. = 5.29mm

ABSF = (1.035*SISF)+(0.608*TPSF)+(0.092AGE)+(0.146*WT)-12.72
       r = 0.88          S.E.E. = 5.48mm

THSF = (0.776*MCSF)+(0.54*TPSF)+1.07
       r = 0.84          S.E.E. = 3.20mm

AGR  = (0.638*AGF)+(0.145*TPSF)-(0.025*AGE)+(0.0707*WT)+3.99
       r = 0.94          S.E.E. = 1.09cm

FAG  = (0.252*AGF)+(0.064*WT)+(1.066*HUM)-(0.017*AGE)+7.60
       r = 0.92          S.E.E. = 0.78cm

WRG  = (0.0234*WT)+(0.563*FEM)+(0.633*HUM)+(0.05*AGF)+3.4
       r = 0.85          S.E.E. = 0.51cm

CHG  = (0.558*WT)-0.565*CAG)+(0.356*AGF)+65.86
       r = 0.86          S.E.E. = 3.55cm

WAG  = (0.495*WT)+(0.315*SSSF)+(0.153*AGE)+(0.25*SISF)+34.0
       r = 0.91          S.E.E. = 3.71cm

GLG  = (0.022*CAG)+(0.177*SISF)-(0.012*AGE)+(0.464*WT)+60.53
       r = 0.88          S.E.E. = 3.05cm

THG = (0.33 *WT)-(0.091*AGE)+(0.227*MCSF)-2.067*HUM)+47.8
       r = 0.90          S.E.E. = 2.06cm

ANG = (0.494*CAG)+(0.783*HUM)-1.74
       r = 0.75          S.E.E. = 1.21cm
```

TABLE AP5.4: PREDICTOR regression equations for male "KNOWN" variables.

```
TPSF = (0.59*MCSF)+(0.24*SSSF)+(0.17*SISF)+0.86
       r = 0.87          S.E.E. = 2.27mm

SSSF = (0.41*SISF)+(0.093*AGE)+(0.32PSF)+()>)&(*WT)-4.19
       r = 0.86           S.E.E. = 2.77mm

BISF = (0.15*SISF)+(0.18*TPSF)+1.66
       r = 0.60            S.E.E. = 2.20mm

SISF = (0.553*SSSF)+(0.462*TPSF)+(0.35*AGF)-14.1
       r = 0.84             S.E.E. = 3.42mm

MCSF = 0.588*TPSF)+(0.19*AGF)-4.30
       r = 0.79             S.E.E. = 2.22mm

AGF  = (0.23*WT)-(0.077*AGE)-(0.12*HT)+39.7
       r = 0.81             S.E.E. = 1.83cm

CAG  = 0.153*WT)(1.13*EM)-(0.032*AGE)-(0.18AGF)+21.7
       r = 0.76           S.E.E. = 1.59cm
```

APPENDIX 4: ANTHROPOMETRIC DATA FOR CASE STUDY PROFILES

BALANCED PHYSIQUES

ID						
Sex	M	M	M	F	F	F
Age	24.56	24.90	31.94	20.36	20.52	26.90
Weight	84.9	82.2	85.3	57.9	74.3	51.5
Height	186.0	184.4	183.5	165.1	171.9	165.3
SKINFOLDS						
Triceps	12.1	8.6	13.1	13.5	18.1	13.0
Subscapular	11.1	8.8	12.3	11.7	21.6	10.1
Biceps	5.2	4.0	3.2	9.0	12.6	3.6
Iliac Crest	13.8	14.5	14.6	11.0	21.8	7.4
Supraspinale	5.6	7.4	6.2	11.6	17.6	7.3
Abdominal	11.9	22.7	26.0	12.4	17.2	10.5
Front Thigh	15.4	14.5	12.3	28.4	33.1	19.6
Medial Calf	9.1	8.0	8.1	18.6	23.7	11.5
GIRTHS						
Arm Relaxed	32.6	30.9	31.8	27.4	29.6	24.0
Arm Flexed	34.8	33.8	33.7	27.5	30.1	25.2
Forearm	30.0	28.7	29.2	23.5	26.8	22.3
Wrist	17.6	17.2	16.9	15.1	17.0	14.2
Chest	100.0	100.5	100.2	84.1	92.2	82.3
Waist	84.1	85.2	84.6	65.4	78.6	64.5
Gluteal	100.8	101.0	104.2	96.8	100.7	89.8
Thigh	60.6	60.1	63.1	57.5	57.1	52.6
Calf	42.2	36.9	39.2	33.9	37.4	32.5
Ankle	24.5	22.2	23.4	20.9	24.0	20.6
BREADTHS						
Humerus	7.45	7.27	6.51	6.54	6.42	5.90
Femur	10.11	9.82	9.84	9.23	9.22	8.53

WEIGHT DOMINANT PHYSIQUES

ID	A	B	C	D	E	F
Sex	M	M	M	F	F	F
Age	20.21	22.41	23.48	20.64	23.14	27.30
Weight	82.7	90.3	66.2	54.9	51.3	70.2
Height	185.3	184.5	170.4	162.4	154.3	172.9
SKINFOLDS						
Triceps	8.7	6.7	6.0	13.3	12.0	10.8
Subscapular	7.8	8.7	8.7	10.3	8.7	10.1
Biceps	3.5	3.9	3.0	3.8	5.3	5.0
Iliac Crest	11.7	9.8	10.8	6.2	8.5	10.0
Supraspinale	5.5	4.7	6.6	5.4	10.9	7.0
Abdominal	8.3	8.1	8.6	8.7	14.5	8.5
Front Thigh	9.8	10.3	9.2	12.9	17.6	26.5
Medial Calf	7.3	5.8	4.4	10.2	9.7	12.6
GIRTHS						
Arm Relaxed	33.1	36.0	30.8	23.9	27.0	28.1
Arm Flexed	36.2	39.1	32.6	25.4	27.8	28.7
Forearm	29.2	31.9	27.3	23.1	23.5	25.1
Wrist	18.3	18.1	16.4	15.1	14.2	15.1
Chest	100.2	106.6	96.4	83.4	83.8	93.7
Waist	81.5	82.6	78.0	66.8	64.2	73.8
Gluteal	100.8	103.1	92.9	89.3	89.4	102.6
Thigh	61.0	61.6	52.7	52.9	53.1	62.9
Calf	38.1	39.8	35.8	35.6	36.6	38.0
Ankle	24.0	24.2	21.1	21.4	20.5	21.9
BREADTHS						
Humerus	7.62	7.68	6.97	6.35	6.00	6.65
Femur	10.19	10.85	9.38	9.02	8.62	9.61

ADIPOSITY DOMINANT PHYSIQUES

ID	A	B	C	D	E	F
Sex	M	M	M	F	F	F
Age	22.65	20.53	22.84	27.55	22.63	21.67
Weight	69.0	64.7	82.9	45.1	58.4	54.0
Height	173.9	173.9	188.3	156.9	164.8	171.2
SKINFOLDS						
Triceps	17.9	13.9	14.7	15.5	25.9	13.1
Subscapular	12.8	11.0	10.3	9.2	15.8	13.5
Biceps	5.1	6.0	7.0	4.2	9.5	7.0
Iliac Crest	23.0	16.0	21.0	7.8	17.0	13.5
Supraspinale	13.5	10.0	18.2	9.9	17.4	13.0
Abdominal	29.0	17.3	28.7	23.3	22.9	18.9
Front Thigh	14.9	14.5	10.6	27.3	31.0	18.9
Medial Calf	7.4	15.1	8.5	14.1	30.3	15.1
GIRTHS						
Arm Relaxed	31.3	29.1	32.5	22.7	26.6	25.4
Arm Flexed	32.8	30.4	34.2	23.2	27.5	25.6
Forearm	26.2	25.6	27.6	21.9	23.0	22.8
Wrist	16.0	16.3	16.4	14.7	13.7	14.4
Chest	97.5	92.3	101.3	79.0	83.6	80.4
Waist	81.6	76.1	82.1	60.6	68.3	63.8
Gluteal	96.5	91.8	99.0	88.4	96.5	87.2
Thigh	56.5	56.7	61.8	46.3	58.7	51.2
Calf	35.2	36.2	37.5	33.0	34.9	35.0
Ankle	21.3	21.1	22.2	21.1	20.0	20.1
BREADTHS						
Humerus						
Femur						

AVERAGE VALUES FOR OLYMPIC ATHLETES

	ROWER	ROWER	CYCLIST	WEIGHTLIFTER
Sex	MALES	FEMALES	MALES	MALES
Age	24.247	23.784	22.952	28.354
Weight	90.0	67.4	69.6	86.9
Height	191.4	174.3	177.1	170.5
SKINFOLDS				
Triceps	8.4	14.6	6.5	7.8
Subscapular	8.7	9.1	7.4	10.6
Biceps	-	-	-	-
Iliac Crest	-	-	-	-
Supraspinale	6.0	6.6	4.9	6.6
Abdominal	9.3	10.6	6.9	11.7
Front Thigh	10.8	21.5	8.2	8.9
Medial Calf	6.3	12.8	5.4	6.7
GIRTHS				
Arm Relaxed	31.7	27.6	27.5	36.0
Arm Flexed	34.9	29.2	30.6	38.6
Forearm	30.3	25.5	27.1	30.8
Wrist	18.5	16.0	16.8	18.7
Chest	103.7	89.6	92.2	106.3
Waist	84.0	70.8	75.5	87.2
Gluteal	-	-	-	-
Thigh	60.2	57.5	55.6	62.6
Calf	39.3	37.0	36.7	39.4
Ankle	-	-	-	-
BREADTHS				
Humerus	7.8	6.7	7.10	7.40
Femur	10.4	9.3	9.80	9.90

OLYMPIC ROWERS

ID	A	B	C	D	E	F
Sex	M	M	M	F	F	F
Age	31.43	24.30	23.19	22.27	26.74	25.12
Weight	91.8	91.7	82.6	65.8	59.4	65.7
Height	194.3	182.0	179.3	172.8	172.4	174.4
SKINFOLDS						
Triceps	6.2	4.9	8.0	15.2	7.3	12.4
Subscapular	7.2	7.4	9.2	10.2	6.1	7.1
Biceps	-	-	-	-	-	-
Iliac Crest	-	-	-	-	-	-
Supraspinale	5.2	4.8	5.8	5.6	4.7	4.8
Abdominal	6.0	7.2	6.8	8.1	6.8	5.4
Front Thigh	8.1	4.9	12.8	17.4	16.7	20.0
Medial Calf	5.3	4.2	6.0	13.2	8.7	10.4
GIRTHS						
Arm Relaxed	30.5	33.9	31.1	27.5	24.2	26.9
Arm Flexed	33.6	37.5	34.6	28.3	26.5	28.6
Forearm	30.7	31.1	28.8	26.0	23.6	24.6
Wrist	18.6	17.6	16.7	16.5	14.7	15.8
Chest	105.7	108.1	101.5	91.2	85.9	89.2
Waist	84.4	85.5	79.4	71.7	68.2	66.8
Gluteal	-	-	-	-	-	-
Thigh	59.9	60.8	60.9	55.7	52.0	55.5
Calf	39.9	41.6	40.0	36.9	35.1	36.7
Ankle	-	-	-	-	-	
BREADTHS						
Humerus	8.10	7.85	7.65	6.90	6.70	6.55
Femur	10.25	10.30	9.95	9.20	9.05	9.05

	OLYMPIC CYCLISTS			OLYMPIC WEIGHTLIFTERS		
ID	A	B	C	A	B	C
Sex	M	M	M	M	M	M
Age	23.65	22.13	20.34	34.91	28.65	29.50
Weight	77.2	71.0	67.6	60.9	78.0	82.9
Height	184.8	175.9	177.0	158.8	160.2	170.8
SKINFOLDS						
Triceps	6.0	8.5	7.7	4.4	6.7	5.2
Subscapular	8.2	7.2	8.1	5.5	9.2	10.8
Biceps	-	-	-	-	-	-
Iliac Crest	-	-	-	-	-	-
Supraspinale	6.2	4.3	4.3	3.8	5.1	6.0
Abdominal	7.4	5.0	6.8	4.6	7.9	7.8
Front Thigh	8.6	9.4	6.5	5.8	7.0	8.4
Medial Calf	4.4	4.8	5.2	4.0	4.0	7.5
GIRTHS						
Arm Relaxed	29.5	27.6	27.6	30.0	33.7	36.9
Arm Flexed	32.0	30.6	30.6	33.0	35.6	40.2
Forearm	28.7	27.2	27.2	26.7	31.1	29.2
Wrist	17.7	16.8	16.3	16.5	19.6	18.8
Chest	95.1	91.5	94.2	93.5	98.6	103.5
Waist	81.1	75.4	75.1	74.5	82.9	89.2
Gluteal	-	-	-	-	-	-
Thigh	57.3	57.3	53.3	54.2	61.0	60.7
Calf	38.3	36.2	35.4	33.0	41.6	39.3
Ankle	-	-	-	-	-	-
BREADTHS						
Humerus	7.10	7.10	7.05	6.25	7.15	7.00
Femur	10.20	9.75	9.95	9.24	9.85	9.65

REFERENCES.

Adams, J., M. Mottola, K.M. Bagnall and K.D. McFadden (1982). Total body fat content in a group of professional football players. An ultrasound-based adiposity assessment system. Unpublished M.Sc. thesis, Simon Fraser University.

Anderson, N.R. (1985). An utrasound-based adiposity assessment system. Unublished M.Sc. thesis, Simon Fraser University.

Bailey, D.A., J.E.L. Carter and R.L. Mirwald (1982). Somatotypes of Canadian men and women. Hum. Biol. 54:813-828.

Bakker, H.K. and R.S. Struikenkamp (1977). Biological variability and lean body mass estimates. Hum. Biol. 53:181-225.

Barkla, D. (1961). The estimation of body measurement of British population in relation to seat design. Ergonomics 4:123-132.

Baumgartner T.A. and A.S. Jackson (1982). Measurement for evaluation in physical education. W.M.C. Brown Company, Iowa. U.S.A. 520-523.

Behnke, A.R., B.G. Feen and W.C. Welham (1942). The specific gravity of healthy men. J.A.M.A. 118:495-498.

Behnke, A.R., O.E. Guttentag and C. Brodsky (1959a). Quantification of body weight and configuration from anthropometric measurements. Human Biol. 31:213-234.

Behnke, A.R. (1959b). The estimation of lean body weight from skeletal measurements. Hum. Biol. 31:295-315.

Behnke, A.R. (1963). Anthropometric evaluation of body composition throughout life. Ann. N. Y. Acad. Science. 110:450-464.

Behnke, A.R. and J.H. Wilmore (1974). Evaluation and regulation of body build and composition. Prentice-Hall Ince, Englewood Cliffs, N.J.

Borms,J., M. Hebbelinck, J. J.E.L. Carter, W.D. Ross, G.Lariviere (1979) Standardization of Basic Anthopometry. In: Novotny and Titlbachova (Eds.) Olympic Athletes - The Mogap Procedure. Methods of Functional Anthropometry. Universitas Carolina Pragensis, Praha, pp 31-39.

Bosze, P. O.G. Eiben, M. Gaal, J. Laszlo (1980). Body measurements of patients with streaked gonads and their bearing on the karyotype. Hum. Genet. 54:355-360.

Boyd, E. (1980). Origins of the study of human growth. University of Oregon Health Center Foundation, Eugene.

Brozek, J. and A. Keys (1951). The evaluation of leanness-fatness in man: norms and interrelationships. Brit. J. Nutr. 5:194-206.

Brozek, J. (1960). The measurement of body composition. In: M.F.A. Montagu, Ed. A handbook of anthropometry. Charles C. Thomas, Publisher, Sprinfield Ill, 78-136.

Brozek, J., F. Grande, J.T. Anderson and A. Keys (1963). Densitometric analysis of body composition: revision of some quantitative assumptions. Ann. N.Y. Acad. Sci. 110:113-140.

Burkinshaw L, P.R.M. Jones and D.W. Krupowicz (1973). Observer Error in Skinfold Thickness Measurements. Hum Biol. 45:273-279

Canada Fitness Survey (1985). Physical fitness of Canadian youth. Fitness Canada, Ottawa.

Carter, J.E.L. (1972). The Heath-Carter Somatotype Method. San Diego State College, California.

Carter, J.E.L. (1982) Body composition of Montreal Olympic athletes. In: J.E.L. Carter (Ed.) Physical structure of Olympic athletes, Part I, The Montreal Olympic Games Anthropological Project. Medicine ans Sport. Karger, Basel, 16:107-116.

Chinn K.S.K. and T.H. Allen (1960). Body fat in men from skinfolds, weight, height and age. U.S. Army Med. Res. Nutr. Lab. Rept. No.248.

Chovanova, E., M. Slamka, L. Pataki (1983). V. Uk. vyuzitie zistovania zlozenia a stavby tela v treningovom procese. Teor. Praxe tel Vych. 31:102-106.

Conant, J.B. (1947) On Understanding Science. New Haven: Yale University Press, p 94.

Costill, D.L., R. Bowers and W.F. Kammer (1970). Skinfold estimates of body fat among marathon runners. Med. Sci. Sports 2:93-95.

Cronk, C.E. and A.F. Roche (1982). Race- and sex-specifici reference data for triceps and subscapular skinfolds and weight/stature. Am. J. Clin. Nutr. 35:347-354.

Damon, A. and R.F. Goldman (1964). Predicting fat from body measurements: densitometric validation of ten anthropometric equations. Hum. Biol. 36:32-44.

Dauncey, M.J., G. Gandy and D. Gardner (1977). Assessment of total body fat in infancy from skinfold thickness measurements. Arch. Dis. Child. 52:223.

de Garay, A.L., L. Levine and J.E.L. Carter (1974). Genetic and anthropological studies of Olympic Athletes. Academic Press, New York.

Dijksterhuis E.J. (1938) Archimedes. I.P. Noordhoff, Groningen.

Dijksterhuis E.J. (1987) Archimedes (trans.). Princeton University Press

Drinkwater, D.T. and W.D. Ross (1980). Anthropometric fractionation of body mass. In: Kinanthropometry II. Ostyn, M., G. Beunen and J.Simons (Eds.), Academic Press, Baltimore, pp.177-188.

Drinkwater, D.T. (1984). An anatomically derived method for the anthropometric estimation of human body composition. Unpublished doctoral dissertation, Simon Fraser University.

Durnin, J.V.G.A. and M.M. Rahaman (1967). The assessment of the amount of fat in the human body from measurements of skinfold thickness. Brit. J. Nutr. 21:681-689.

Durnin, J.V.G.A. and J. Womersley (1969). Skinfold thickness and body fat in middle aged adults. J. Physiol. 200:105–106.

Durnin, J.V.G.A. and J. Womersley (1974). Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16–72 years. Brit. J. Nutr. 32:77–97.

Edwards, D.A.W. (1951). Differences in the distribution of subcutaneous fat with sex and maturity. Clin. Sci. 10:305–315.

Edwards D.A.W., W.H. Hammond, M.J.R. Healy, J.M. Tanner and R.H. Whitehouse (1955). Design and Accuracy of calipers for measuring subcutaneous tissue thickness. Brit. J. Nutr. 9:133–143.

Eiben, O.G., W.D. Ross, W. Christensen and R.A. Faulkner (1976). Proportionality characteristics of female athletes. Anthrop. Kozl. 20:55–67.

Eiben, O.G. (1978). Changes in body measurements and proportion of children, based on Kormend growth study. In: Auxology: Human growth in health and disorder. Proceedings of the Serona Symposia, Volume 13. L. Gedda and P.Parisi (Eds.) Academic Press, London, pp.187–198.

Eiben, O.G. (1980). Recent data on variability in physique: some aspects of proportionality. In: Kinanthropometry II. M. Ostyn, G. Beunen, J. Simons (Eds.) University Park Press, Baltimore, pp.69–77.

Evans, D.J., R.G. Hoffman, R.K. Kalkhoff and A.H. Kissebah (1984). Relationship of body fat topography to insulin sensitivity and metabolic profiles in premenopausal women. Metabolism 33:68.

Faulhaber, J. (1978). Algunos cambios morfologicos durnante el crecimiento. Anales de Antropologia 15:323–340.

Fidanza, F., A. Keys and J.T. Anderson (1953). Density of body fat in man and other animals. J. App. Physiol. 6:252–256.

Fitness and Amateur Sport Canada (1986) Canadian Standardized Test of Fitness (CSTF) operations manual. 3rd ed, Ottawa.

Fletcher, R.F. (1962). The measurement of total body fat with skinfold calipers. Clin. Sci. 22:333.

Flint, M.M., E.L. Drinkwater, C.L. Wells and S.M. Horvath (1977). Validity of estimating body fat of females: effect of age and fitness. Hum. Biol. 49:559–572.

Florey, C.D.V. (1970) The use and misuse of the ponderal index and other weight-height ratios in epidemiological studies. J. Chronic Diseases 23:93–101.

Frisancho, A.R. (1974). Triceps skinfold and upper arm muscle size norms for assessment of nutritional status. Am. J. Clin. Nutr. 27:1052–1058.

Frisancho, A.R. (1981). New norms of upper limb fat and muscle areas for assessment of nutritional status. Am. J. Clin. Nutr 34:2540–2545.

Frisancho, A.R. (1984). New standards of weight and body composition by frame size and height for assessment of nutritional status of adults and the elderly. Am. J. Clin. Nutr. 40:808-819.

Garn, S.M. (1954). Fat patterning and fat intercorrelations in the adult male. Human Biol. 26:59-69.

Garn, S.M. (1955). Relative fat patterning: an individual characteristic. Hum. Biol. 27:75-89.

Garn, S.M. and S.D. Pesick (1982). Comparison of the Benn Index and other body mass indices in nutritional assessments. Am. J. Clin. Nutr. 36:573-575.

Garn, S.M. (1986). Who are the obese? Currents 2:26-27.

Garn, S.M, W.R. Leonard and V.M. Hawthorne (1986). Three limitations of the body mass index. Am. J. Clin. Nutr. 44:996-997.

Goldbourt, U. and J. Medlie (1982). Weight-height indices. Br. J. Prev. Soc. Med. 16:1116-1126.

Gueguen, A., A. Tumba, H. Vandenberghe, J.P. Fryns (1983). Comparison of 2 groups -26 Klinefelter and 307 controlson the basis of body and craniofacial measurements. Journal de Genetique Humaine 31:141-156.

Hall, A.R. (1956). The scientific revolution: 1500-1800. The formation of the modern scientific attitude. Beacon Press, Boston.

Haisman, M.F. (1970) The assessment of body fat content in young men from measurements of body density and skinfold thickness. Hum. Biol. 42:679-688.

Hamill, P.V.V., T.A. Drizd, C.L. Johnson, R.B. Reed, A.F. Roche, W.M. Moore (1979). Physical growth: National Center for Health Statistics percentiles. Am. J. Clin. Nutr. 32:607-629.

Hartz, A.J., D.C. Rupley, R.K. Kalkhoff and A.A. Rimm (1983). Relationship of obesity to diabetes: influence of obesity level and body fat distribution. Prev. Med. 12:351.

Hebbelinck, M. and J. Borms (1978). Korperliches wachstum und leistungsfahigkeit bei schulkindern. Barth, Leipzig.

Hebbelinck, M., W.D. Ross, J.E.L. Carter, J. Borms (1980). Anthropometric characteristics of female Olympic rowers. Can. J. App. Sp. Sci. 5:255-260.

Helmuth, H. (1982). An anthropometric survey of Tyendinega Mohawk children: secular trends. Can. J. of Anthrop. 3:131-141.

Hogben L. (1957). Statistical Theory: The relationship of Probability, credibility and Error. London. George Allen and Unwin Ltd.

Jackson A.S. and M.L. Pollock. (1976) Factor analysis and multivariate scaling of anthropometric variables for the assessment of body composition. Med. Sci. Sports 8(3):196-203.

Jackson A.S., M.L. Pollock (1978). Generalized equations for predicting body density in men. Brit. J. Nutr. 40:497–504.

Jackson A.S., M.L. Pollock and L.R. Gettman (1978). Selected skinfold and girth measurements and percent fat estimates. Res. Q. 49(4):546–551.

Jackson A.S., M.L. Pollack and A. Ward (1980). Generalized equations for predicting body density in women. Med. Sci. Sports Ex. 12(3):175–182.

Jackson, A.S. and M.L. Pollock (1985). Practical assessment of body composition. Physician and Sports Med. 13:76–90.

Jelliffe, D.B. (1966). The assessment of nutritional status of the community. WHO Monograph #53, Geneva.

Jette M. (1981) Guide for anthropometric measurements of Canadian adults, Ottawa.

Johnston, F.E. (1982). Relationships between body composition and anthropometry. Hum. Biol. 54:221–245.

Johnston, F.E., A.N. Palone, H.L. Taylor, and L.M. Schell (1982). The relationship of body fat weight, determined densitometrically, to relative weight and triceps skinfold in American youths 12–17 years of age. Amer. J. Phys. Anthrop. 57:1–6.

Johnston F.E., P.V.V. Hamill and S. Lemeshow (1972) Skinfold thickness of children 6–11 years. United states DHEW pub. no. (HSM) 73:1602 Washington D.C., US Govt. Pub. Office.

Katch F.I. and V.L. Katch (1984). The body composition profile. techniques of measurement and applications. Clin. Sports Med. 3: 31–63.

Katch, F.I. and E.D. Michael (1968). Prediction of body density from skinfold and girth measurements of college females. J. Appl. Physiol. 25:92–94.

Katch, F.I. and W.D. McArdle (1973). Prediction of bodyu density from simple anthropometric measurements in college–age men and women. Hum. Biol. 45:445–454.

Keys A. and J. Brozek (1953) Body Fat in adult man. Physiol. Rev. 33:245–325.

Kissebah, A.H., N. Vydelingum, R. Murray, D.J. Evans, A.J. Hartz, R.K. Kalkhoff and P.W. Adams (1982). Relation of body fat distribution to metabolic complications of obesity. J. Clin. Endocrinol. Metab. 54:254.

Krotkiewski, M., P. Bjorntorp, P. Sjostrom and U. Smith (1983). Impact of obesity on metabolism in men and women: importance of regional adipose tissue distribution. J. Clin. Invest. 72:1150.

Lewis, S., W.L. Haskell, H. Klein, J. Halpern and P.D. Wood (1979). Prediction of body composition in habitually active middle aged men. J. Appl. Physiol. 39:221–225.

Lohman, T.G., R.A. Boileau and B.H. Massey (1975). Prediction of lean body mass in young boys from skinfold thicknesses and body weight. Hum. Biol. 47:245–262.

Lohman, T.G. (1981). Skinfolds and body density and their relationship to body fatness: a review. Hum. Biol. 53:181-225.

Lohman T.G. (1982). Body composition methodology in sports medicine

Lohman T.G., J.H. Wilmore, F. Roby and B.H. Massey (1983). Interinvestigator reliability of skinfolds. In: AAHPERD Research Abstracts. Washington D.C.: AAPHERD p.122.

Lohman T.G., M.L. Pollock, M.H. Slaughter, L.J. Brandon and R.A. Boileau (1984) Methodological factors and the prediction of body fat in female athletes. Med. Sci. Sports Ex. 16:92-96.

Lohman T.G., A.S. Roche, R. Matorell (1987). Anthropometric Standardization Reference Manual, Human Kinetics, Champaign.

Lukaski, H.C. (1987) Methods for the assessment of human body composition: traditional and new. Am. J. Clin. Nutr. 46:537-556.

Malina R.M. (1969). Quantification of fat, muscle, and bone in man. Clin. Orthopaed Rel. Res. 65:9-38.

Marfell-Jones M.J. (1984) An anatomically-validated method for the anthropometric prediction of segmental masses. Ph.D. Thesis, Simon Fraser University.

Martin, A.D. (1984). An anatomical basis for assessing human body compositon: evidence from 25 cadavers. Unpublished doctoral dissertation, Simon Fraser University.

Martin, A.D., W.D. Ross, D.T. Drinkwater, J.P. Clarys (1985). Prediction of body fat by skinfold caliper: assumptions and cadaver evidence. Int. J. Obesity 8:17-25.

Matiegka, J. (1921). The testing of physical efficiency. Am. J. Phys. Anthr. 4:223-230.

Miller, R., W.D. Ross, A. Rapp, M. Roede (1980). Sex chromosome aneuploidy and anthropometry: a new proportionality assessment using the phantom stratagem. Am. J. Med. Genet. 5:125-135.

Mueller, W.H. and L. Stallones (1981). Anatomical distribution of subcutaneous fat: skinfold site choice and construction of indices. Human. Biol. 53:321-335.

Nagamine S. and S. Suziki (1964). Anthropometry and body composition of Japanese young men and women. Hum. Biol. 36:8-15.

Nash, H.L. (1985). Body fat measurement: weighting the pros and cons of electrical impedence. Phys. Sportsmed. 13:124-128.

Noppa, H., M. Andersson, C. Bengtsson, A. Bruce and B. Isaksson (1979). Body compositon in middle-aged women with special reference to the correlation between body fat mass and anthropometric data. Am. J. Clin. Nutr. 32:1388-1395.

Parizkova, J. (1961). Total body fat and skinfold thickness in children. Metabolism 10:794-807.

Pascale, L.R., M.I. Grossman, H.S. Sloane, and T. Frankel (1956). Correlations between thickness of skinfolds and body density in 88 soldiers. In: Body measurements and nutrition. J. Brozek (Ed.) Wayne State Univ. Press, Detroit, pp.55-66.

Pelz, J., D. Timm, E. Eyermann, G.K. Hinkel, M. Kirchner and G. Verron (1982). Body height in Turner's syndrome. Clinicl Genetics 22:62-66.

Perez, B.M. (1982). Los atletos venezolanos, su tip fisico. Universidad Central de Venezuela, Caracas.

Pheasant, S.T. (1982a). A technique for estimating anthropometric data from the parameters of the distribution of stature. Ergonomics 25:981-992.

Pheasant, S.T. (1982b). Anthropometric estimates for British civilian adults. Ergonomics 25:993-1001.

Pollock M.L. and A.S. Jackson (1984). Research progress in validation of clinical methods of assessing body composition. Med. Sci. Sports Ex. 16(6):606-613.

Quetelet, MA: A treatise on man and the development of his faculties. Chambers, Edinburgh. (1842).

Rathburn, E.N. and N. Pace (1945). Studies on body composition. I. The determination of total body fat by means of the body specific gravity. J. Biol. Chem. 158:667-676.

Reilly, T. and M. Townshead (1982). Application of the unisex Phantom concept to anthropometry of young gymnasts. Ergonomics 25:

Roche, A.F., R.M. Siervogel, W.C. Chumlea and P. Webb (1987). Grading body fatness from limited anthropometric data. Am. J. Clin. Nutr. 34:2831-2838.

Roebuck Jr., J.A., K.H.E. Kroemer and W.G. Thomson (1975). Engineering anthropometry methods. Wiley, New York.

Ross, W.D. and N. Wilson (1974). A stratagem for proportional growth assessment. In: J. Borms and M. Hebbelinck (Eds.) Children and exercise IV. International Symposium on Pediatric Work Physiology (Den Haan, Belgium) Acta Paediatrica Belgica. Suppl. 28:169-182.

Ross, W.D. (1976). Metaphorical models for the study of human shape and proportionality. In: Physical education, sport and the sciences. F. Landry and W.A.R. Orban (Eds). University of Oregon, Eugene, Microform, 284-304.

Ross, W.D., D.A. Bailey, R.L. Mirwald, C.H. Weese (1977). Proportionality in interpretation of longitudinal metabolic function data in boys. In: Frontiers of activity and child health. R.J. Shepard and H. Lavallee (eds). Int. Symp. Paed. Work Physiol., Pelican, Quebec, pp.225-236.

Ross, W.D. (1978). Kinanthropometry: an emerging technology; In Landry and Orban, Biomechanics of sport and kinanthropometry. 6:269-282.

Ross, W.D., D.T. Drinkwater, N.O. Whittingham and R.A. Faulkner (1980). Anthropometric prototypes; age 6 to 18 years. In: Children and Exercise IX. K. Berg and B.O. Eriksson (Eds.) University Park Press, Baltimore, pp.3-12.

Ross, W.D. and R. Ward (1980). Growth patterns, menarch, and maturation in physically active girls. In: The female athlete. A. Popma (Ed.) National Conference about Women in Sport and Recreation, Inst. Hum. Perf., Simon Fraser University.

Ross, W.D. and R. Ward (1981). Sexual dimorphism and human proportionality. In: Sexual Dimorphism in Homo Sapiens. Hall, R.L. (Ed.) Praeger, New York, pp.317-361.

Ross, W.D., T.I. Grand, G.R. Marshall and A.D. Martin (1982). On human and animal geometry. In: Howell, M. and B.D. Wilson (Eds). Conference '82, Brisbane.

Ross, W.D. and M.J. Marfell-Jones (1982). Kinanthropometry. In: Physiological testing of the elite athlete. McDougall, J.D. and H.A. Green (eds.), Mutual Press, Ottawa, pp. 75-115.

Ross, W.D., R. Ward, R.M. Leahy, J.A.P. Day (1982). Proportionality of Montreal Athletes; In Carter, The Structure of Olympic Athletes. Part I. The Montreal Olympic Games Anthropological Project. Medicine ans Sport. (Karger, Basel) 16:81-106.

Ross, W.D., R. Ward, B.A. Sigmon and R.M. Leahy (1983). Anthropometric concomitants of X-chromosome aneuploidies. In: Cytogenetics of the Mammalian X-chromosome, Part B: X Chromosome Anomalies and their Clinical Manifestation. In: A.V. Sandberg (Ed.) Alan R. Liss, New York, pp.127-157.

Ross, W.D. and R. Ward (1984). Proportionality of Olympic Athletes. In: Physical structure of olympic athletes. Pt. II, Kinanthropometry of Olympic athletes. J.A.P. Day (Ed.) Human Kinetics, Champaign, pp.203-220.

Ross W.D. and R. Ward (1985). The O-SCALE system. Instructional Mánual, Rosscraft, Whiterock, B.C. Canada.

Ross, W.D. and R. Ward (1986). Scaling anthropometric data for size and proportionality. In: Kinanthropometry III. T. Reilly, J. Watson and J. Borms (Eds). E. & F.N. Spon, London, pp.85-91.

Ross, W.D., A. D. Martin and R. Ward (1987). Body composition and aging: theoretical and methodological implications. Coll. Anthropol. 11:15-44.

Satwanti, K.M., H. Bharadwaj and P. Singh (1977). Relationship of body density to body measurements in young punjabi women: applicability of body composition prediction equations derived for women of European descent. Hum. Biol. 49:203-213.

Scott, M. G. (1959). Research Methods in Health, Physiacl Education, Recreation (2nd Ed.) American Association for Health, Physical Education and Recreation. Washington D.C.

Sheldon, WH. (1942) Varieties of temperament: A Psychology of constitutional differences. Harper. New York

Sheldon, WH; Dupertius, GW; McDermott, E: Atlas of Men. Harper & Brothers, New York. (1954).

Sinning, W.E. (1978). Anthrompometric estimation of body density, fat, and lean body weight in women gymnasts. Med. Sci. Sports. 10:243-249.

Sinning, W.E. (1980). Use and misuse of anthropometric estimates of body composition. J. Phys. Ed. Rec. 51:43-45.

Sinning, W.E., D.G. Dolny, K.D. Little, L.N. Cunningham, A. Racaniello, S.F. Siconolfi, J.L. Sholes (1985). Validity of "generalized" equations for body compositon analysis in male athletes. Med. Sci. Sports Exerc. 17:124-130.

Siri (1957) University of California, Radiation Laboratory Publication No. 3349.

Skibinska, A. (1979). Anthropometry czny model czlowieka. Wychowanie Fizyczne Sport 4:3-11.

Sloan, A.W., J.J. Burt and C.S. Blyth (1962). Estimation of body fat in young women. J. appl. Physiol. 17:967-970.

Sloan, A.W. (1967). Estimation of body fat in young men. J. Appl. Physiol. 23:311-315.

Sloan, A.W. and A. Shapiro (1972). A comparison of skinfold measurements in three standard calipers. Hum Biol. 44:29-36.

Smith, D.P. and R.W. Boyce (1977). Prediction of body density and lean body weight in females 25-37 years old. Am. J. Clin. Nutr. 30:560-564.

Spivak, C.D. (1915). The specific gravity of the human body. Arch. Int. Med. 15:628-642.

SPSS Inc. (1986). SPSSx users guide. Edition 2. McGraw-Hill Book Co., New York.

Stewart, T.D. (Ed.) (1952). Hrdlicka's Practical Anthropometry. Wistar Inst. Anat. Biol., Philadelphia.

Tanner, J.M. (1976). Clinical longitudinal standards for height, weight, height velocity and weight velocity and the stages of puberty. Arch. Dis. Child. 51:170-179.

U.S. Department of Health, Education and Welfare (1977). NCHS Growth Curves for Children Birth-18 Years , United States. DHEW Publication No. (PHS) 78-1650, National Center for Health Statistics, Hyattsville, Md.

Vague J. (1956). The degree of masculine differentiation of obesities: A factor detrmining predisposition to diabetes, atherosclerosis, gout, and uric calculous disease. Am. J. Clin. Nutr. 4:20.

Vajda, A.S. and M. Hebbelinck (1978). Secular growth data in Belgian populations since 1840. In: Pediatric Work Physiology. Borms, J. and M. Hebbelinck (Eds). Karger, Basel, Medicine and Sport 11:134-139.

Weiner, J.S. and J.A. Lourie (1981). Practical Human Biology. Academic Press, London.

Weisner, R.L., P.J. Norris, R. Birch, R.S. Bernstein, J. Wang, M. Yang, R.N. Pierson Jr., B.T. Van Ittalie (1985). Obesity and hypertension. Hypertension 7:578.

Wilmore, J.H. and A.R. Behnke (1969). Anthropometric estimation of body density and lean body weight in young men. J. Appl. Physiol. 27:25-31.

Wilmore, J.H. and A.R. Behnke (1970). An anthropometric estimation of density and lean body weight in young women. Am. J. Clin. Nutr. 23:267-274.

Wilmore, J.H. (1983) Body composition in sport and exercise: directions for future research. Med. Sci. Spts. Exer. 15:21-31.