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BODY FAT PATTERNING OF THE SUBCUTANEOUS ADIPOSE TISSUE

by M. S. YUHASZ

Faculty of Physical Education, The University of Western Ontario, London, Canada

Abstract: The body's fat suit lies adherent to the muscle and is covered and held in place by the skin. The suit is not of even thickness. It varies from a few millimeters to 60 or more. It is a living suit — rich in blood and nerve supply. It grows with the developing body, changing in size and thickness with age, activity and nutrition.

Measurement. The variable thickness of the fat suit can be represented by a sampling of thickness measurements in the various regions of the body. A plot of the raw score thickness values represents the absolute subcutaneous adipose tissue pattern and gives a visual graphical representation of it. When the absolute score values are converted into their Z score equivalents, pattern differences due to amount of fat are eliminated. The degree of similarity between relative fat patterns can be determined by using GARN's (1955) standard deviation of the differences in *z* scores (sigma d *z*), the correlation of the Z transforms, or by a delta vector technique developed by MACDONALD (1978).

Results. Subcutaneous adipose tissue thickness measurements were taken at 15 sites on 20 sets of twins at The University of Western Ontario anthropometrical laboratory. The patterns were assessed for similarity and were found to differ no more than a single individual could differ from himself. The genetic control over the variation was found to be extremely high.

YUHASZ (1977) has shown that male and female athletes as separate groups have patterns similar to each other and to their normal peers. However, intrasport comparison reveals dissimilar individual fat patterns among athletes in the same sport discipline. The relative fat pattern appears to be an individual characteristic, and shows a high degree of stability throughout one's adult life. Dietary restrictions or overnutrition, resulting in changes in total body fatness don't appear to influence the body fat pattern.

Key words: Body composition, fat, subcutaneous adipose tissue, athletes.

Introduction

Human beings store their energy as fat in specialized cells located internally — in the chest cavity, and externally under the skin and adherent to the fascia and muscle. The subcutaneous adipose tissue can be depicted as a close fitting body fat suit that is held in place by the skin. With gross anatomical dissection the fat suit can be dissected from the overlying muscle. The overall dimension, size and mass of the fat suit is dependent upon the body's skeletal and muscular structure.

The fat suit — unlike other clothing used as thermal insulators — is not of even thickness, but varies appreciably in the same individual. Over some body parts there is very little fat, over others there is a great deal. These fat pads — the relatively greater thickness of the subcutaneous adipose tissue in specifically isolated body regions — are common and normal. Fat pads are located on the abdomen, over the iliac crest, over the sacrum, between and below the scapulae, on the inner thigh, over the trochanter, on the calf, and elsewhere. Several variations and combinations are possible and they're not necessarily associated with sex, age, obesity or leanness, or body type. There is no fat on the eyelids, and none on the male sex organ. It is a 'living' suit, rich in blood supply and nerve, and metabolically active. It grows with the developing body, and can change in thickness from season to season, and for some month to month. The suit is bilaterally symmetrical. Its weight may be as low as 4—5% of the body weight (2 or 3 kg) and as high as 60% of the body weight (125—130 kg).

The mature male's fat suit can be differentiated from the mature female suit not only by its size and by the breasts but by the relative greater thickness of the female suit in the upper arm, and upper leg and over the gluteals, whereas the male's suit is thicker in the trunk and thinner in the arms and legs with a smaller amount over the gluteals. The thickness of the subcutaneous adipose tissue measured at 53 sites (EDWARDS 1951) and then averaged for the entire fat suit has been estimated to be 12 mm for women and 7.5 mm for men. The normal female has an average subcutaneous fat thickness approximately 1.75 times that of the normal male. EDWARDS also found that the typical fat pattern for women remains constant over a wide range of body weight and fatness.

Human adipose tissue comprises a very large share of the body's mass. Women, over 30 years of age, have average total body fat values of 32 to 36 per cent, while their muscle weight is approximately 28—30 percent and their bone weight approximately 14—15 percent when compared to their total body weight. The same age group of males will average 25 to 28 percent body fat, 40% muscle and 15 percent bone. Women have over one-half of the weight of their subcutaneous adipose tissue on their legs, about 30% on their trunk and 15% on their arms. The estimate for men differs. They have more on their trunk, approximately 60%, 30% on their legs and 10% on their arms.

The subcutaneous adipose tissue is the largest storehouse of energy. Recent cadaver analysis (ROSS et al. 1981) suggests that 75 to 85% of the total adipose tissue is located externally, and 15 to 25% internally. The percentage varies between individuals and with sex, and increases with increasing fatness. It would be unwise to assume that a constant proportion and a high relationship exists between the amount of internal and external body fat.

The amount and distribution of the subcutaneous adipose tissue has a great deal to do with one's body shape and appearance. Changes in contour of the mature body occurs predominantly because of increases in the thickness of the subcutaneous adipose tissue. In many cases, alterations in the amount and location of one's external fat is of deep concern and worry to many people. Research investigations in this area are attempting to solve some of these problems.

Measurement

In vivo measurement of the thickness of the subcutaneous adipose tissue layer has been accomplished radiographically, and more recently by ultrasound, but hasn't gained widespread use with either instrument due to equipment cost and/or safety. Specifically designed calipers such as the Harpenden caliper are simple to use, relatively inexpensive, have been validated and have gained widespread acceptance for the measurement of the subcutaneous adipose tissue. If a sufficient number of fat site locations are selected from one side and from the various regions of the body, the mass of the external fat and the variation in thickness of the fat suit can be properly represented. To satisfy these criteria, the number of measurement sites should be from 10 to 16. The site locations that have been used are the biceps, triceps, sub scapular, supra-iliac, mid axillary, pectoral or juxta nipple, umbilicus, front and rear thigh, rear and medial calf, trochanter, lower medial and upper medial thigh, pubis and forearm. The head, hands and feet are rarely, if ever, measured. The gluteal region ought to be measured but for practical and personal reasons has not been measured.

Subcutaneous adipose tissue classification by body region

The normal male and female fat pattern or conformation by body region is well recognized and easily described. Further attempts have been made at verbal or descriptive sub-classifications within these patterns with limited success. Indicating the greater relative thickness of the adipose tissue in one or more of the regions and labelling the classification is of general use at best. There are a few females who distribute their body fat like the male norm, and there are males who distribute their fat similar to the female norm. Some individuals have concentrations in the lower body region. This latter classification occurs with some frequency with women. They have exceptionally large amounts of fat on the lower and upper leg, over the gluteals, and throughout the pelvic region, with very low deposits on the trunk and lower and upper arms. Visual judgments of body fat classification have only resulted in a few gross classifications. We must rely on measurement and pattern analysis to be more precise in recognizing additional fat patterns. For example, an individual may display a typical male normal pattern, except for wide variation in the sub-scapular area, or in two areas such as the supra-iliac and the juxta-nipple sites. Are the variations sufficiently large, and do they occur with sufficient frequency to be labelled as different types?

Subcutaneous adipose tissue patterning

The distribution of the subcutaneous adipose tissue can be objectified by measuring the thickness of the adipose tissue layer at different body sites and plotting the raw score thickness values on a suitable coordinate graph; in a specific or set sequence and joining the plotted points. This visual graphical representation of the raw score thickness values represents the absolute subcutaneous adipose tissue pattern or profile. This isolated site technique allows individual or group values to be plotted and compared as to their levels of fatness as well as the shape of the pattern.

If the absolute (raw) score values are converted into their z score equivalents, and these measurements plotted on a suitable coordinate graph, pattern differences due solely to the amount of fat would be eliminated. Each individual measurement is expressed relative to the group mean value. The group value is the reference standard or zero pattern and when expressed graphically is a straight line parallel to the abscissa. The standard score or *z* score series of plots has been called the relative fat pattern.

GARN (1955) was the first to work with relative body fat patterns in his quest to identify and categorize human body fat patterns. He developed an objective, numerical approach to pattern comparison. The degree of similarity between an individual pattern to the normal or zero pattern was determined by finding the standard deviation of the *z* scores of the series of plots. Higher values of this index represented a more variable pattern, lower values, approaching zero represented a pattern similar to the normal pattern. As a result of this work, GARN concluded that there were more and more complicated relative fat patterns than we could conveniently forced into categories.

GARN developed another statistic to compare two relative fat patterns. The principle was essentially the same as the one just outlined. The standard deviation of the differences in *z* scores between corresponding plots of the two patterns (sigma dz) was calculated. A value of zero defined a perfect match between the *z* patterns, and values greater than 0.50 indicated dissimilarity between the patterns.

GARN's approach to provide a single index for pattern analysis was the only technique developed strictly for this purpose, but seems to be unduly influenced by crossovers and coincidental points. The product-moment correlation of the paired values would be another way to provide an index value for pattern comparison.

Objective numerical approaches to pattern analysis have and are restricted to the comparison of the shapes of two patterns or profiles at a time. The combined effect of the slopes of the lines joining one plotted point to another reveals the specific characteristics of one's body pattern. In order to compare the shapes of two patterns, one must compare the slopes of corresponding segments in sequence, and combine them. DU MAS (1946) introduced the method and MACDONALD extended and applied it to body fat patterning. MACDONALD (1978) developed the delta vector technique that combines the segment-by-segment results to provide a precise, single meaningful value describing the similarity/dissimilarity of the patterns. The cosine of the angle between the vectors of adjacent pairs of measurement in sequence will range from 1.0 to −1.0.

Genetic influence

In a study by MACDONALD and YUHASZ at the University of Western Ontario, subcutaneous adipose tissue measurements were taken at 15 sites at premarked anatomical landmarks on 20 sets of twins (nine pairs of identical and eleven pairs of fraternal). The raw score values were converted into their *z* score equivalents, and these measurements plotted on a suitable coordinate graph. Intra pair comparison of these relative patterns was made using three techniques; GARN's standard deviation of the differences in *z* scores (sigma dz), the correlation of the *z* transforms in the two patterns and a delta vector technique developed by MACDONALD. The results showed a high degree of similarity between twins, whether identical or fraternal (Figures 1, 2).

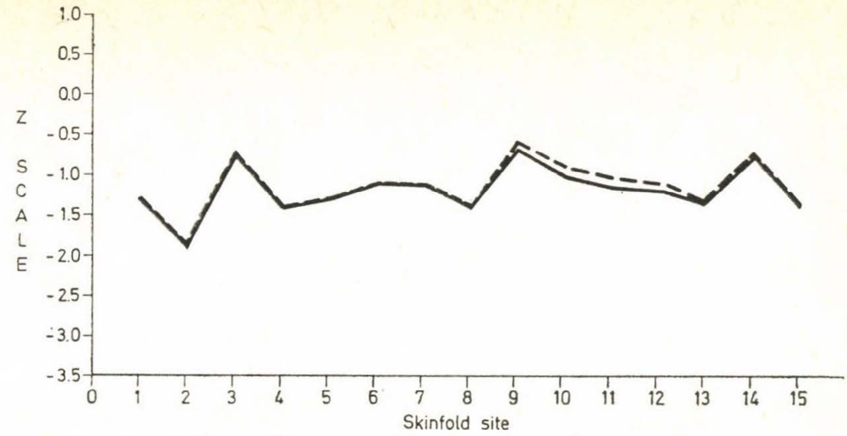

Fig. 1. **Body fat patterns of identical twins**

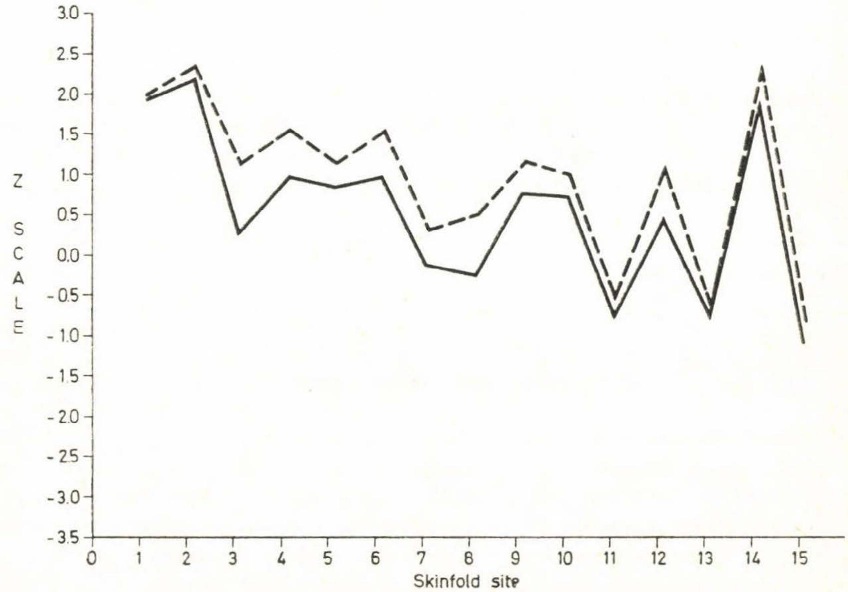

Fig. 2. **Body fat patterns of fraternal twins**

The twins' pattern plots were found to differ no more than a single individual would differ from himself. The genetic control over these values was found to be extremely high.

Athletes

Athletes, as a group, have less body fat than their peers, but their subcutaneous adipose tissue configuration parallels their reference peers (YUHASZ 1977). Male and female college athletes, in a range of individual and team

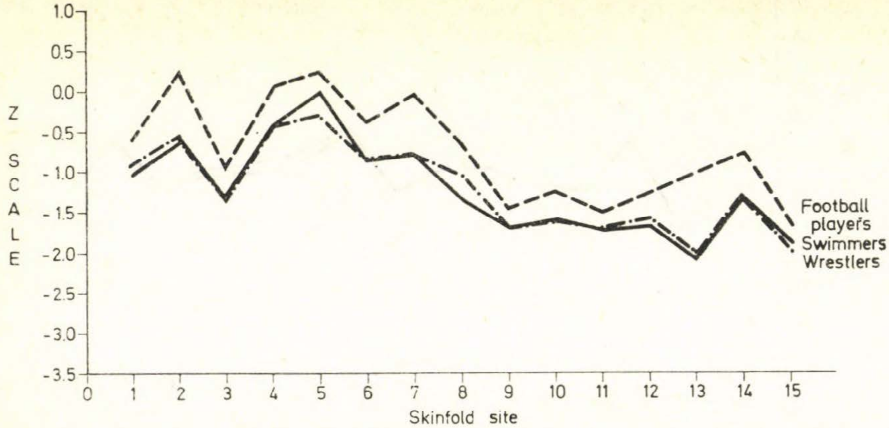

Fig. 3. **Relative body fat patterns of football players, swimmers, and wrestlers (each 8 per cent fat)**

sports such as swimming, basketball, gymnastics, rowing, wrestling and ice hockey, follow this pattern (Fig. 3). Young female athletes, gymnasts, swimmers and skaters, who have achieved a relatively high level of success in their sport at the national level are similar in body fat patterning to their normal peer group.

This also means that athletes in different sports, when compared as separate groups, will display pattern plots similar to each other — as long as the sample size is sufficiently large.

Intra sport comparison

Intra sport comparison reveals dissimilar fat patterns among the athletes in the same sport discipline. All swimmers do not have the same or similar fat patterns; nor do wrestlers, basketball players or hockey players.

In a preliminary analysis of 20 members of a university men's ice hockey team, it was found that seven of the hockey players showed pattern plots that could be recognized as similar to the normal male pattern (Fig. 4). Three others were similar to the male norm except for an extreme difference in one fat site location. The remainder appeared to be different from each other, and could not be classified (Fig. 5). When swimmers, wrestlers and football players who have the same total percentage of body fat, determined by body density techniques, are compared they often have different fat patterns (Fig. 6). When wrestlers and football players, with the same total thickness of adipose tissue are compared, they also have dissimilar body fat patterns (Fig. 7).

There appears to be no requirement for a specific body fat pattern in the sport disciplines mentioned. The athletes bring their own genetically established body fat pattern to the sport in which they participate, and it appears not to influence their performance. We should expect to see some selectivity in the adipose tissue pattern, if a specific pattern were essential to the sport.

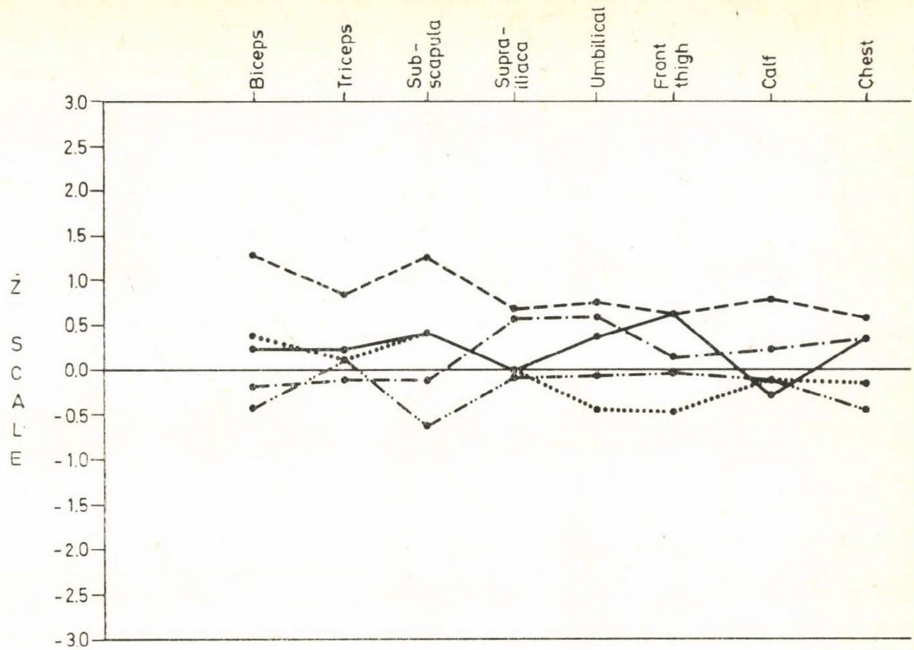

Fig. 4. **Ice hockey players normal relative fat patterns**

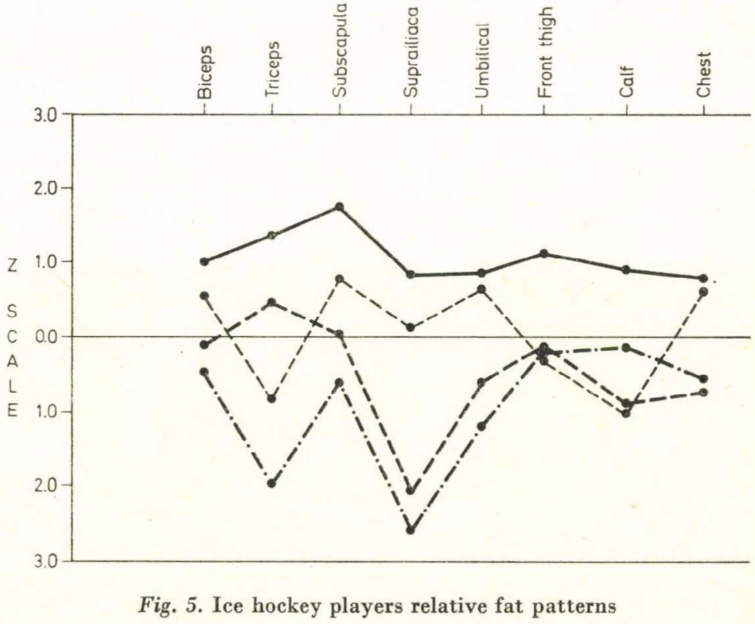

Fig. 5. **Ice hockey players relative fat patterns**

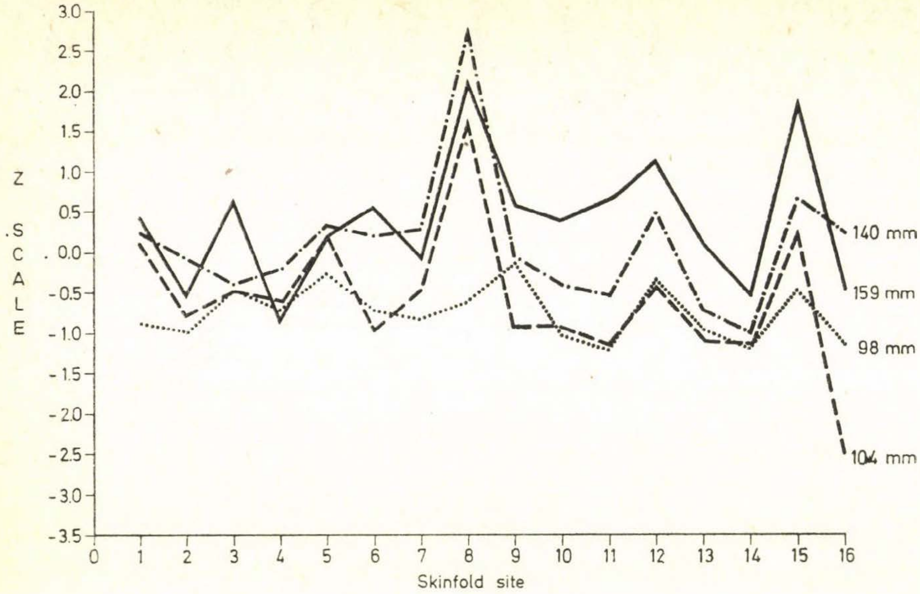

Fig. 6. **Relative body fat patterns of four wrestlers (each 4 per cent fat)**

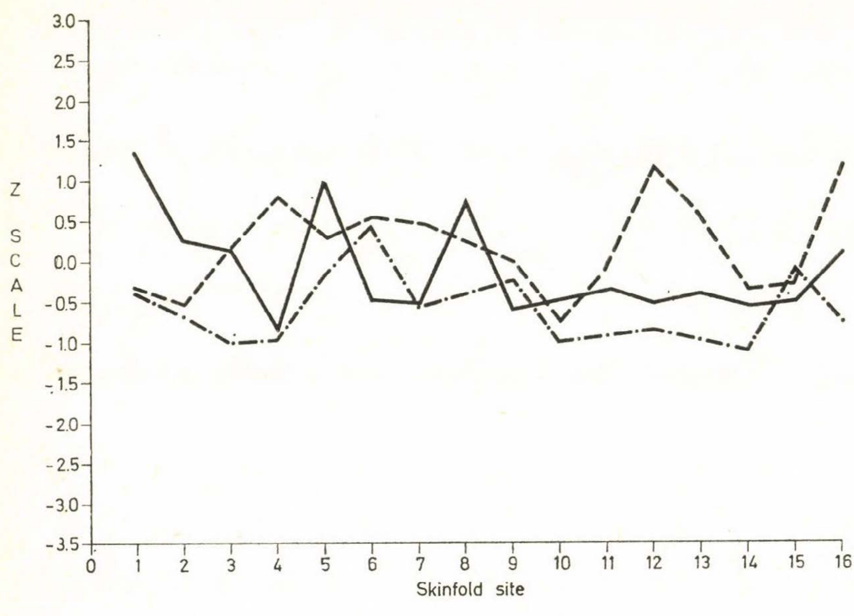

Fig. 7. **Relative body fat patterns of three football players (each 3 per cent fat)**

Effect of training and detraining

Individual male and female athletes who decrease their level of body fatness under intense training conditions in a specific sport appear to maintain their subcutaneous adipose tissue fat pattern, regardless of the specific requirements of the sport. Athletes who are measured some time after the completion of their competitive sport season, also maintain their relative fat pattern.

A female discus and shot putter who was under an intensive training program, including heavy weight training for a 12 month period decreased her body fat significantly, while her pattern maintained the same shape. When we plotted a college wrestler's fat patterns at his peak training period, and after a month of no training, we found that the subcutaneous adipose tissue pattern retained its conformation.

Aging effects

A group of 25 women, ranging in age from 35—54 years, were measured prior to and following a 9 month exercise training program conducted 3 times a week by the author. Subcutaneous adipose tissue measurements were made at 7 sites, and body density and % total body fat calculated. Twenty-five of

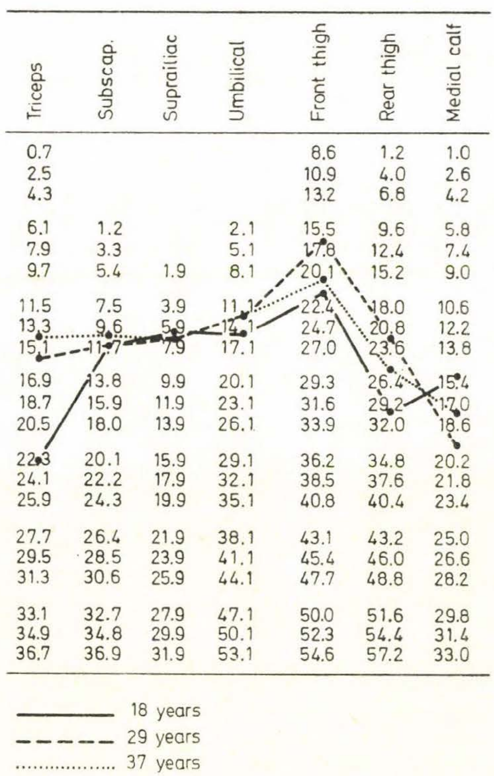

Fig. 8. **A woman's longitudinal relative fat patterns**

Z Score	Biceps	Mid axillary	Triceps	Subscapula	Suprailiaca	Lateral forearm	Umbilical	Pubis	Front thigh	Rear thigh	Calf	Medial calf	Lower medial thigh	Upper medial thigh	Trochanter	Total	% Fat
+3		0.8	1.8			1.2			2.8	1.3	2.4	1.9				14.1	
	0.7	1.3	2.5	0.7		1.7			3.9	2.8	3.4	2.7	1.0		0.4	27.5	
	1.2	1.8	3.3	1.5	0.7	2.1			5.0	4.3	4.4	3.4	2.3	0.4	2.3	40.9	0.6
	1.7	2.3	3.9	2.3	1.3	2.5			6.1	5.8	5.4	4.1	3.6	1.8	4.3	54.3	1.8
+2	2.1	2.9	4.7	3.1	1.9	2.9	0.3		7.1	7.3	6.4	4.8	4.9	3.2	6.2	67.7	3.0
	2.6	3.4	5.5	3.9	2.5	3.4	1.5	0.9	8.2	8.8	7.4	5.5	6.2	4.6	8.2	81.1	4.2
+1	3.0	3.9	6.2	4.6	3.1	3.8	2.7	2.4	9.3	10.3	8.4	6.2	7.5	6.0	10.1	94.5	5.4
	3.5	4.4	6.9	5.4	3.7	4.2	3.9	3.9	10.4	11.8	9.4	6.9	8.8	7.4	12.1	107.9	6.6
	3.9	4.9	7.6	6.2	4.3	4.7	5.1	5.4	11.5	13.3	10.4	7.6	10.1	8.8	14.0	121.3	7.8
	4.4	5.5	8.4	6.9	4.9	5.1	6.3	6.9	12.6	14.8	11.4	8.3	11.4	10.2	15.9	134.7	9.0
0	4.9	5.9	9.1	7.7	5.5	5.5	7.5	8.1	13.7	16.3	12.4	8.9	12.7	11.6	17.9	148.1	10.2
	5.3	6.5	9.8	8.5	6.1	5.9	8.7	9.9	14.8	17.8	13.4	9.7	14.0	13.0	18.9	161.5	11.4
	5.8	7.0	10.6	9.2	6.7	5.4	9.9	11.4	15.9	19.3	14.4	10.4	15.3	14.4	21.9	174.9	12.6
	6.3	7.5	11.3	10.0	7.3	6.8	11.1	12.9	17.0	20.8	15.4	11.1	16.6	15.8	23.8	188.3	13.8
-1	6.7	8.1	12.0	10.8	7.9	7.2	12.3	14.4	18.1	22.3	16.4	11.8	17.9	17.2	25.8	201.7	15.0
	7.2	8.6	12.8	11.6	8.5	7.7	13.5	15.9	19.2	23.8	17.4	12.5	19.2	18.6	27.7	215.1	16.2
	7.6	9.1	13.5	12.3	9.1	8.1	14.7	17.4	20.3	25.3	18.4	13.2	20.5	20.0	29.7	228.5	17.4
-2	8.1	9.6	14.2	13.1	9.7	8.5	15.9	18.9	21.4	26.8	19.4	13.9	21.8	21.4	31.6	241.9	18.6
	8.6	10.1	14.9	13.9	10.3	8.9	17.1	20.4	22.5	28.3	20.4	14.6	23.1	22.8	33.6	255.3	19.8
	9.0	10.7	15.7	14.6	10.9	9.4	18.3	21.9	23.6	29.8	21.4	15.3	24.4	24.2	35.5	268.7	21.0
-3	9.5	11.2	16.4	15.4	11.5	9.8	19.5	23.4	24.7	31.3	22.4	15.9	25.7	25.6	37.5	282.1	22.2

——— Gymnasts

—·—·—· Skaters

– – – – Swimmers

·········· Non. athletes

Fig. 9. **11—14 year-old female athletes' fat measurements**

the original 55 women were retested 8 years later. The organized exercise program had been discontinued in the intervening period. A small number of the women had remained physically active with individual programs, or with other organized exercise classes in the community but the majority had reverted to their normal inactive lifestyles. Analysis of the initial and the 8 year later body fat patterns showed that the patterns were similar in most instances. Measurements were available on 1 subject at 18, 29 and 37 years of age, which showed a relatively similar body fat pattern (Fig. 8).

Pre-pubertal girls

In a study presently under analysis in our laboratory, young female elite swimmers, gymnasts, and skaters were similar to each other and to a sample of their peers in their subcutaneous adipose tissue pattern (Fig. 9). When compared with college age swimmers and gymnasts, there appeared to be no difference in pattern.

Summary and Discussion

The location and number of fat cells are genetically influenced, while the level of fatness is environmentally controlled, under normal conditions. Concentration of fat cells in the subcutaneous adipose tissue are relatively thicker in some body regions than in others, and a typical male and female pattern has been described. Most males tend to display patterns similar to the typical male and females to the typical female pattern. The fat pattern, however, appears to be an individual characteristic that is relatively stable over time, at varying levels of thinness-fatness, and is not altered by different forms of physical activity or diet. The deposition or mobilization of fat from the cell cannot volitionally or preferentially be altered by specific forms of exercise, sport or physical activity.

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Author's address: Prof. MICHAEL S. YUHASZ, Ph .D.
Faculty of Physical Education
University of Western Ontario
Thames Hall
London
Canada N6A 3K7