STRUCTURAL CHARACTERISTICS OF FEMALE DISTANCE RUNNERS
OF DIFFERENT PROFICIENCY LEVELS

by

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B.P.E., The University of British Columbia, 1977

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF PHYSICAL EDUCATION

in

THE FACULTY OF GRADUATE STUDIES
(School of Physical Education and Recreation)

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA
February 1983

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ABSTRACT

The purpose of this investigation was to look at the structural characteristics of recreational, adult female distance runners. The subjects were divided into two different speed categories: group one consisted of eleven women who averaged a velocity of seven minutes per mile or faster over a race distance of ten thousand meters or longer; and group two consisted of twelve women who averaged seven and one half to eight and one half minutes per mile over this distance. The two groups were compared using anthropometrical measures, body composition, age of menarche, training practices and athletic background, and iron stores. The anthropometrical and body composition measures were compared with those of a reference group of university females (group three).

Anthropometrical measures were appraised using absolute values and Phantom Z-values of group means. The Phantom Z-values were plotted on graphs plus and minus one standard error. Differences were found in hand length (group one was smaller), sitting height (group three was larger), foot length (group three was smaller), and transverse chest width (group three was smaller). The trend was for group one, the faster runners, to be smaller in absolute values and smaller in girth Z-values.

Group one was found to have lower density values, lower sum of skinfolds, and less adipose mass. Proportional Z-values for skinfolds were significantly lower in group one than group three and lower than group two at all sites but front thigh.

Age of menarche was not significantly different between group one and two but group one had a significantly greater number of later maturers than group two when compared using chi-square analysis.
Questionnaires determining training practices and activity in adolescence were used with chi-square analysis to determine frequency distribution. The women in group one trained more frequently and had been running a greater number of years than those in group two. Although activity in adolescence was not significantly different, a greater number in group one had been 'active' in adolescence compared with those in group two.

Iron stores for both groups fell within normal value ranges.

Due to the small sample size of the two running groups definite conclusions are not warranted. Nevertheless, tentative ones based on the group means seem to indicate that the superior group of runners was smaller in structure, had lower body fat, a greater amount of time devoted to training, a larger number were later maturers, and more were active in adolescence.

While some measures cannot be changed with training it seems that training plays a large role in running proficiency and extensive training can influence body fat and muscle mass.
TABLE OF CONTENTS

Chapter | Page
---|---
ABSTRACT | ii
LIST OF TABLES | vi
LIST OF FIGURES | vii
ACKNOWLEDGEMENTS | viii
I STATEMENT OF THE PROBLEM | 1
   Introduction | 1
   Explanation of the Study | 4
   Delimitations | 5
   Limitations | 5
   Definition of Terms | 6
II REVIEW OF LITERATURE | 7
   Size | 7
   Proportions | 9
   Shape | 11
   Body Composition | 12
      Measurements of Body Fat | 12
      Body Fat and Performance | 14
   Fractionation of Body Mass | 16
   Age of Menarche | 16
   Training and Athletic Background | 18
   Iron Stores. | 19
III METHODS AND PROCEDURES | 21
   Subjects | 21
   Apparatus and Measuring Procedures | 21
   Analysis | 23
      Body Composition | 25
      Statistical Analysis | 25
      Age at Menarche | 25
      Somatotype Analysis | 26
      Training and Athletic Background | 26
      Iron Stores | 27
IV RESULTS AND DISCUSSION | 28
   Anthropometrical Data | 28
   Proportional Body Masses | 39
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Somatotyping</td>
<td>42</td>
</tr>
<tr>
<td>Body Composition</td>
<td>42</td>
</tr>
<tr>
<td>Age at Menarche</td>
<td>47</td>
</tr>
<tr>
<td>Training Practices and Athletic Background</td>
<td>48</td>
</tr>
<tr>
<td>Skinfold Measures verses Training Frequency</td>
<td>49</td>
</tr>
<tr>
<td>Iron Stores</td>
<td>49</td>
</tr>
<tr>
<td>Discussion</td>
<td>50</td>
</tr>
<tr>
<td><strong>V SUMMARY, CONCLUSIONS AND RECOMMENDATIONS</strong></td>
<td>54</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>57</td>
</tr>
<tr>
<td>APPENDIX A</td>
<td>64</td>
</tr>
<tr>
<td>Informed Consent Form</td>
<td></td>
</tr>
<tr>
<td>APPENDIX B</td>
<td>66</td>
</tr>
<tr>
<td>Menarche Questionnaire</td>
<td></td>
</tr>
<tr>
<td>APPENDIX C</td>
<td>68</td>
</tr>
<tr>
<td>Training Background Questionnaire</td>
<td></td>
</tr>
<tr>
<td>APPENDIX D</td>
<td>70</td>
</tr>
<tr>
<td>Athletic Background Questionnaire</td>
<td></td>
</tr>
<tr>
<td>APPENDIX E</td>
<td>72</td>
</tr>
<tr>
<td>Phantom Specifications for Estimation of Fractionated Body Masses by the Drinkwater Tactic</td>
<td></td>
</tr>
<tr>
<td>APPENDIX F</td>
<td>74</td>
</tr>
<tr>
<td>Anthropometrical Raw Data for Subjects in Groups One and Two</td>
<td></td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Size</td>
<td>28</td>
</tr>
<tr>
<td>II Anthropometrical Measurements Absolute Values</td>
<td>30</td>
</tr>
<tr>
<td>III Anthropometrical Measurements Proportional Phantom Z-Values</td>
<td>32</td>
</tr>
<tr>
<td>IV Proportional Body Masses (Drinkwater Tactic)</td>
<td>39</td>
</tr>
<tr>
<td>V Proportional Body Masses (Drinkwater Tactic) Phantom Z-Values</td>
<td>40</td>
</tr>
<tr>
<td>VI Somatotypes</td>
<td>42</td>
</tr>
<tr>
<td>VII Skinfold Measures</td>
<td>43</td>
</tr>
<tr>
<td>VIII Skinfold Measures Proportional Phantom Z-Values</td>
<td>45</td>
</tr>
<tr>
<td>IX Hydrostatic Weighing Density Values</td>
<td>47</td>
</tr>
<tr>
<td>X Age of Menarche</td>
<td>47</td>
</tr>
<tr>
<td>XI Age of Menarche Above and Below Average</td>
<td>48</td>
</tr>
<tr>
<td>XII Training Practices Number of Days per Week</td>
<td>48</td>
</tr>
<tr>
<td>XIII Training Practices Number of Years Running</td>
<td>49</td>
</tr>
<tr>
<td>XIV Activity in Adolescence</td>
<td>49</td>
</tr>
<tr>
<td>XV Iron Stores</td>
<td>50</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>1</td>
<td>Mean Z Values: Lengths, Breadths, Girths Group 1 vs Group 3</td>
</tr>
<tr>
<td>2</td>
<td>Mean Z Values: Lengths, Breadths, Girths Group 2 vs Group 3</td>
</tr>
<tr>
<td>3</td>
<td>Mean Z Values: Lengths, Breadths, Girths Group 1 vs Group 2</td>
</tr>
<tr>
<td>4</td>
<td>Mean Z Values: Lengths, Breadths, Girths Group 1 vs Group 2 vs Group 3</td>
</tr>
<tr>
<td>5</td>
<td>Proportional Body Masses (Drinkwater Tactic) Mean Z Values Group 1 vs Group 3</td>
</tr>
<tr>
<td>6</td>
<td>Proportional Body Masses (Drinkwater Tactic) Mean Z Values Group 2 vs Group 3</td>
</tr>
<tr>
<td>7</td>
<td>Proportional Body Masses (Drinkwater Tactic) Mean Z Values Group 1 vs Group 2</td>
</tr>
<tr>
<td>8</td>
<td>Proportional Body Masses (Drinkwater Tactic) Mean Z Values Group 1 vs Group 2 vs Group 3</td>
</tr>
<tr>
<td>9</td>
<td>Skinfold Measures Proportional Z Values Group 1 vs Group 3</td>
</tr>
<tr>
<td>10</td>
<td>Skinfold Measures Proportional Z Values Group 2 vs Group 3</td>
</tr>
<tr>
<td>11</td>
<td>Skinfold Measures Proportional Z Values Group 1 vs Group 2</td>
</tr>
<tr>
<td>12</td>
<td>Skinfold Measures Proportional Z Values Group 1 vs Group 2 vs Group 3</td>
</tr>
</tbody>
</table>
ACKNOWLEDGEMENTS

I wish to thank the members of my thesis committee: Dr. S. R. Brown (Committee Chairman), Dr. R. Mosher, Mr. L. Pugh, and Dr. W. D. Ross. I would especially like to thank Dr. Brown for his valuable and inexhaustable assistance in writing the final draft, and Dr. Ross for his enthusiasm for the subject of kinanthropometry.

I would also like to thank the women who participated in the study as subjects and those persons who helped me in the data collection process and computer analysis.

And, finally I extend a special thank you to my husband, family, and friends for encouraging and supporting me throughout my studies.
CHAPTER 1

STATEMENT OF THE PROBLEM

Introduction

Women distance runners have increased greatly in number in recent years and this constitutes both an interesting social phenomenon, and an opportunity for scientific study of female structure and function in relation to long distance running performance. Several reasons can be advanced for doing descriptive studies of this relationship. One is that there is very little information about female distance runners and factors which influence performance. There has been a widely held conviction in lay, if not also in athletic circles, that women were not suited for distance running, and that those who did were rather different in structure from normal. The data for male distance runners shows consistency while that which has so far been obtained for women does not; thus, more information is needed to help in reducing confusion about the factors influencing female distance running performance. At this stage descriptive studies are needed in order to determine future directions in research on female distance runners.

In competition where the participants are running because they have the desire to do so and not because they were chosen, a relatively common training background is not present as it is in international competitions. Thus, any differences in ability related to structure may be masked by differences in ability due to functional status (training). Therefore, a proper investigation must include data of both kinds. A thorough record of training and athletic background of the participants should be taken.
There has, for many centuries, been an awareness of the relationship between bodily structure and function as it relates to performance. Philostratos Flavius of ancient Greek times (circa 170-250 A.D.) (Juthner, 1969) described how participants of a given sport should be of a specific physique in order to be successful. Many recent studies have shown this from various points of view. Hirata (1966) studied the size and age of the competitors of the 1964 Tokyo Olympic Games. He found significant group differences in height, weight, and age of participants of the different events.

Another aspect of physique is that of proportion - length, girth, and width relationships. de Garay et al. (1974) analysed biacromial and biiliocristal widths as well as arm, trunk, and leg lengths of various groups of athletes. They found athletes in a specific sport exhibited the same general trends in these body proportions.

The body composition of athletes has also been studied. Behnke and Wilmore (1974) and Krahenbuhl et al. (1979) found athletes to have less fat and a greater body density, as measured by hydrostatic weighing, than non-athletes.

Somatotyping is a method of looking at physique from the point of view of body shape. de Garay et al. (1974) determined the somatotype of each athlete and looked at each component separately. They found male athletes to vary according to their sport but the small sample of women proved to be balanced mesomorphs (3 - 4 - 3).

Most of the studies previously done on athletes have been concerned with elite male athletes. With the rapid increase of participation by women in sport
there is interest in filling a gap in the scientific knowledge of the relationship of structure and function in women athletes. It is a matter of scientific curiosity to see if their relationship is similar to that seen in the male athlete or if the relationship differs.

In areas of study where there is a paucity of information it is necessary to proceed on intuition based on observations. One might proceed by assuming that the structural differences between female long distance runners and non-athletes would approximate the differences between male long distance runners and the normal population. Male distance runners are reported to be short, very lean, ecto-mesomorphs, with small biacromial and biiliocristal widths (de Garay et al., 1974).

One cannot verify this assumption from the few studies of female long distance runners as the results have been equivocal in some respects. The runners have been shown to be lean but size was distinctly different in different samples (Malina et al., 1971; Brown & Wilmore, 1971; Wilmore & Brown, 1974). No studies concerning female distance runners and reporting proportions or somatotype were found.

An additional perspective in considering elements influencing levels of achievement in female athletes is age of menarche. It has been found that female athletes experience a later menarche than do non-athletes (Malina et al., 1978). Malina et al. (1978) hypothesized that the physique of later maturing girls is more suited for successful athletic performance: they were longer-legged, narrower hipped, more linear, had less weight for height and less fat than their early maturing peers.
Because of these structural differences related to later maturation it is necessary to collect age of menarche data in any exploratory study of influences on the performance of women. Up to the present time the literature examining age of menarche has only dealt with young athletes whose training has been through adolescence. While cause and effect relationships cannot be determined, it is unknown whether the later maturing females continue to be the ones to excel or if these differences are minimized in adult years.

Low iron stores have been associated with increased participation in endurance activities. Since iron is an important substance in oxygen transport it seems reasonable to assume that acceptable levels are important for performance. A test for adequate iron stores should be done when contrasting proficiency levels in order to rule out the possibility that lower performance is not due to low iron stores.

Explanation of the Study

This study compared two groups of female distance runners of different proficiency levels with respect to anthropometrical measurements, training backgrounds, age of menarche, and iron stores, and compares these groups with a reference group in anthropometrical measures. The runners were chosen from the entrants of several races of 10,000 meters or longer. The 10,000 meter distance was chosen because it is a popular long distance race requiring an extensive amount of endurance training. There were two groups: one of eleven members who averaged seven minutes per mile or less over the distance and the other of twelve members who averaged seven and one half to eight and one half
minutes per mile over the distance.

The women were measured using anthropometric measures of size (height, weight, lengths, breadths, and girths), shape (somatotype), proportions (lengths, breadths, and girths in relation to height), and body composition (underwater weighing and skinfold thicknesses). The two groups were compared with a reference group (ninety-four women measured in a tri-university study in British Columbia) in size, shape, proportions, and skinfold thicknesses.

The runners were given questionnaires to ascertain their present training practices, their athletic background, and their age of menarche. A blood sample was taken and analysed for ferritin, serum iron, total iron binding capacity, hemoglobin, and red blood cells.

**Delimitations**

1. This study is concerned with females who entered the 10,000 meter races of the CP Air series during January and February, 1980, who fell into the previously described speed categories and who were available for measuring.

**Limitations**

1. The participants were chosen according to performances in one or two races. It was not possible therefore, to take into account the true ability of any subject who may have had an 'off' day. The exclusion of subjects with average velocities between seven and seven and one half minutes per mile was intended to ensure a clear separation in running ability of the two groups.

2. The age of menarche was recalled by the subjects and not taken from records. Studies have
shown that most females can recall the date of menarche within an acceptable level of accuracy for group comparisons (Livson & McNeill, 1962; Damon et al., 1969; Bergsten-Brucefors, 1976).

Definition of Terms

The terms used in this work have the same specific denotation as those utilized in the sciences which deal with human measurement and description.
CHAPTER II
REVIEW OF LITERATURE

For many years researchers seeking knowledge of the perfect physique for specific athletic events have been reporting on the size, shape, proportions, and body composition of athletes in varying sports. Compared to males, women have been participating in sport for a relatively short period of time, but the time that females have been competing in long distance running events has been an even shorter period. Very little information on the physique of these female long distance runners has been recorded.

This review of literature is restricted almost entirely to material on runners. Some is concerned with contrasts between male distance runners and non-runners or, in some cases, sprinters. Information on female sprinters is contrasted with information on non-runners and the limited available information on distance runners.

The review is composed of material coming under these topic headings: size, shape, proportions, body composition, age of menarche, training and athletic background, and iron stores.

(In this chapter all values are averages for groups unless stated to the contrary.)

Size

Hirata (1966) compared the height, weight, and age of various classes of competitors in the 1964 Tokyo Olympic Games. At that time the longest footrace for women was 800 meters. With male runners he found that the longer the race distance, the shorter, lighter, and older the athletes tended to be. The marathoners
weighed 60.8 kg and were 170.3 cm in height while
the 10,000 meter runners were 62.0 kg and 172.7 cm.
De Garay et al. (1974) reported data on athletes at
the 1968 Mexico Olympic Games and found the height of
the 10,000 meter runners to be 171.9 cm and the reference
group to be 170.4 cm but the marathoners were shorter
at 168.7 cm. The 10,000 meter runners and marathoners
were lighter (59.8 kg and 56.6 kg respectively) than
the reference males (63.1 kg). The distance runners
were lighter than all the athletes.

Pipes (1977) reported his two, three, and six
mile male runners to be the lightest of all the
athletes studied but the female distance runners
were heavier than the sprinters, one half and mile
runners, and jumpers, but were second in body fat,
with only the sprinters having less. Wilmore and
Brown (1974) reported an average height of 169.4 cm
for their long distance runners which is tall for
women. The female distance runners in the study by
Brown and Wilmore (1971) were also tall - 167.4 cm.
The runners in Wilmore and Brown's study (1974)
were 57.2 kg but when an atypical person - an ultra-
marathoner (35.4% body fat, 71.5 kg) is taken out the
group weight was 55.8 kg. Brown and Wilmore's women
(1971) weighed 50.7 kg.

Height and weight are the usual measures of
size used in surveys but in more detailed analyses
of special populations, measures of lengths, breadths,
and girths can be employed. The choice of these
measurements may depend on the insights gained from
other studies or from particular hypotheses proposed.
In studies where there are no distinct perspectives
about which measures might show differences in people
with different training backgrounds or other factors
which might influence performance, one chooses to include a reasonably large number of measures and looks for possible differences which might then show some relationships to performance. This is a speculative approach but is a reasonable first step in advancing into new territory where one does not know what to expect and samples are small.

There are several ways of comparing individuals and groups on the measurements of lengths, breadths, and girths. One way is to compare absolute values. This is not a satisfactory method as it does not account for differences in individual heights. Another, more satisfactory method is to translate the measurements into proportions of height. This can be done by two methods. The first is to divide the individual measure by the subject's height and show a percentage of height score. The other method, which is quickly gaining wide-spread acceptance is to compare proportional Z-values which have scaled all subjects to a common height. This method of comparison is referred to as the Phantom stratagem (Ross & Wilson, 1974) and is based on the concept of a theoretical reference unisex human figure and the comparison of proportionality differences among groups. It

"expresses a subject's anthropometric measures in terms of standard deviations (Z-values) from those designated for a unisex reference human. This is achieved by scaling the subject's variables to the reference human stature (170.18 cm)."

(Ross & Ward, unpublished)

Proportions

As with all other body measurement analytical systems, basic data on body proportions is lacking on female long distance runners. Day et al. (1977)
compared European champions to Belgian runners (3000 meter distance) and to a reference group of Flemish physical education undergraduates. They ascertained that the runners had proportionally longer lower limbs, with the thigh length more pronounced, narrower humerus and femur diameters, broader biiliocristal widths, and smaller girths than the reference group, and that the more proficient runners (the European champions) varied more from the reference group than did the Belgian runners. Conversely, Burke and Brush (1979) found their distance runners (aged 16.2 years, cross country runners training 50 plus miles per week) to have a shorter thigh length with the lower leg more pronounced in comparison with their non-athletic controls (they compared percentage of total leg). They hypothesized that this would afford a biomechanical advantage in that

"the closer that the center of gravity of the whole leg is to the hip joint, the smaller the moment of inertia during the recovery phase of the stride with consequent reduction in the resistance to forward motion."

(Burke & Brush, 1979:184)

Eiben et al. (1976) also reported a proportionally longer lower leg for their female middle distance runners than for their non-athletic teacher college controls and the Phantom.

Male distance runners have been reported to have shorter trunks and longer legs than controls (Slocum & James, 1968), narrower biiliocristal diameters than all other athletes studied (Parizkova, 1977), narrow biacromial diameters (de Garay et al., 1974; Parizkova, 1977), proportionally short arms (de Garay et al. 1974), and a deficiency of arm girth compared with chest and leg size which would indicate a lack of muscle in the little used upper extremities (Behnke, 1966).
Shape

Carter (1975) defines somatotype as a "description of present morphological conformation" (1975:1-1). It is an attempt to describe body shape with a simple three numerical rating. Somatotype encompasses form and composition without the influence of absolute size. For a complete description of somatotyping the reader is referred to Carter (1975).

It has been shown that the somatotypes of athletes in a specific sport are fairly homogeneous and that somatotypes vary from sport to sport (Carter, 1970). Carter (1970) also showed that certain somatotypes which appear in the general population do not appear in an athletic population, these being somatotypes high in endomorphy, very high in ectomorphy, and very low in mesomorphy.

Unfortunately most of the studies on female distance runners did not report somatotypes nor did they report the data which would enable somatotypes to be calculated. Wilmore, Brown and Davis (1977) reported a somatotype of 3.2 - 2.1 - 3.7 for twenty-three distance runners. de Garay et al. (1974) found their female athletes (all events) to be balanced mesomorphs (3 - 4 - 3). Westlake (1967) reported a somatotype of 3 - 4 - 3.5 for her distance runners (800 meters) - they being the lowest of all the athletes in endomorphy and in mesomorphy. Day's European champion distance runners (1500 and 3000 meters) exhibited a somatotype of 2.0 - 4.0 - 3.5 (1977). For non-athletic women enrolled in a fitness class, de Woskin (1967) has reported a somatotype of 5.9 - 4.8 - 3.5 (40 females, age 44 years). de Garay's female non-athletic Mexican reference group showed a somatotype of 5.1 - 3.9 - 2.3 (1974).
de Garay et al. (1974) discovered that thesomatotypes of male Olympic athletes varied according
to the sport, with long distance runners (5000 and
10,000 meters) and marathoners being nearly alike
(1.4 - 4.1 - 3.6 and 1.4 - 4.3 - 3.5 respectively).

Body Composition
The body is made up of four masses: fat, bone,
muscle, and a residual portion. Fat is the most
labile of the components - the one which causes the
greatest variation in the human shape and the one
most influenced by activity and nutrition.

Measurements of Body Fat
There are many ways of measuring fat content
in vivo; among these are hydrostatic weighing, $40_K$
total body water, radiography, and skinfold measures.
Hydrostatic weighing to determine body density and
percent body fat is a relatively common procedure for
assessing individuals and small groups, but with large
groups of people the time involved is great so it is
usual to measure skinfolds to predict percent body fat.
As Malina points out (1969) both of these methods have
limitations. Hydrostatic weighing formulas assume constant
densities of muscle, fat, and bone for all individuals
which Bakker and Struikenkamp (1977), in their review of
literature, showed to be untrue. Differences in bone
mineralization due to sex, size and ethnic differences
cause discrepancies in body fat estimation from density
measurements (Jones & Corlett, 1980). Bone density is
known to decrease with age (Malina, 1969) and can increase
with intense physical activity (Aloia et al., 1978).
Muscle becomes more dense with physical activity (Malina,
1969). Consequently, depending on a persons' activity level,
sex, ethnic background and size, the underwater weighing
technique can underestimate or overestimate fat levels.
Also, accurate underwater weighing must have the subject's complete co-operation. If a person is uncomfortable with emptying his lungs underwater or cannot sit still on the sling in the water, errors will be made.

Katch and Katch (1980) listed four sources of error in using underwater weighing for the prediction of percent body fat:

1. a variance in water content of the body, independent of body fatness;
2. a variance in protein to bone mineral ratio;
3. a variance in density of obesity tissue; and
4. a variance in fat content.

The assessment of body fat using skinfold measures also has its limitations. These limitations are based upon two important assumptions that are made when skinfold prediction equations are formulated. These assumptions are:

1. that the skinfolds are related to total body fat; and
2. that the sites selected are representative of the fat in the body.

(Carter, 1979)

Individual skinfold measures could be accurately made but when inserted into an equation may produce errors of prediction of density or percent fat. Damon and Goldman (1964) compared results from ten skinfold formulas with densitometrically determined body fat on a small sample of athletic young men. The simplest approach using the triceps and subscapular skinfolds came closer to predicting total body fat than other more elaborate measures but the accuracy of prediction still decreased considerably for those subjects at the extremes of age, height, and weight in the group and for those who were more endomorphic.

Individual skinfold measures could be taken
very correctly by the measurer but may still produce errors of fat thickness measurement. Clegg and Kent (1967) found skinfold compressibility to vary at different sites, to vary between individuals, and to be greater in females than in males. They also found increased compressibility with an increase in skinfold thickness. This could lead to considerable errors of prediction when using a female formula for female athletes whose skinfold thicknesses are much less than the general female population.

Katch et al. (1973) looked for the best predicting formula for percent body fat in women and concluded that:

"regression equations should only be applied to subjects similar in physical characteristics, including age and weight, to those on whom the equations are derived. The present equations may not be as valid when applied to athletic young men and women who regularly engage in strenuous physical training or conditioning, or for very large or small individuals who could be visually classified as thin or obese." (1973:453)

and Katch and Katch (1980): "no single prediction equation appears to be valid and usable on different segments of the population even though generalized equations have been proposed. It is well documented that prediction equations derived on one particular segment of the population do a relatively poor job when used to predict other population values. Thus regression equations are said to be 'population specific'. (1980:257)

Body Fat and Performance

Body fat is negatively correlated with physical performance and athletes tend to have less fat than the general population. Malina (1971) found a body fat value of 19.1% in his sample of female collegiate distance runners using the formula of Sloan et al. (1962)
for density and Brozek et al. (1963) for fat. His 'distance' runners however, were competing in distances of only 440 and 880 yards, and one mile.

Pipes (1977), in a study of collegiate females running two, three, and six miles, reported a body fat of 13.8% using hydrostatic weighing and Siri's formula for percent fat (1956).

Wilmore and Brown (1974), using the same method, reported a value of 15.2% for their group of national and international calibre female distance runners (two miles to marathon distance). When one of their participants, who was 35.4% body fat, and an ultra-marathoner, is left out of the group calculations, the average percentage is 13.2%.

Wilmore, Brown, and Davis (1977) also using this method, found an average percentage of 16.9% for national and international competitors (two miles to marathon) ages 17 to 51. They found the four best runners to have less than 10% body fat and the two best to have six percent.

These figures are very much lower than those of normal females. Values of 23.4% (Malina, 1971; 17.6 to 23.1 years), 25.7% (Wilmore & Behnke, 1970; college women), and 28.1% (Wilmore and Brown, 1974; average age of 31.7 years) have been reported.

There is a large difference in body fat values between male distance runners and normal males. Pipes (1977) found a value of 3.5% for his collegiate runners of two, three, and six mile distances. Pollock et al. (1977), using hydrostatic weighing with Siri's formula (1956), found a mean value of 5.0% for national and international calibre distance runners (three to six miles) and 4.3% for marathon runners. They reported a value of 13.4% for college age controls.
Fractionation of Body Mass

Drinkwater and Ross (1980) developed a method of using the Phantom Z-values to derive proportional body masses for the four components of fat, bone, muscle, and residual mass. These masses can be derived independently of each other and can be summed to test for error between obtained (actual weight) and predicted (sum of four masses) total body mass. This method "assumes that the deviation of any anthropometric tissue indicator from a given value in standard scores will be the same as the deviation of the particular tissue mass". (Hebbelinck, 1980)

Hebbelinck et al. (1980) justify the usage of this four component model saying it provides more useful information about the body of an athlete than does the conventional two component model.

Ross et al. (1980) compared male and female runners (all distances) with male and female student controls. Using the four component system they found the runners to have less body fat than their control counterparts and the female runners to have the same percentage fat as the male controls. The female runners had the lowest percentage of bone while the males (both groups) had the highest. The runners were relatively similar and had the highest percentage of muscle mass while the female students had the least. Residual mass was the same for all groups.

Age of Menarche

Age of menarche has long been accepted as an indication of maturity. If the age at which a female experiences her first menses is known she can be classed as an early, normal, or late maturer. There seems to be a correlation between body build and early/late
maturation. Malina et al. (1978) stated that later maturing girls were longer legged, narrower hipped, more linear, had less weight for height and less relative fatness than their early maturing peers; early maturers seem to be broader and fatter and early maturation is negatively correlated with ectomorphy.

Malina et al. (1973) compared the age of menarche of track and field athletes with that of non-athletes. The athletic groups (divided into sprinters, distance runners, jumpers and hurdlers, discus and javelin, and shot putters) did not differ significantly among themselves but experienced menarche at a significantly later age than the non-athletes (13.58 and 12.23 years respectively).

Malina et al. (1976) also looked at age at onset of menses in 145 participants at the 1976 Olympic Games. They found that the athletes were, on the average, later maturers than the general population in their own countries. They also found that the Olympic runners were significantly later than U.S. national intercollegiate track and field athletes (14.3 as opposed to 13.6 years) but field athletes are generally earlier maturers than track athletes (runners specifically) (Malina et al., 1973) so perhaps this comparison is not relevant.

Ross et al. (1976) and Faulkner (1976) found elite skaters to be later maturers than non-athletes, and Cameron (1981) found elite gymnasts to experience menarche later than non-athletes and recreational gymnasts. They concluded that the small, lean body of the pre-menarcheal female had a distinct advantage in sports such as figure skating and gymnastics where the body is propelled through space.
In 1978 Malina et al. proposed a two part hypotheses to explain later menarche and success in sports. The first part suggested that the physique of later maturing girls is more suitable for successful athletic performance (being longer legged, narrower hipped, more linear, having less weight for height and less relative fatness than early maturers). The second part stated that perhaps due to a socialization process, early maturers are 'socialized away' from athletics through social and status related motives. Also, sexual maturation often leads to a decrease in physical skills involving running and jumping. Later maturers, due to their advanced age at menarche, may never experience this process, or, being older, and also having had success in sports (which is motivation to continue) they can cope with the social pressures.

**Training and Athletic Background**

Intense training has been shown to affect weight (de Vries, 1975), body composition (Parizkova & Poupa, 1963; Parizkova, 1968), and bone mass (Guyton, 1976; Aloia et al., 1978), and training in adolescence can possibly affect proportions (Parizkova, 1973) and age at menarche (Malina et al., 1973, 1976; Ross et al., 1976; Faulkner, 1976; Cameron, 1981). None of the studies previously cited describes the type of training practices used by the athletes except for the occasional mentioning of milage run per week (Ehn, 1980; Wilmore & Brown, 1974). No literature was found specifically dealing with training and athletic background of women runners. Personal experience would suggest that proficiency increases with frequency and intensity of training but no research on female runners was found to substantiate this observation.
Pollock et al. (1975) studied training frequency and improvement in cardiovascular function and body composition of middle aged men (28-64 years). Three groups ran 30-45 minutes two, three, or four days per week for twenty weeks. The groups running three or four days per week showed decreases in weight and percent body fat, all showed increases in cardiovascular function but the four day per week group increased significantly more than did those running two and three days. This would indicate that frequency of training is an important criterion for increased ability.

Nothing has been reported on adult female distance runners and training practices or training in adolescence.

**Iron Stores**

In the past several years many researchers have looked at a medical condition called "sports anemia". The name has arisen because it is found in athletes who engage in strenuous physical endurance training. Stewart et al. (1972) found their endurance Olympic athletes to have decreased hemoglobin and packed cell volume levels but adequate intakes of protein and iron. Clement et al. (1977) and Clement & Asmundson (1979, 1982) showed their athletes (distance runners) to have low iron stores and low dietary intake of protein and iron. The athletes studied by Ehn et al. (1980) (male distance runners training 120-200 km per week) had low iron stores, increased elimination of iron and low absorption values of iron. This is contrary to normal. Usually in persons with low iron stores there is an increase in the rate of absorption to replenish storage iron (Ehn et al. 1980).

Many studies exist to show that suboptimal
levels of hemoglobin and iron stores occur in endurance athletes. Some explanations offered are: decreased dietary intake of protein and iron (Clement et al., 1977; Clement and Asmundson, 1979, 1982), decreased absorption of iron from the gut (Ehn et al., 1980), increased destruction of red blood cells (Yoshimura, 1970), and an increase in blood volume due to physical training resulting in a decrease in hemoglobin concentration (Oscai et al., 1968). There have been few attempts to analyze the effects of this depleted condition on the performance of the athlete. Those researchers who showed a definite decrease in performance with a decrease in hemoglobin and iron stores were not studying persons whose decrease was caused by strenuous physical activity (Van Dobeln, 1957; Viteri and Torun, 1974; Ekblom, Goldberg, & Gullbring, 1972). Stewart et al. (1972) tried to say that their Australian Olympic athletes who were low in iron stores did not do as well in competition as those who were normal, but from their numbers it appears almost an equal number from each group (iron normal and iron suboptimal) made it to the finals of the Olympic Games. 

More long-term studies are needed to determine if low hemoglobin and low iron stores caused by strenuous physical training result in a decrease in physical performance.
CHAPTER III
METHODS AND PROCEDURES

Subjects
Subjects consisted of twenty-three female distance runners of whom eleven fell into the speed category of group one, i.e., running at an average pace of seven minutes per mile or faster over 10,000 meters (6.2 miles) or longer. Group two consisted of twelve women who ran at an average pace of from seven and one half to eight and one half minutes per mile over 10,000 meters or longer. The names of the women were taken from the results of at least two races held during January and February of 1980. (Two race results were necessary in all cases in order to eliminate the effects of 'a bad day' and the effect which terrain in any one race might have on average velocity. Subjects were chosen only if their velocities for both races were in the same category, i.e., group one or group two.) The eligible women were sent letters of introduction and explanation and these were followed by a telephone call to confirm participation and set dates and times for measuring. The measuring was done in early April, 1980.

All subjects were over the age of eighteen years and were assumed to have completed their growth spurt.

All subjects were tested after at least a six hour fast.

Apparatus and Measuring Procedures
Subjects reported to the lab in bathing suits and were asked to sign an informed consent form (Appendix
A). Hydrostatic weighing was performed using the method described by Behnke and Wilmore (1974). Vital capacity was measured using a spirometer with the subject immersed neck height in water. Readings of weight were taken until three were obtained which were relatively equal and in the upper half of the measurements (a minimum of five and a maximum of twelve readings were taken).

Anthropometric measures were taken according to the Montreal Olympic Games Anthropometric Procedures (MOGAP) criterion (Carter, 1977; 1982).

A Swiss-made anthropometer, a small steel precision caliper, and a cloth tape (checked for possible stretching) were used to measure lengths, widths, and girths; a sliding height scale and a balance scale were used for height and weight; and Harpenden skinfold calipers were used for the skinfold measures. All measuring was done by trained measurers.

Subjects were asked to fill in a questionnaire recalling the age at which they started to menstruate and also how certain they were of this date (Appendix B).

Participants were also given questionnaires regarding their athletic background during adolescence and present training practices (Appendices C & D).

Two vials of blood (10cc each) were taken from the anticubital vein by a trained nurse. One vial was centrifuged within three hours and the serum separated from the plasma. The specimens were refrigerated over-night and delivered to the lab the next day. B.C. Bio-Medical Laboratories (Burnaby, B.C.) did the analysis. The blood was analysed for circulation iron, total iron binding capacity (TIBC), percent saturation, ferritin, red blood cells (RBC), hemoglobin (Hb), and hematocrit (HCT).
Analysis

Anthropometric Values

Absolute values were examined for anomalies, but the primary comparison was done using Phantom Z-values and visual graphs, which are part of the Phantom method.

The following formula was used to find the Phantom Z-values:

\[ Z = \frac{1}{s} \left( \frac{v \cdot 170.18^d}{h} - p \right) \]

where:
- \( z \) is a proportionality value z-score
- \( s \) is the phantom standard deviation for the given variable
- \( v \) is any variable
- 170.18 is the phantom height constant
- \( h \) is the subject's height
- \( d \) is a dimensional exponent which is 1 for all heights, lengths, breadths, girths, and skinfold thicknesses; 2 for all area values; and 3 for all weights and volumes
- \( p \) is the phantom value for the variable

(Ross & Ward, 1982)

For the Phantom variables and standard deviations see Appendix E.

Using these Z-values, proportional body masses were derived for the four components - fat, bone, muscle, and residual mass. This is termed the Drinkwater Tactic of fractionated body masses. (Drinkwater & Ross, 1980). The formula used was:

\[ M = \frac{(z \times s + p)}{\left( \frac{170.18^d}{h} \right)} \]

where:
- \( M \) is any mass such as fat mass, skeletal mass, muscle mass, or residual mass
- \( z \) is the obtained mean phantom z-value for the subject associated with a given mass
- \( s \) is the phantom standard deviation for the mass
- \( p \) is the phantom value for the mass
- \( h \) is the obtained height for the subject
- \( d \) is a dimensional exponent which has a value
of 3 in this application

170.18 is the phantom height constant

The variables used for the estimation of the different masses are:

- **fat:**
  - triceps skinfold (mm)
  - subscapular skinfold (kg)
  - suprailiac skinfold
  - abdominal skinfold
  - front thigh skinfold
  - medial calf skinfold

- **skeletal:**
  - bi-epicondylar humerus width (cm)
  - bi-epicondylar femur width (kg)
  - wrist girth
  - ankle girth

- **muscle:**
  - relaxed arm girth - triceps skinfold (cm)
  - chest girth - subscapular skinfold (kg)
  - thigh girth - front thigh skinfold
  - calf girth - medial calf skinfold
  - forearm girth

- **residual:**
  - biacromial breadth (cm)
  - transverse chest width (kg)
  - biliocristal breadth
  - anterior-posterior chest depth

According to Drinkwater and Ross (1980) the Drinkwater Tactic has a number of attractive features:

1. "It accounts for the body mass, that is, the sum of the four components approximates body mass (with an absolute error tolerance of 5% (...)). This method has the theoretical advantage of permitting all four components to be derived independently of total body mass, with the total mass serving as a major validity criterion.

2. The fat mass or percent fat is not a maverick estimation compared to anthropometrical regression equations for prediction of body fat, as proposed in the literature, but is somewhere in the mid-range of these predicted values." (1980:186)

and possibly:

3. Due to its usage of the Phantom unisex
figure as a reference point, the Drink-water Tactic can compare any measurement of a tissue mass between groups.

The percent error will also be calculated using the formula:

\[
\% \text{ error} = \left( \frac{\text{predicted body mass} - \text{obtained body mass}}{\text{obtained body mass}} \right) \times 100
\]

where: predicted body mass = fat mass + muscle mass + skeletal mass + residual mass

obtained body mass = scale weight

Body Composition

Body densities were derived from hydrostatic weighing and Siri's formula (1956). Skinfold measures of the three groups were compared using the total of the six skinfolds taken and were also used in the fractionation of body mass.

Statistical Analysis

Tables and graphs were used to show relationships and comparisons of proportions (lengths, breadths, girths), skinfold measures and body masses between group one, group two, and group three - the reference group. The Phantom Z-values were plotted on graphs and the horizontal bars were set at one standard error on either side of the mean. When the groups' bars did not overlap, significance was inferred (Ross et al., 1982).

A two-tailed t-test was used to examine the differences in densities between group one and group two.

Age at Menarche

Age at menarche group differences were examined using a standard two-tailed t-test. Members of group one and two were then divided into early and late maturers using the average age of menarche of the reference group as the division, and analysed using a chi-square test in order to determine if there was a
statistically significant greater number of early maturers in either group.  

Somatotype Analysis  
Somatotype was calculated using the Heath-Carter method (Carter, 1975).  

Training and Athletic Background  
The groups were sub-divided into those who trained five times per week or more and those who trained less than five times per week. (Three to five times per week of aerobic exercise have been recommended for best results of cardiovascular conditioning (American College of Sports Medicine, 1975; de Vries, 1975). More than five times per week has not been shown to improve cardiovascular condition faster than five times. However, five times per week improves functional ability faster than three times per week (given the same intensity). This 'cut-off point' of five times per week was chosen also because training five times or more per week requires, on average, more than every other day and requires more of a commitment from the runner. Four times per week or less averages every other day or less for training.)  
The groups were also divided according to the number of years individuals had been running. The three categories were: a. more than five years; b. two to five years; and c. less than two years. These categories were chosen somewhat arbitrarily but so that the women were divided into long-time runners, medium, and relative beginners (particularly with respect to the 10,000 meter distance).  

From the questionnaire on physical activity during adolescence the women in each group were classified as 'active' during adolescence or 'non-
active' during adolescence. Participation in extra-curricular activities was taken as 'active'. School intramural participation was taken as 'non-active'.

All of these groups were analysed for frequency distribution using chi-square analyses.

Level of Significance

The 0.05 level of confidence was chosen arbitrarily as the level of significance for all of the above analyses.

Iron Stores

Each parameter indicating iron stores was surveyed to see if all members and group means fell within normal limits.
CHAPTER IV
RESULTS AND DISCUSSION

This study compared two groups of female distance runners of different proficiency levels with respect to anthropometrical measurements, training backgrounds, age of menarche, and iron stores, and contrasted these groups with controls in anthropometrical measurements.

Since this was a descriptive study, much use was made of graphs and tables and only when paired mean scores showed specific differences was statistical analysis used.

This chapter is divided into several parts: specific results and discussion of anthropometrical assessment; training practices and athletic background; age of menarche data; very briefly, iron stores; and a general discussion concerning all aspects of the study.

Anthropometrical Data

Size

Table I gives the mean size data (height and weight) for each of the three groups as well as age.

<table>
<thead>
<tr>
<th>TABLE I: SIZE</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>± standard deviations</td>
<td></td>
</tr>
<tr>
<td>group 1</td>
<td>group 2</td>
<td>group 3</td>
</tr>
<tr>
<td>height (cm)</td>
<td>162.26 ± 3.57</td>
<td>163.68 ± 6.52</td>
</tr>
<tr>
<td>weight (kg)</td>
<td>53.97 ± 4.72</td>
<td>57.01 ± 6.32</td>
</tr>
<tr>
<td>age (years)</td>
<td>27.45 ± 6.9</td>
<td>31.92 ± 6.8</td>
</tr>
</tbody>
</table>
Group one, the faster runners, was the shortest and lightest and much more homogeneous in all measures than the other two groups. They are similar to elite male distance runners who are shorter and lighter than the general population (de Garay et al., 1974; Hirata, 1966). Two previous reports of characteristics of female distance runners showed them to be tall and light (Wilmore & Brown, 1974; Brown & Wilmore, 1971).

Table II gives the absolute means and standard deviations for the three groups for length, breadth, and girth measurements. (Appendix F contains the raw anthropometrical data for each subject in groups one and two.)

The general trend is for group one to be smaller on all measures. But, since they are shorter in stature, this would explain all the other height measures being smaller; also the lower weight and shorter stature seem to be reflected in smaller girth and breadth measures. Absolute values are the basic information of anthropometry studies but have limited use when comparing body structure. They show size differences but have to be transformed for use in further analyses.

Table III shows the means and standard deviations for the Z-values based on the unisex Phantom reference; figures 1, 2, 3, and 4 show these values in graph form.
<table>
<thead>
<tr>
<th>Anthropometric Measurement</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>acromial height</td>
<td>130.8 ± 3.4</td>
<td>132.9 ± 6.3</td>
<td>134.6 ± 5.8</td>
</tr>
<tr>
<td>radial height</td>
<td>100.4 ± 2.6</td>
<td>102.2 ± 5.4</td>
<td>103.5 ± 4.5</td>
</tr>
<tr>
<td>stylion height</td>
<td>78.3 ± 2.9</td>
<td>79.7 ± 4.0</td>
<td>80.8 ± 3.6</td>
</tr>
<tr>
<td>dacty lion height</td>
<td>60.9 ± 2.7</td>
<td>61.1 ± 4.1</td>
<td>62.4 ± 3.4</td>
</tr>
<tr>
<td>tibial height</td>
<td>42.3 ± 2.9</td>
<td>42.9 ± 4.1</td>
<td>42.7 ± 2.3</td>
</tr>
<tr>
<td>spinale height</td>
<td>90.1 ± 3.1</td>
<td>91.6 ± 5.1</td>
<td>91.0 ± 5.5</td>
</tr>
<tr>
<td>trochanterion height</td>
<td>82.3 ± 3.2</td>
<td>85.1 ± 4.8</td>
<td>not measured</td>
</tr>
<tr>
<td>foot length</td>
<td>23.9 ± 1.0</td>
<td>24.0 ± 1.3</td>
<td>23.8 ± 1.1</td>
</tr>
<tr>
<td>sitting height</td>
<td>85.0 ± 2.3</td>
<td>86.2 ± 3.5</td>
<td>88.4 ± 2.9</td>
</tr>
<tr>
<td>arm girth relaxed</td>
<td>24.9 ± 2.0</td>
<td>26.1 ± 1.4</td>
<td>25.9 ± 1.9</td>
</tr>
<tr>
<td>arm girth flexed</td>
<td>26.6 ± 1.5</td>
<td>27.2 ± 1.5</td>
<td>27.1 ± 1.4</td>
</tr>
<tr>
<td>forearm girth</td>
<td>23.0 ± 0.9</td>
<td>23.4 ± 1.2</td>
<td>23.6 ± 1.5</td>
</tr>
<tr>
<td>wrist girth</td>
<td>14.7 ± 0.5</td>
<td>15.0 ± 0.7</td>
<td>14.9 ± 0.7</td>
</tr>
<tr>
<td>chest girth</td>
<td>82.3 ± 3.3</td>
<td>84.3 ± 3.8</td>
<td>84.6 ± 4.5</td>
</tr>
<tr>
<td>waist girth</td>
<td>66.3 ± 3.3</td>
<td>68.0 ± 4.4</td>
<td>68.0 ± 4.0</td>
</tr>
<tr>
<td>thigh girth</td>
<td>53.7 ± 3.6</td>
<td>55.8 ± 3.8</td>
<td>55.6 ± 3.4</td>
</tr>
<tr>
<td>calf girth</td>
<td>33.4 ± 2.0</td>
<td>34.2 ± 2.1</td>
<td>34.7 ± 2.1</td>
</tr>
<tr>
<td>ankle girth</td>
<td>20.7 ± 1.0</td>
<td>21.2 ± 1.3</td>
<td>20.9 ± 1.3</td>
</tr>
</tbody>
</table>

cont'd...
<table>
<thead>
<tr>
<th>Measurement</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biacromial breadth</td>
<td>35.4 ± 1.0</td>
<td>35.1 ± 1.4</td>
<td>35.5 ± 1.6</td>
</tr>
<tr>
<td>Biliocristal breadth</td>
<td>27.0 ± 1.6</td>
<td>28.1 ± 1.6</td>
<td>27.5 ± 1.9</td>
</tr>
<tr>
<td>Transverse chest width</td>
<td>25.0 ± 1.1</td>
<td>25.7 ± 1.5</td>
<td>24.5 ± 1.3</td>
</tr>
<tr>
<td>Biepicondylar humerus width</td>
<td>6.2 ± 0.4</td>
<td>6.2 ± 0.4</td>
<td>6.3 ± 0.3</td>
</tr>
<tr>
<td>Biepicondylar femur width</td>
<td>8.7 ± 0.3</td>
<td>9.0 ± 0.4</td>
<td>9.0 ± 0.4</td>
</tr>
<tr>
<td>Anterior-posterior chest depth</td>
<td>16.5 ± 1.0</td>
<td>17.4 ± 1.4</td>
<td>16.8 ± 2.3</td>
</tr>
<tr>
<td>Total arm (acromial - dactylion)</td>
<td>69.9 ± 2.2</td>
<td>71.8 ± 2.9</td>
<td>72.2 ± 3.3</td>
</tr>
<tr>
<td>Forearm (radial - stylion)</td>
<td>22.1 ± 1.9</td>
<td>22.6 ± 2.5</td>
<td>22.7 ± 1.4</td>
</tr>
<tr>
<td>Hand (stylion - dactylion)</td>
<td>17.5 ± 1.3</td>
<td>18.5 ± 1.3</td>
<td>18.4 ± 1.2</td>
</tr>
<tr>
<td>Upper arm (acromial - radial)</td>
<td>30.4 ± 1.4</td>
<td>30.7 ± 1.5</td>
<td>31.1 ± 1.8</td>
</tr>
<tr>
<td>Arm (acromial - stylion)</td>
<td>52.5 ± 1.9</td>
<td>53.3 ± 3.6</td>
<td>53.8 ± 2.9</td>
</tr>
<tr>
<td>Leg (height - sitting height)</td>
<td>77.2 ± 2.9</td>
<td>77.5 ± 4.5</td>
<td>77.3 ± 4.3</td>
</tr>
<tr>
<td>Thigh (leg - tibial height)</td>
<td>34.9 ± 2.1</td>
<td>34.6 ± 2.4</td>
<td>34.6 ± 2.2</td>
</tr>
<tr>
<td>Measure</td>
<td>Group 1</td>
<td>Group 2</td>
<td>Group 3</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>---------------</td>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Hand length</td>
<td>-0.646 ± 1.57</td>
<td>0.545 ± 2.10</td>
<td>0.020 ± 1.37</td>
</tr>
<tr>
<td>Forearm length</td>
<td>-1.058 ± 1.38</td>
<td>-0.842 ± 1.45</td>
<td>-0.903 ± 0.75</td>
</tr>
<tr>
<td>Upper arm length</td>
<td>-0.366 ± 0.63</td>
<td>-0.335 ± 0.71</td>
<td>-0.346 ± 0.61</td>
</tr>
<tr>
<td>Sitting height</td>
<td>-0.159 ± 0.46</td>
<td>-0.065 ± 0.55</td>
<td>0.205 ± 0.47</td>
</tr>
<tr>
<td>Thigh length</td>
<td>0.567 ± 1.07</td>
<td>0.253 ± 1.17</td>
<td>0.038 ± 0.72</td>
</tr>
<tr>
<td>Tibiale laterale length</td>
<td>-0.189 ± 0.97</td>
<td>-0.095 ± 1.19</td>
<td>-0.392 ± 0.46</td>
</tr>
<tr>
<td>Foot length</td>
<td>-0.375 ± 0.97</td>
<td>-0.454 ± 0.93</td>
<td>-0.866 ± 0.78</td>
</tr>
<tr>
<td>Biepicondylar humerus width</td>
<td>0.000 ± 0.99</td>
<td>-0.036 ± 0.98</td>
<td>-0.161 ± 0.88</td>
</tr>
<tr>
<td>Biacromial breadth</td>
<td>-0.459 ± 0.59</td>
<td>-0.781 ± 1.00</td>
<td>-0.822 ± 0.76</td>
</tr>
<tr>
<td>Transverse chest width</td>
<td>-0.952 ± 0.64</td>
<td>-0.663 ± 0.93</td>
<td>-1.606 ± 0.72</td>
</tr>
<tr>
<td>Anterior-posterior chest depth</td>
<td>-0.127 ± 0.85</td>
<td>0.412 ± 0.97</td>
<td>-0.025 ± 1.10</td>
</tr>
<tr>
<td>Biiliocristal breadth</td>
<td>-0.265 ± 1.10</td>
<td>0.208 ± 0.97</td>
<td>-0.360 ± 1.01</td>
</tr>
<tr>
<td>Biepicondylar femur width</td>
<td>-0.764 ± 0.76</td>
<td>-0.380 ± 0.71</td>
<td>-0.741 ± 0.87</td>
</tr>
<tr>
<td>Wrist girth</td>
<td>-1.327 ± 0.90</td>
<td>-1.112 ± 1.04</td>
<td>-1.484 ± 0.97</td>
</tr>
<tr>
<td>Forearm girth</td>
<td>-0.720 ± 0.73</td>
<td>-0.582 ± 0.81</td>
<td>-0.637 ± 1.19</td>
</tr>
<tr>
<td>Arm girth relaxed</td>
<td>-0.318 ± 0.94</td>
<td>0.130 ± 0.65</td>
<td>-0.112 ± 0.89</td>
</tr>
<tr>
<td>Measurement</td>
<td>Group 1</td>
<td>Group 2</td>
<td>Group 3</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------</td>
<td>-----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Chest girth</td>
<td>-0.298 ± 0.67</td>
<td>-0.019 ± 0.99</td>
<td>-0.177 ± 0.95</td>
</tr>
<tr>
<td>Waist girth</td>
<td>-0.532 ± 0.91</td>
<td>-0.262 ± 1.16</td>
<td>-0.450 ± 0.96</td>
</tr>
<tr>
<td>Thigh girth</td>
<td>0.121 ± 0.86</td>
<td>0.494 ± 0.87</td>
<td>0.322 ± 0.83</td>
</tr>
<tr>
<td>Calf girth</td>
<td>-0.097 ± 0.86</td>
<td>0.134 ± 1.00</td>
<td>0.191 ± 0.89</td>
</tr>
</tbody>
</table>
FIGURE 1: MEAN Z-VALUES
LENGTHS, BREADTHS, GIRTHS
GROUP 1 VS GROUP 3

-2 -1 0 1

GROUP 1 ——
GROUP 3 ——

HAND LENGTH (STYLIILON-DACTYLIION)
FOREARM LENGTH (RADIALE-STYLIILON)
UPPER ARM LENGTH (ACROMIALE-RADIALE)
SITTING HEIGHT
THIGH LENGTH (HT-SIT-HT.-TIBIALE HT.
TIBIALE LATERALE HEIGHT
FOOT LENGTH (AKROPODION-PTERANION)

BI-EPICONDYLAR HUMERUS WIDTH
BIACROMIAL BREADTH
TRANSVERSE CHEST BREADTH
ANTERIOR-POSTERIOR CHEST DEPTH
BIILIIOCRISTAL BREADTH
BI-EPICONDYLAR FEMUR WIDTH

WAIST GIRTH (DISTAL STYLOID PROCESSE
FOREARM GIRTH (MAXIMUM RELAXED)
ARM GIRTH RELAXED
CHEST GIRTH (MESOSTERNALE)
WAIST GIRTH (MINIMAL CIRCUMFERENCE)
THIGH GIRTH (1 CM DISTAL GLUTEAL LIN
CALS GIRTH (MAXIMUM CIRCUMFERENCE)
FIGURE 2: MEAN Z-VALUES
LENGTHS, BREADTHS, GIRTHS
GROUP 2 VS GROUP 3

HAND LENGTH (STYLIOn-DACTYLI0N)
FOREARM LENGTH (RADIALE-STYLI0N)
UPPER ARM LENGTH (ACROMIALE-RADIALE)
SITTING HEIGHT
THIGH LENGTH (HT-SIT.HT.-TIBIALE HT.
TIBIALE LATERALE HEIGHT
FOOT LENGTH (AKROPODIOn-PTERNION)

BI-EPICOIN).LAR HUMERUS WIDTH
BIACROMIAL BREADTH
TRANSVERSE CHEST BREADTH
ANTERIOR-POSTERIOR CHEST DEPTH
BIILIACRISTAL BREADTH
BI-EPICOIN).LAR FEMUR WIDTH

WAIST GIRTH (DISTAL STYLOID PROCESSE
FOREARM GIRTH (MAXIMUM RELAXED)
ARM GIRTH RELAXED
CHEST GIRTH (MESOSTEANALE)
WAIST GIRTH (MINIMAL CIRCUMFERENCE)
THIGH GIRTH (1 CH DISTAL GLUTEAL LIN
CALF GIRTH (MAXIMUM CIRCUMFERENCE)
FIGURE 3: MEAN Z-VALUES
LENGTHS, BREADTHS, GIRTHS
GROUP 1 VS GROUP 2

Hand length (styliion-dactyliion)
Forearm length (radiale-styliion)
Upper arm length (acrohiale-radiale)
Sitting height
Thigh length (ht-sit.h.-tibiale ht.
Tibiale laterale height
Foot length (akropodion-pterion)

Basi-epicondylar humerus width -
Biacromial breadth
Transverse chest breadth
Anterior-posterior chest depth
Biliochristal breadth
Basi-epicondylar femur width

Waist girth (distal styloid process)
Forearm girth (maximum relaxed)
Arm girth relaxed
Chest girth (mesosternale)
Waist girth (minimal circumference)
Thigh girth (1 cm distal gluteal line
Calf girth (maximum circumference)
FIGURE 4: MEAN Z-VALUES
LENGTHS, BREADTHS, GIRTHS
GROUP 1 VS GROUP 2 VS GROUP 3

HAND LENGTH (STYLION-DACTYLION)
FOREARM LENGTH (RADIALE-STYLION)
UPPER ARM LENGTH (ACRONIALE-RADIALE)
SITTING HEIGHT
THIGH LENGTH (HT-SIT.HT.-TIBIALE HT.
TIBIALE LATERALE HEIGHT
FOOT LENGTH (AKROPODION-PTERION)

BI-EPICONDYLAR HUMERUS WIDTH
BIACROHIAL BREADTH
TRANSVERSE CHEST BREADTH
ANTERIOR-POSTERIOR CHEST DEPTH
BIILIACRISTAL BREADTH
BI-EPICONDYLAR FEMUR WIDTH

WRIST GIRTH (DISTAL STYLOID PROCESSE
FOREARM GIRTH (MAXIMUM RELAXED)
ARM GIRTH RELAXED
CHEST GIRTH (MESOSTERNALE)
WAIST GIRTH (MINIMAL CIRCUMFERENCE)
THIGH GIRTH (1 CM DISTAL GLUTEAL LIN
CALF GIRTH (MAXIMUM CIRCUMFERENCE)
As can be seen from the graphs no group shows a marked difference from the other two groups on any of the measurements. The largest difference shows group three to have a smaller transverse chest width than groups one and two. Since the members in groups one and two engage in an activity which requires large amounts of oxygen, they could have, by expanding their chest on inhalation, caused a permanent increase in the size of the ribcage. However, this may indicate that women who have a larger transverse chest, or chest cavity, may find running more comfortable and therefore stay with the sport at least long enough to build up stamina for the ten kilometer distance.

There are three areas where a small difference between groups is shown. These are: smaller hand length in group one compared with groups two and three, a larger sitting height in group three compared with groups one and two, and a shorter foot length in group three compared with groups one and two.

The larger sitting height in group three is not shown to be balanced by a shorter leg length (thigh length and tibiale height) but looking at figures 1 and 2 we can see that, in fact, group three has a shorter thigh length than group one and is located in the lower portion of the standard error for group two. This difference may show up to a greater extent in a larger sample size.

Groups one and two are relatively similar in anthropometrical characteristics with group three differing from one or the other. Group three is smaller than group one in biacromial breadth with group two the same as group three but overlapping group one. Group two is larger than group three.
in biiliocristal breadth with groups one and three the same but group one overlapping group two.

Proportional Body Masses

The Drinkwater Tactic was used to calculate proportional body masses. Table IV gives the values for the three groups, table V shows the proportional body masses in phantom Z-values, and figures 5, 6, 7, and 8 show this in graph form.

<table>
<thead>
<tr>
<th>TABLE IV: PROPORTIONAL BODY MASSES (DRINKWATER TACTIC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>adipose mass</td>
</tr>
<tr>
<td>kg</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>skeletal mass</td>
</tr>
<tr>
<td>kg</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>muscle mass</td>
</tr>
<tr>
<td>kg</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>residual mass</td>
</tr>
<tr>
<td>kg</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>predicted mass</td>
</tr>
<tr>
<td>obtained mass</td>
</tr>
<tr>
<td>% error</td>
</tr>
</tbody>
</table>

In group one the percentage fat is lower than in group two and considerably lower than in group three. The skeletal and residual masses are relatively the same for all three groups but the muscle mass in group three was lower than in groups one and two. Hebbelinck et al. (1980) found their female Olympic rowers to differ similarly from a
reference group and stated "the tissues represented by these masses (fat and muscle) were more susceptible to training effects than the skeletal and residual mass tissues." (1980:261)

<table>
<thead>
<tr>
<th>TABLE V: PROPORTIONAL BODY MASSES (DRINKWATER TACTIC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHANTOM Z-VALUES</td>
</tr>
<tr>
<td>---------------------------------------------------------</td>
</tr>
<tr>
<td>group 1</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>adipose mass</td>
</tr>
<tr>
<td>bone mass</td>
</tr>
<tr>
<td>muscle mass</td>
</tr>
<tr>
<td>residual mass</td>
</tr>
</tbody>
</table>

All three groups fall below the Phantom in proportional adipose mass and the deviation from zero is greater as the proficiency of the runners increases with group one deviating the most. Group three may fall below zero due to the nature of the sample (university women predisposed to exercise) and since group one spends more time training this could explain why they have the smallest mass. While groups one and two do not vary much in bone mass, it is interesting to note that group two has a greater proportional bone mass than group three and that group one falls on the lower side of group two. This would seem to indicate that group two tended to be larger framed than the other two groups.

Groups one and two have a greater proportional muscle mass than group three which is not surprising due to their training. The residual mass is greater in groups one and two than in group three.
FIGURE 5: PROPORTIONAL BODY MASSES  
(DRINKWATER TACTIC)  
MEAN Z-VALUES GROUP 1 VS GROUP 3

group 1

group 3

WEIGHT
ADIPOSE MASS
BONE MASS
MUSCLE MASS
RESIDUAL MASS

FIGURE 6: PROPORTIONAL BODY MASSES  
(DRINKWATER TACTIC)  
MEAN Z-VALUES GROUP 2 VS GROUP 3

group 2

group 3

WEIGHT
ADIPOSE MASS
BONE MASS
MUSCLE MASS
RESIDUAL MASS

FIGURE 7: PROPORTIONAL BODY MASSES  
(DRINKWATER TACTIC)  
MEAN Z-VALUES GROUP 1 VS GROUP 2

group 1

group 2

WEIGHT
ADIPOSE MASS
BONE MASS
MUSCLE MASS
RESIDUAL MASS

FIGURE 8: PROPORTIONAL BODY MASSES  
(DRINKWATER TACTIC)  
MEAN Z-VALUES GROUP 1 VS GROUP 2 VS GROUP 3

group 1

group 2

group 3

WEIGHT
ADIPOSE MASS
BONE MASS
MUSCLE MASS
RESIDUAL MASS
Somatotyping

The somatotypes of the three groups are presented in Table VI. Group one had a lower value of endomorphy (3.0) than groups two and three which were identical (4.0). This difference and this similarity of endomorphic values of the groups do not correspond precisely with values of percent fat or fat mass for the three groups. In these latter two measures, the difference between groups one and two are similar to the differences between groups two and three. The anomaly may lie in the way endomorphy, percent fat, and fat mass are estimated. For endomorphy, calculations are based on upper body skinfold measures. For fat mass and percentage fat, estimates are made from measures which include leg skinfolds. The legs are an important specific region for fat deposition in women (Edwards, 1951).

Mesomorphy and ectomorphy were similar for all groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Endomorphy</th>
<th>Mesomorphy</th>
<th>Ectomorphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.0</td>
<td>3.4</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>1.04</td>
<td>0.82</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>1.0-4.5</td>
<td>2.1-4.9</td>
<td>1.5-4.5</td>
</tr>
<tr>
<td>2</td>
<td>4.0</td>
<td>3.7</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>0.81</td>
<td>0.83</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>3.0-5.5</td>
<td>2.7-5.3</td>
<td>1.0-4.0</td>
</tr>
<tr>
<td>3</td>
<td>4.0</td>
<td>3.5</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>1.24</td>
<td>0.95</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Body Composition

Table VII gives the means and standard deviations of the six skinfold measures.

While the difference in total skinfolds between
group one and two was not statistically significant
it is fairly large. Non-significance may be ex-
plained by the small sample numbers.

For four of the sites, groups two and three
are similar and group one has the lowest values.
The abdominal skinfold size increased progressively
from group one through group three, although the
difference between group one and two was larger
than the difference between groups two and three.
Groups one and two were similar in front thigh
skinfold values with group three having a much
larger value. This may be related to their exercise
which is primarily of the lower body but this does
not explain the data on medial calf skinfolds.
Group one had a much lower medial calf skinfold
value than did groups two and three which were
similar.

<table>
<thead>
<tr>
<th>TABLE VII: SKINFOLD MEASURES (MM ± STANDARD DEVIATION)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>triceps</td>
</tr>
<tr>
<td>subscapular</td>
</tr>
<tr>
<td>suprailiac</td>
</tr>
<tr>
<td>abdominal</td>
</tr>
<tr>
<td>front thigh</td>
</tr>
<tr>
<td>medial calf</td>
</tr>
<tr>
<td>total</td>
</tr>
</tbody>
</table>

Table VIII gives the proportion Z-values for
each of the six skinfold sites and figures 9, 10,
11 and 12 show these in graph form. Group one is
significantly smaller on all six skinfolds than
group three while group two differs from group three only on the abdominal and front thigh sites. Group one is significantly smaller than group two on all but the front thigh site.

FIGURE 9: SKINFOLD MEASURES
PROPORTIONAL Z-VALUES
GROUP 1 VS GROUP 3

FIGURE 10: SKINFOLD MEASURES
PROPORTIONAL Z-VALUES
GROUP 2 VS GROUP 3
<table>
<thead>
<tr>
<th>Skinfold Location</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triceps</td>
<td>-0.508 ± 0.91</td>
<td>0.259 ± 0.57</td>
<td>0.594 ± 1.32</td>
</tr>
<tr>
<td>Subscapular</td>
<td>-1.583 ± 0.71</td>
<td>-0.889 ± 0.74</td>
<td>-0.896 ± 1.02</td>
</tr>
<tr>
<td>Suprailiac</td>
<td>-1.775 ± 0.70</td>
<td>-1.181 ± 0.79</td>
<td>-1.146 ± 1.07</td>
</tr>
<tr>
<td>Abdominal</td>
<td>-2.134 ± 0.43</td>
<td>-1.425 ± 0.55</td>
<td>-1.095 ± 0.94</td>
</tr>
<tr>
<td>Front thigh</td>
<td>-0.738 ± 0.76</td>
<td>-0.636 ± 0.51</td>
<td>0.087 ± 1.07</td>
</tr>
<tr>
<td>Medial calf</td>
<td>-1.472 ± 1.09</td>
<td>-0.397 ± 1.09</td>
<td>-0.090 ± 1.39</td>
</tr>
<tr>
<td>Weight</td>
<td>-0.265 ± 0.61</td>
<td>-0.058 ± 0.70</td>
<td>-0.265 ± 0.71</td>
</tr>
</tbody>
</table>
Densities were derived from hydrostatic weighing (groups one and two only). Table IX gives the obtained values, standard deviations and ranges. Though the groups were not significantly different the body composition implications are the same as
for the sum of skinfolds and the Drinkwater Tactic (the greater the density the lower the amount of body fat). Group one had a greater density than group two and was a much more homogenous group.

<table>
<thead>
<tr>
<th>TABLE IX: HYDROSTATIC WEIGHING DENSITY VALUES</th>
</tr>
</thead>
</table>
group 1 1.059 ± 0.007 range 1.049 - 1.070    |
group 2 1.047 ± 0.010 range 1.027 - 1.061    |

Age at Menarche

Table X shows the mean age of menarche for the three groups.

| TABLE X: AGE OF MENARCHE (YEARS ± STANDARD DEVIATION) |
group 1 14.14 ± 1.10 range 12.58 - 15.58    |
group 2 12.50 ± 0.74 range 11.75 - 14.3    |
group 3 12.90 ± 1.10                        |

When the results for groups one and two were analysed using a two-tailed t-test no significant difference was found. Members of groups one and two were then designated either 'early' or 'late' maturers using 12.9 years as the dividing age (12.9 years was the age at menarche of group 3) and the numbers were analysed using a chi-square test for the possibility that the faster group would have more later maturers. The results showed this to be so at the 0.02 level of significance (Table XI).

Age at menarche has not heretofore been looked at when studying females past the teenage years but
data shown in Table XI suggests that perhaps it is an important factor when studying the function of female distance runners.

<table>
<thead>
<tr>
<th>TABLE XI: AGE OF MENARCHE ABOVE AND BELOW AVERAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 12.9 years</td>
</tr>
<tr>
<td>group 1</td>
</tr>
<tr>
<td>group 2</td>
</tr>
<tr>
<td>chi-square</td>
</tr>
</tbody>
</table>

Training Practices and Athletic Background

The frequency responses to the questionnaires are given in tables XII, XIII, and XIV. Chi-square analysis showed significant differences between the groups in number of days per week participants ran and the number of years they had been running. There was no significant difference between the groups in activity in adolescence. This would suggest that the more frequently one trains the faster one becomes in distance running.

<table>
<thead>
<tr>
<th>TABLE XII: TRAINING PRACTICES NUMBER OF DAYS PER WEEK</th>
</tr>
</thead>
<tbody>
<tr>
<td>5+ times per week</td>
</tr>
<tr>
<td>group 1</td>
</tr>
<tr>
<td>group 2</td>
</tr>
<tr>
<td>chi-square</td>
</tr>
</tbody>
</table>
TABLE XIII: TRAINING PRACTICES

<table>
<thead>
<tr>
<th>NUMBER OF YEARS RUNNING</th>
<th>GROUP 1</th>
<th>GROUP 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;5 years</td>
<td>7 subjects</td>
<td>0</td>
</tr>
<tr>
<td>2 - 5 years</td>
<td>4 subjects</td>
<td>4</td>
</tr>
<tr>
<td>&lt;2 years</td>
<td>0</td>
<td>8 subjects</td>
</tr>
</tbody>
</table>

chi-square = 14.75 significant at 0.01 level

TABLE XIV: ACTIVITY IN ADOLESCENCE

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>GROUP 1</th>
<th>GROUP 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>active</td>
<td>8 subjects</td>
<td>5 subjects</td>
</tr>
<tr>
<td>non-active</td>
<td>3 subjects</td>
<td>7 subjects</td>
</tr>
</tbody>
</table>

chi-square = 2.25 not significant

This could be explained by reasoning that as training becomes more frequent so does the intensity. In order to know the intensity of the training it is necessary to study the physiological make-up of the subject - at what percentage of their maximal ability they are training and if they are training above or below their anaerobic threshold. Physiological make-up was not studied in this research.

Skinfold Measures verses Training Frequency

A biserial correlation was done comparing total skinfold thicknesses to the amount of training done. The correlation (r = -0.335) was not significant with this small sample size.

Iron Stores

Iron store measurements were taken to rule
out the possibility that the women in group two were slower because of lowered iron stores. Table XV shows this is not the cause of their lower proficiency level. All group values for all measures were within the ranges of normal as stated by Clement and Asmundson (1982).

<table>
<thead>
<tr>
<th>TABLE XV: IRON STORES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>group 1</td>
</tr>
<tr>
<td>Hb (gm)</td>
</tr>
<tr>
<td>RBC (million)</td>
</tr>
<tr>
<td>HCT</td>
</tr>
<tr>
<td>Iron ( /dl)</td>
</tr>
<tr>
<td>TIBC ( /dl)</td>
</tr>
<tr>
<td>% sat</td>
</tr>
<tr>
<td>Ferritin ( /ml)</td>
</tr>
</tbody>
</table>

Hb = hemoglobin  RBC = red blood cells  HCT = hematocrit  TIBC = total iron binding capacity  % sat = % saturation

* Clement & Asmundson, 1982

Discussion

The results show that the runners are shorter and lighter than the reference group and that the higher the proficiency level the more they differ from that group. They are lighter not only because they are shorter but also because they have less body fat. The shorter stature is in accordance with data found for male distance runners (de Garay et al. 1974; Pipes, 1977) who are usually shorter than average. The biomechanical advantage afforded a shorter stature may be as Tanner (1964) stated:
"a small man needs less energy and smaller muscles to run at a constant pace (...) He is, therefore, best adapted to long distance running and is typically a small, short legged, narrow shouldered athlete relatively lacking in muscle".

This shorter stature of the women of group one is not in agreement with data found for female distance runners by Brown and Wilmore (1971) and Wilmore and Brown (1974). They also had small sample sizes but their runners were relatively tall in relation to normal women. In a study by Slaughter et al. (1981) where five groups of female athletes were compared in relation to height, weight, and other variables, the gymnasts were the shortest group and the cross country runners (162.8 cm, 51.0 kg) were a close second. The distances run and the type of event are different in all four studies (Wilmore & Brown, Brown & Wilmore, Slaughter et al., and the present study) and this makes it impossible to determine any possible association between event and trend of height of successful runners. So, for determining the optimum height of women for success in distance running more research is needed, and especially in the different distance events. With male distance runners, the height becomes larger from the sprints to 3000 to 5000 meters and then gets smaller again as the distance increases, with the marathoners being the shortest. Research is needed on females who specialize in the running events to see if the same differentiation in height occurs.

The runners are also lower in body fat than the reference group - the higher the proficiency level of the group the lower the amount of fat. This is in concurrence with the findings of Day et al. (1977) who found less body fat as the proficiency of the distance runners increased. Body composition was looked at using three techniques - the Drinkwater Tactic, the sum of
six skinfold measures, and hydrostatic weighing. All three techniques showed the same trend - the faster group had less fat than the slower group, and both were lower than the reference group. This could be explained by the amount of training but a biserial correlation showed no significant relationship between individuals' body fat and training - possibly due to small sample size. It is also possible that the runners with the least amount of fat will excel in distance running and, meeting with success, will stay with the sport.

Conley et al. (1981) found their fourteen trained, competition experienced 10,000 meter runners (average age 24.1 years, average velocity 7.04 minutes per mile) to be lower in body fat than non-athletes. This was a sample selected from the top twenty women in one 10,000 meter road race in which 300 women entered. The percent body fat was not correlated to race time in this group.

The general trend in aging in our society is to increased body fat and decreased muscle mass. In this study the average ages of group one and two were much older than group three, but the body fat was lower and muscle mass higher. These trends show a distinct departure from the usual changes associated with the aging process in our society.

It is interesting to note (although difficult to explain) the later age of menarche in the faster group, with a significant number of participants being later maturers even though age at menarche was not statistically significant. When the groups were divided into early and late maturers a significantly greater number of the fast group were later maturers. Sidhu and Singal (1981) found their adult sportswomen had experienced a later age at menarche than did non-athletic women of the same age group.
The faster group had been running a greater number of years and ran more times per week than group two.

Group two and group three were relatively similar in all aspects measured although there was a trend for group two to have lower skinfold measures. This general similarity could be explained by the fact that the members comprising the reference group, group three, were taken from physical education and elementary teacher training classes and may be more inclined toward exercise than the normal population.

The women in group one, since they had been running longer than those in group two, may have been the ones that were successful - they were doing well in competitions or had lost weight - and that those who are not successful do not continue in the sport. Those women in group two that stayed with their training may have been in transition towards and may now qualify for group one and those that did not may not be still running. (A cursory look at the result sheets of the same CP Air series of runs two years later show relatively few women still competing in these events but, at the same time, approximately half the names of this study's participants were cited in results of longer races (fifteen kilometer to marathon distance). Most had stayed in the same speed category as in this study.)
CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This study looked at the structure of female distance runners in two different speed categories - seven minutes per mile or less over 10,000 meters or longer (group one) and seven and a half to eight and a half minutes per mile over 10,000 meters or longer (group two). These two groups were compared using anthropometrical measures, percent body fat, age of menarche, training practices and athletic background, and iron stores. The anthropometrical measures were compared to a reference group of university females (group three).

Anthropometrical measures were appraised using absolute values and Phantom Z-values of group means. These were plotted on graphs plus and minus one standard error. When one group bar for a specific variable did not overlap another group's bar, significance was inferred. Differences of one standard error were seen in hand length (group one was smaller), sitting height (group three was larger), foot length (group three was smaller), and transverse chest width (group three was smaller).

The trend was for group one, the faster runners, to be smaller in absolute values and smaller in girth Z-values.

Body fat was measured using hydrostatic weighing techniques for body density, skinfold calipers, and the Drinkwater Tactic for adipose mass. Group one had lower density values, lower total of skinfold measures, and lower adipose mass values, all indicating less body fat. Proportional Z-values for skinfold measures showed group one to be significantly lower than group three at all sites and lower than group
two at all sites but the front thigh. Groups two and three were similar at all sites but the front thigh.

Maturation age of the two groups (one and two) was looked at from two points of view: by average age at menarche and by numbers which fell on either side of a dividing point represented by the average age of menarche of the reference group (designated 'early' maturers if the age was before the average age of the reference group, or 'late' maturers if the age was after). Average age of menarche was much later (by 1.64 years) in group one than in group two, but this difference was not statistically significant. When members of each group were divided into early and late maturers, group one, by chi-square analysis, had significantly more later maturers than group two.

Groups one and two were asked to fill in questionnaires concerning training practices and athletic background. Group one, on average, trained more days per week and had been training more years than group two. Five days per week was used as the dividing point on frequency and a significantly greater number of women in group one trained five days per week or more than did in group two. For length of time training the groups were divided into three groups: running five years or longer, running two to five years, and running less than two years. A significantly greater number in group one had been running five years or longer and all had been running longer than two years. No one in group two had been running longer than five years. In the area of athletic background and activity in adolescence, there was no significant difference between groups in
the number of women who reported themselves to be very active in adolescence and those who were not active.

All the women of the running groups were measured for iron stores in order to control the possible influence of that factor on running performance. None of the women had below normal values. Also, the mean values of groups one and two were similar.

Due to the small sample size of the two running groups definite conclusions are not warranted. Nevertheless, tentative ones based on the group means seem to indicate that the superior group of runners was smaller in structure, had lower body fat, a greater amount of time devoted to training, a larger number were later maturers, and more were active in adolescence.

While some of the measures cannot be changed with training it seems that training plays a large role in running proficiency and training can influence body fat and muscle mass.

Recommendations for Future Studies

1. As women specialize in the different distance events, a study is needed to see if the same differences exist as do for men.

2. A long term study (of two to five years) is needed on recreational distance runners, measuring percent body fat, to see the actual level of activity needed to lose fat and the pattern of fat loss.
REFERENCES


Faulkner, R. A.: Physique Characteristics of Canadian Figure Skaters. Unpublished Master of Science (Kinesiology) thesis, Simon Fraser University, Canada, 1976.


APPENDIX A

INFORMED CONSENT FORM
INFORMED CONSENT FORM

A Study of Various Parameters of Female Distance Runners Related to Level of Running Proficiency.

This study will look at the structure, training practices, athletic background, iron stores, and age of menarche of two groups - those who averaged seven minutes per mile or less over a distance of five miles or longer and those who averaged seven and a half to eight and a half minutes per mile.

Structure will be studied using anthropometric measures of size, shape, proportions and body composition. Training practices (of the two to three months just prior to the race, the year before the race, and how long one has been running), athletic background (the period during junior and senior high school), and age of menarche (first menstruation) will be obtained by personal interview. A blood sample will be taken to be analysed for iron stores.

Information of this kind, while abundant on male distance runners, is very scarce on females. Also, it has been shown recently that a high percentage of female runners, especially distance runners, are low in iron stores. The results of these tests will be communicated to you as soon as possible, especially to those who are found to be below normal, so measures can be taken to correct this condition.

The procedures used in this study present minimal risks to the subject.

Your personal results will be forwarded to you at the completion of the study along with a brief summary of the findings. However, your results will be number coded and therefore will remain confidential.

These measurements will take approximately two and a half hours to perform.

In signing this consent form I state that I have read and understood the description of the tests. Any questions which occurred to me have been answered to my satisfaction. I enter into the study willingly and understand that I may withdraw at any time.

DATE: ___________________ SIGNATURE: ___________________

WITNESS: ___________________
APPENDIX B
AGE AT MENARCHE QUESTIONNAIRE
1. Menarche or the onset of menstruation is a maturity indicator used to study growth and development patterns.

2. Most female athletes participating in many different sports are reported to have experienced a later menarche than females in the general population. It is not known if this is due to the athletic activity or if those who experience a later menarche have an advantage in athletics. The purpose of looking at age of menarche in this study is to see if there is any advantage later in life to having experienced a later menarche in adolescence.

3. We would appreciate your cooperation. Please give the month and year of the first occurrence.

   month  year

   and check the statement which best describes your estimate.
   1. certain of the date
   2. fairly certain
   3. only approximate
   4. best estimate but uncertain

4. Give date of birth

   day  month  year
APPENDIX C

TRAINING BACKGROUND QUESTIONNAIRE
TRAINING BACKGROUND QUESTIONNAIRE

Frequency - how long have you been running regularly?

- how many times per week did you run
  a) during the past three (3) month?
  b) during the past year?
  c) before that?

Duration - how long do your runs last (break down into days if necessary)
  a) during the past three (3) months?
  b) during the past year?
  c) before that?

Intensity - describe in terms of long slow distance, hill work, track work, pace.
APPENDIX D

ATHLETIC BACKGROUND QUESTIONNAIRE
ATHLETIC BACKGROUND QUESTIONNAIRE

during junior and senior high school were you active? (compared to now)

did you participate in school sports and which ones?
  intramural:

  extramural:

  intensity (compare with now):

  frequency (days per week):

  did you belong to outside clubs? which sports?

  describe frequency, intensity, duration, and competition:
APPENDIX E

PHANTOM SPECIFICATIONS FOR ESTIMATION OF FRACTIONATED BODY MASSES BY THE DRINKWATER TACTIC
PHANTOM SPECIFICATIONS FOR ESTIMATION OF FRACTIONATED BODY MASSES BY THE DRINKWATER TACTIC

<table>
<thead>
<tr>
<th>MASS</th>
<th>SUBSET INDICATORS</th>
<th>P</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAT (kg)</td>
<td>triceps skinfold (mm)</td>
<td>15.4</td>
<td>4.47</td>
</tr>
<tr>
<td></td>
<td>subscapular skinfold</td>
<td>17.2</td>
<td>5.07</td>
</tr>
<tr>
<td></td>
<td>suprailiac skinfold</td>
<td>15.4</td>
<td>4.47</td>
</tr>
<tr>
<td></td>
<td>abdominal skinfold</td>
<td>25.4</td>
<td>7.78</td>
</tr>
<tr>
<td></td>
<td>front thigh skinfold</td>
<td>27.0</td>
<td>8.33</td>
</tr>
<tr>
<td></td>
<td>medial calf skinfold</td>
<td>16.0</td>
<td>4.67</td>
</tr>
<tr>
<td>SKELETAL (kg)</td>
<td>bi-epicondylar humerus width (cm)</td>
<td>6.48</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>bi-epicondylar femur width</td>
<td>9.52</td>
<td>0.48</td>
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<tr>
<td></td>
<td>wrist girth (distal to styloids)</td>
<td>16.35</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>ankle girth (smallest)</td>
<td>21.71</td>
<td>1.33</td>
</tr>
<tr>
<td>MUSCLE (kg)</td>
<td>relaxed arm girth - triceps sf*</td>
<td>22.05</td>
<td>1.91</td>
</tr>
<tr>
<td></td>
<td>chest girth - subscapular sf*</td>
<td>82.36</td>
<td>4.86</td>
</tr>
<tr>
<td></td>
<td>thigh girth - front thigh sf*</td>
<td>47.33</td>
<td>3.59</td>
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<tr>
<td></td>
<td>calf girth - medial calf sf*</td>
<td>30.22</td>
<td>1.97</td>
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<tr>
<td></td>
<td>forearm girth</td>
<td>25.13</td>
<td>1.41</td>
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<tr>
<td>RESIDUAL (kg)</td>
<td>biacromial breadth (cm)</td>
<td>38.04</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>transverse chest width</td>
<td>27.92</td>
<td>1.74</td>
</tr>
<tr>
<td></td>
<td>bi-iliocristal breadth</td>
<td>28.84</td>
<td>1.75</td>
</tr>
<tr>
<td></td>
<td>anterior-posterior chest depth</td>
<td>17.50</td>
<td>1.38</td>
</tr>
</tbody>
</table>

* skinfold correction = (girth) - (skinfold/10) x pi

Ross & Wilson, 1974
APPENDIX F

ANTHROPOMETRICAL RAW DATA
FOR SUBJECTS IN GROUPS ONE AND TWO
ANTHROPOMETRICAL RAW DATA
FOR SUBJECTS IN GROUPS ONE AND TWO

GROUP 1

Subject 07

body weight (kg) - 45.6
height (cm) - 157.1
triceps sf (mm) - 12.5
subscapular sf (mm) - 8.0
suprailiac sf (mm) - 5.4
abdominal sf (mm) - 5.7
front thigh sf (mm) - 19.0
medial calf sf (mm) - 5.4
acromial height (cm) - 125.9
radial height (cm) - 96.2
stylion height (cm) - 73.5
dactyliion height (cm) - 56.2
tibial height (cm) - 38.8
spinale height (cm) - 86.4
trochanterion height (cm) - 78.2
arm girth relaxed (cm) - 22.6
arm girth flexed (cm) - 24.6
forearm girth (cm) - 22.2
wrist girth (cm) - 15.0
chest girth (cm) - 77.2
waist girth (cm) - 60.9
thigh girth (cm) - 48.8
calf girth (cm) - 32.2
ankle girth (cm) - 21.1
biaeocromial breadth (cm) - 34.3
biiliocristal breadth (cm) - 25.8
transverse chest (cm) - 22.4
foot length (cm) - 24.5
beipicondylar humerus width (cm) - 5.75
beipicondylar femur width (cm) - 8.40
sitting height (cm) - 83.1
anterior-posterior chest depth (cm) - 17.6
head girth (cm) - 53.8
neck girth (cm) - 28.9
Subject 08

body weight - 53.1
height - 161.6
triceps sf - 11.5
subscapular sf - 14.1
suprailiac sf - 8.5
abdominal sf - 11.8
front thigh sf - 20.0
medial calf sf - 7.6
acromial height - 127.9
radial height - 98.3
stylion height - 74.5
dacltylion height - 58.6
tibial height - 41.9
spinal height - 91.2
trochanterion height - 82.8
arm girth relaxed - 24.5
arm girth flexed - 26.5
forearm girth - 22.5
wrist girth - 14.8
chest girth - 82.4
waist girth - 69.3
thigh girth - 54.2
calf girth - 31.0
ankle girth - 20.8
biacromial breadth - 35.7
biiliocristal breadth - 28.0
transverse chest - 25.0
foot length - 24.2
biepicondylar humerus width - 5.75
biepicondyial femur width - 8.85
sitting height - 83.4
anterior-posterior chest depth - 17.2
head girth - 51.8
neck girth - 31.2
Subject 09

body weight - 55.1
height - 166.6
triceps sf - 9.9
subscapular sf - 7.0
suprailiac sf - 5.9
abdominal sf - 6.7
front thigh sf - 15.8
medial calf sf - 6.5
acromial height - 135.1
radial height - 103.5
stylion height - 80.4
dactylion height - 61.6
tibial height - 41.9
spinale height - 93.1
trochanterion height - 84.8
arm girth relaxed - 22.9
arm girth flexed - 26.9
forearm girth - 23.1
wrist girth - 15.4
decit girth - 80.3
waist girth - 65.2
thigh girth - 56.1
calf girth - 35.6
ankle girth - 21.6
biacromial breadth - 34.3
biiliocristal breadth - 26.0
transverse chest - 24.7
foot length - 24.3
biepicondylar humerus width - 5.78
biepicondylar femur width - 8.52
sitting height - 87.2
anterior-posterior chest depth - 15.2
head girth - 55.5
neck girth - 32.7
Subject 10

body weight - 56.6
height - 164.0
triceps sf - 10.6
subscapular sf - 6.7
suprailiac sf - 4.7
abdominal sf - 6.6
front thigh sf - 16.5
medial calf sf - 8.1
acromial height - 132.0
radial height - 100.2
stylion height - 78.2
dactylion height - 61.0
tibial height - 41.4
spinale height - 91.7
trochanterion height - 83.3
arm girth relaxed - 24.9
arm girth flexed - 27.3
forearm girth - 23.5
wrist girth - 15.1
chest girth - 79.2
waist girth - 64.4
thigh girth - 52.5
calf girth - 34.2
ankle girth - 21.0
biacromial breadth - 34.4
biliocristal breadth - 27.8
transverse chest 24.3
foot length - 23.6
biceps Femur width - 6.80
biceps Femur width - 9.00
sitting height - 84.7
anterior-posterior chest depth - 17.1
head girth - 52.4
neck girth - 32.8
Subject 11

body weight - 51.8
height - 161.3
triceps sf - 12.2
subscapular sf - 8.1
suprailiac sf - 6.7
abdominal sf - 8.5
front thigh sf - 19.6
medial calf sf - 8.0
acromial height - 131.8
radial height 102.3
stylion height - 81.2
dactylion height - 65.3
tibial height - 40.9
spinale height - 85.9
trochanterion height - 78.5
arm girth relaxed - 25.3
arm girth flexed - 26.5
forearm girth - 23.5
wrist girth - 14.0
chest girth - 81.3
waist girth - 63.3
thigh girth - 53.7
calf girth - 34.0
ankle girth - 21.6
biacromial breadth - 34.4
biiliocristal breadth - 25.4
transverse chest 25.4
foot length - 21.1
biepicondylar humerus width - 6.6
biepicondylar femur width - 8.55
sitting height - 84.4
anterior-posterior chest depth - 15.6
head girth - 56.3
neck girth 29.4
Subject 12

body weight - 53.0
height - 159.3
triceps sf - 16.8
subscapular sf - 7.5
suprailiac sf - 7.6
abdominal sf - 9.8
front thigh - 27.7
medial calf sf - 18.2
acromial height - 129.2
radial height 99.8
stylion height 77.8
daclylon height - 60.3
tibial height - 42.5
spinale height - 92.4
trochanterion height - 81.9
arm girth relaxed - 24.0
arm girth flexed - 26.0
forearm girth - 23.2
wrist girth - 14.9
chest girth - 80.5
waist girth - 68.8
thigh girth - 54.5
calf girth - 32.7
ankle girth - 19.6
biacromial breadth - 35.1
bililiocristal breadth - 29 2
transverse chest - 25.6
foot length - 24.6
biepicondylar humerus width - 6.2
biepicondylar femur width - 8.67
sitting height - 81.1
anterior-posterior chest depth - 15.1
head girth - 53.1
neck girth - 30.2
Subject 13

body weight - 58.3
height - 165.0
triceps sf - 14.5
subscapular sf - 8.7
suprailiac sf - 13.1
abdominal sf - 10.6
front thigh sf - 20.6
medial calf sf - 8.6
acromial height - 131.2
radial height - 102.7
stylion height - 76.4
dacty lion height - 60.1
tibial height - 41.9
spinale height - 92.1
trochanterion height - 87.0
arm girth relaxed - 26.4
arm girth flexed - 28.1
forearm girth - 24.2
wrist girth - 14.8
chest girth - 84.1
waist girth - 67.5
thigh girth - 56.5
calf girth - 35.4
ankle girth - 20.2
biacromial breadth - 36.0
biiliocristal breadth - 28.9
transverse chest 25.2
foot length - 24.0
biepicondylar humerus width - 6.3
biepicondylar femur width - 8.60
sitting height - 87.4
anterior-posterior chest depth - 18.5
head girth - 56.6
neck girth - 30.8
Subject 16

body weight - 54.0
height - 156.4
triceps sf - 17.2
subscapular sf - 15.2
suprailiac sf - 8.2
abdominal sf - 8.2
front thigh sf - 20.0
medial calf sf - 5.0
acromial height - 124.9
radial height - 95.8
stylion height 76.3
dactyliion height - 58.7
tibial height - 37.5
spinale height - 84.0
trochanterion height - 76.7
rm girth relaxed - 26.8
arm girth flexed - 29.1
forearm girth - 23.3
wrist girth - 14.9
chest girth - 83.8
waist girth - 71.1
thigh girth - 53.9
calf girth - 33.5
ankle girth - 20.4
biacromial breadth - 35.6
biiliocristal breadth - 27.8
transverse chest 25.3
foot length 23.3
biepicondylar humerus width - 5.85
biepicondylar femur width - 8.68
sitting height - 86.5
anterior-posterior chest depth - 16.6
head girth - 55.0
neck girth - 32.8
Subject 17

body weight - 61.8
height - 162.2
triceps sf - 16.6
subscapular sf - 9.7
suprailiac sf - 10.8
abdominal sf - 14.8
front thigh sf - 31.4
medial calf sf - 17.4
acromial height - 132.5
radial height - 101.0
stylion height - 80.6
dactylion height - 62.8
tibial height - 46.4
spinale height - 90.9
trochanterion height - 84.0
arm girth relaxed - 28.7
arm girth flexed - 27.9
forearm girth - 23.6
wrist girth - 14.3
chest girth - 88.3
waist girth - 69.7
thigh girth - 59.0
calf girth - 35.7
ankle girth - 21.6
biacromial breadth - 36.6
biiliocristal breadth - 28.3
transverse chest - 26.4
foot length - 24.5
biepicondylar humerus width - 6.28
biepicondylar femur width - 9.49
sitting height - 82.8
anterior-posterior chest depth - 16.0
head girth - 54.7
neck girth - 31.8
Subject 18

body weight - 57.3
height - 167.1
triceps sf - 10.8
subscapular sf - 6.6
suprailiac sf - 4.4
abdominal sf - 5.6
front thigh sf - 19.0
medial calf sf - 7.6
acromial height - 135.4
radial height - 102.8
styliion height - 81.8
dactyliion height - 64.6
tibial height - 46.2
spinale height - 91.9
trochanterion height - 85.4
arm girth relaxed - 25.9
arm girth flexed - 26.4
forearm girth - 22.7
wrist girth - 14.9
chest girth - 87.2
waist girth - 65.8
thigh girth - 55.3
calf girth - 33.5
ankle girth - 21.2
biacromial breadth - 37.4
biiliocristal breadth - 25.9
transverse chest 26.4
foot length - 24.7
biepicondylar humerus width - 6.35
biepicondylar femur width - 8.8
sitting height - 87.4
anterior-posterior chest depth - 16.2
head girth - 55.0
neck girth - 30.3
Subject 22

body weight - 47.1
height - 164.2
triceps sf - 4.6
subscapular sf - 4.2
suprailiac sf - 2.9
abdominal sf - 3.8
front thigh - 8.6
medial calf sf - 3.2
acromial height - 132.6
radial height - 101.5
stylion height - 80.9
dactylion height - 60.5
tibial height - 45.8
spinale height - 90.9
trochanterion height - 82.5
arm girth relaxed - 22.1
arm girth flexed - 23.7
forearm girth - 21.0
wrist girth - 13.6
chest girth - 80.8
waist girth - 62.9
thigh girth - 46.2
calf girth - 29.5
ankle girth - 18.3
biacromial breadth - 35.8
biiliocristal breadth - 24.3
transverse chest - 24.7
foot length - 24.0
biepicondylar humerus width - 6.3
biepicondylar femur width - 8.4
sitting height - 87.4
anterior-posterior chest depth - 16.5
head girth - 56.7
neck girth - 29.1
GROUP 2

Subject 01

body weight - 44.1
height - 150.3
triceps sf - 14.8
subscapular sf - 9.6
suprailiac sf - 12.4
abdominal sf - 12.2
front thigh sf - 17.8
medial calf sf - 12.6
acromial height - 120.9
radial height - 92.6
stylion height 75.0
dacty lion height - 54.2
tibial height - 35.7
spinale height - 80.2
trochanterion height - 75.1
arm girth relaxed - 23.5
arm girth flexed - 25.3
forearm girth - 20.8
wrist girth - 13.2
chest girth - 79.2
waist girth - 61.3
thigh girth - 50.6
calf girth - 33.0
ankle girth - 18.8
biacromial breadth - 32.9
biiliocristal breadth - 26.3
transverse chest - 23.5
foot length - 21.9
biepicondylar humerus width - 5.11
biepicondylar femur width - 7.91
sitting height - 82.3
anterior-posterior chest depth - 16.0
head girth - 56.9
neck girth - 31.2
Subject 02

body weight - 57.1
height - 168.8
triceps sf - 16.9
subscapular sf - 9.4
suprailiac sf - 8.6
abdominal sf - 10.6
front thigh sf - 24.2
medial calf sf - 19.8
acromial height - 137.8
radial height - 106.2
stylion height - 83.5
dacluylion height - 64.8
tibial height - 41.9
spinale height - 94.2
trochanterion height - 88.9
arm girth relaxed - 25.5
arm girth flexed - 27.4
forearm girth - 23.3
wrist girth - 14.5
chest girth - 83.3
waist girth - 66.2
thigh girth - 55.4
calf girth - 34.6
ankle girth - 21.9
biacromial breadth - 36.1
biiliocristal breadth - 27.2
transverse chest - 25.6
foot length - 24.3
biepicondylar humerus width - 5.92
biepicondylar femur width - 8.91
sitting height - 92.6
anterior-posterior chest depth - 15.0
head girth - 54.0
neck girth - 30.5
Subject 03

body weight - 50.6
height - 162.1
triceps sf - 18.2
subscapular sf - 10.6
suprailiac sf - 4.8
abdominal sf - 7.2
front thigh sf - 18.4
medial calf sf - 10.8
acromial height - 129.7
radial height - 97.7
stylion height - 73.5
dactylion height - 56.0
tibial height - 40.5
spinale height - 90.8
trochanterion height - 84.7
arm girth relaxed - 24.6
arm girth flexed - 25.6
forearm girth - 22.7
wrist girth - 15.0
chest girth - 81.3
waist girth - 70.2
thigh girth - 49.6
calf girth - 31.4
ankle girth - 19.5
biacromial breadth - 36.7
biiliocristal breadth - 26.6
transverse chest - 25.8
foot length - 23.7
biepicondylar humerus width - 6.44
biepicondylar femur width - 8.43
sitting height - 83.5
anterior-posterior chest depth - 16.1
head girth - 53.8
neck girth - 30.8
Subject 04

body weight - 51.5
height - 155.0
triceps sf - 17.2
subscapular sf - 14.5
suprailiac sf - 6.6
abdominal sf - 16.0
front thigh sf - 20.8
medial calf sf - 9.6
acromial height - 127.5
radial height - 97.3
stylion height - 75.3
dactylion height - 57.4
tibial height - 40.5
spinale height - 85.4
trochanterion height - 78.9
arm girth relaxed - 27.0
arm girth flexed - 28.6
forearm girth - 23.1
wrist girth - 14.4
chest girth - 86.6
waist girth - 69.8
thigh girth - 54.3
calf girth - 31.7
ankle girth - 20.6
biacromial breadth - 36.3
biiliocristal breadth - 27.1
transverse chest 26.1
foot length - 21.7
biepicondylar humerus width - 6.23
biepicondylar femur width - 8.89
sitting height - 81.1
anterior-posterior chest depth - 16.5
head girth - 52.4
neck girth - 30.8
Subject 05

body weight - 62.1
height - 170.6
triceps sf - 13.0
subscapular sf - 17.2
suprailiac sf - 11.6
abdominal sf - 19.2
front thigh sf - 16.4
medial calf sf - 12.0
acromial height - 143.4
radial height - 111.2
stylion height - 85.9
dactyliion height - 67.9
tibial height - 47.8
spinaile height - 99.5
trochanterion height - 90.8
arm girth relaxed - 25.9
arm girth flexed - 26.3
forearm girth - 22.9
wrist girth - 15.0
chest girth - 85.0
waist girth - 72.0
thigh girth - 54.7
calf girth - 33.0
ankle girth - 22.0
biacromial breadth - 33.3
biiliocristal breadth - 30.6
transverse chest - 25.2
foot length - 25.2
biepicondylar humerus width - 6.51
biepicondylar femur width - 9.08
sitting height - 86.1
anterior-posterior chest depth - 20.0
head girth - 56.7
neck girth - 32.2
Subject 06

body weight - 64.9
height - 163.8
triceps sf - 18.4
subscapular sf - 18.2
suprailiac sf - 10.6
abdominal sf - 15.4
front thigh - 26.8
medial calf sf - 15.4
acromial height - 133.6
radial height - 100.4
stylion height - 77.3
dacty lion height - 59.6
tibial height - 44.3
spinale height - 95.9
trochanterion height - 90.2
arm girth relaxed - 27.2
arm girth flexed - 29.1
forearm girth - 23.6
wrist girth - 15.8
chest girth - 90.0
waist girth - 72.2
thigh girth - 62.3
calf girth - 35.3
ankle girth - 23.1
biacromial breadth - 35.1
biiliocristal breadth - 30.0
transverse chest - 25.0
foot length - 26.0
bipeicondylar humerus width - 6.1
bipeicondylar femur width - 9.17
sitting height - 82.7
anterior-posterior chest depth - 17.5
head girth - 55.8
neck girth - 32.3
Subject 14

body weight - 64.4
height - 160.3
triceps sf - 13.3
subscapular sf - 9.9
suprailiac sf - 11.5
abdominal sf - 16.9
front thigh sf - 14.0
medial calf sf - 5.9
acromial height - 129.9
radial height - 100.7
stylion height - 78.6
daecy lion height - 61.4
tibial height - 39.9
spinale height - 90.4
trochanterion height - 82.2
arm girth relaxed - 28.2
arm girth flexed - 29.1
forearm girth - 25.6
wrist girth - 16.0
chest girth - 92.1
waist girth - 76.4
thigh girth - 58.0
calf girth - 36.0
ankle girth - 22.2
biacromial breadth - 35.7
biiliocristal breadth - 30.9
transverse chest - 28.9
foot length - 25.3
biepicondylar humerus width - 6.37
biepicondylar femur width - 9.32
sitting height - 86.9
anterior-posterior chest depth - 17.2
head girth - 56.0
neck girth - 33.1
Subject 15

body weight - 54.8
height - 163.2
triceps sf - 14.4
subscapular - 12.5
suprailiac sf - 10.4
abdominal sf - 14.2
front thigh sf - 17.7
medial calf sf - 9.9
acromial height - 130.8
radial height - 100.9
stylion height - 80.6
dactylion height - 60.4
tibial height - 38.2
spinale height - 92.4
trochanterion height - 83.7
arm girth relaxed - 26.0
arm girth flexed - 27.5
forearm girth - 23.0
wrist girth - 15.0
chest girth - 79.8
waist girth - 67.1
thigh girth - 53.8
calf girth - 32.2
ankle girth - 20.2
biacromial breadth - 32.8
biiliocristal breadth - 28.2
transverse chest - 23.8
foot length - 23.6
biepicondylar humerus width - 6.17
biepicondylar femur width - 8.97
sitting height - 87.1
anterior-posterior chest depth - 19.5
head girth - 53.2
neck girth - 29.8
Subject 19

body weight - 63.4
height - 170.7
triceps sf - 21.2
subscapular sf - 16.0
suprailiac sf - 17.4
abdominal sf - 18.1
front thigh sf - 20.2
medial calf sf - 24.8
acromial height - 138.7
radial height - 106.8
stylion height - 84.2
dactylion height - 64.2
tibial height - 46.4
spinale height - 95.6
trochanterion height - 89.3
arm girth relaxed - 27.5
arm girth flexed - 27.9
forearm girth - 24.4
wrist girth - 15.2
chest girth - 85.1
waist girth - 67.5
thigh girth - 61.4
calf girth - 36.2
ankle girth - 20.9
biacromial breadth - 34.9
biliocristal breadth - 28.2
transverse chest - 26.8
foot length - 24.8
biericondylar humerus width - 6.7
biericondylar femur width - 9.3
sitting height - 88.9
anterior-posterior chest depth - 17.3
head girth - 55.6
neck girth - 31.1
Subject 20

body weight - 59.4
height - 166.4
triceps sf - 15.6
subscapular sf - 13.8
suprailiac sf - 10.0
abdominal sf - 17.6
front thigh sf - 28.0
medial calf sf - 18.4
acromial height - 134.7
radial height - 104.6
stylion height - 82.5
dactylion height - 63.7
tibial height - 45.3
spinale height - 90.2
trochanterion height - 86.9
arm girth relaxed - 27.5
arm girth flexed - 28.5
forearm girth - 24.0
wrist girth - 15.5
chest girth - 83.5
waist girth - 66.9
thigh girth - 58.4
calf girth - 34.9
ankle girth - 20.3
biamacromial breadth - 35.1
biiliocristal breadth - 26.6
transverse chest - 26.7
foot length - 22.8
bielicondylar humerus width - 6.5
bielicondylar femur width - 9.47
sitting height - 88.2
anterior-poster chest depth - 17.6
head girth - 55.8
neck girth - 31.6
Subject 21

body weight - 54.5
height - 161.4
triceps sf - 13.4
subscapular sf - 7.4
suprailiac sf - 5.6
abdominal sf - 6.3
front thigh sf - 22.4
medial calf sf - 10.6
acromial height - 128.3
radial height - 99.3
stylion height - 78.1
dactylion height - 59.1
tibial height - 45.7
spinale height - 90.6
trochanterion height - 82.8
arm girth relaxed - 25.0
arm girth flexed - 26.1
forearm girth - 23.5
wrist girth - 15.4
chest girth - 82.9
waist girth - 63.0
thigh girth - 55.4
calf girth - 38.2
ankle girth - 22.6
biacromial breadth - 36.2
biiliocristal breadth - 27.2
transverse chest - 24.2
foot length - 24.2
biepicondylar humerus width - 6.4
biepicondylar femur width - 9.0
sitting height - 84.7
anterior-posterior chest depth - 17.3
head girth - 55.4
neck girth - 30.5
Subject 23

body weight - 57.3
height - 171.6
triceps sf - 14.6
subscapular sf - 7.5
suprailliac sf - 7.4
abdominal sf - 11.6
front thigh sf - 24.0
medial calf sf - 14.6
acromial height - 139.9
radial height - 109.0
stylion height - 81.5
daclylion height - 64.9
tibial height - 49.0
spinae height - 93.9
trochanterion height - 87.9
arm girth relaxed - 25.7
arm girth flexed - 25.2
forearm girth - 23.5
wrist girth - 14.7
chest girth - 82.8
waist girth - 62.9
thigh girth - 54.2
calf girth - 33.5
ankle girth - 21.8
bicipital breadth - 36.1
biiliocristal breadth - 27.9
transverse chest - 27.1
foot length - 24.7
biceps condylar humerus width - 6.2
biceps condylar femur width - 9.3
sitting height - 90.0
anterior-posterior chest depth - 18.5
head girth - 55.0
neck girth - 31.5