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Effects of Physical Exercise on Total Body Fat Content

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Abstract : Skinfold thickness was measured at four selected sites - biceps, triceps, subscapular and suprailiac in 179 male Sri Lankan athletes who constituted the national training pools for swimming, rugger and athletics.

For the purpose of comparison identical measurements were taken from 200 age matched sedentary University Students who were living in almost identical conditions but not taking part in any organised physical training programmes.

Linear regression equations for the different age groups were used for the prediction of body density from the logarithm of the sum of the skinfold thickness at the four sites and the body fat content was calculated from density using the equation of Siri.

The sedentary students were found to have the highest body fat content (12.9 %) while the army long distance runners had the lowest (6.1 %).

Though no significant differences were observed in the total body fat content of the swimmers, rugby players, athlotes who took part in field events and the sedentary students, very significant differences were observed in the total body fat content of the athletes who participated in track events and the sedentary group.

It appears that endurance training produces a marked lowering of the total body fat content.

1. Introduction

Several methods are available for estimating body fat and most of these methods are based on the assumption that the body can be considered to consist of two components of relatively constant composition but which are distinctly different. These components are (1) the body fat, which includes the entire content of chemical fat or lipids in the body having a fairly constant density and (2) the fat free mass (FFM) which includes all the rest of the body apart from fat and which also has a fairly constant density. A considerable proportion (about $\frac{2}{3}$) of the total body fat in man is in subcutaneous adipose tissue.[20]

Though individuals vary both in the absolute thickness of the subcutaneous fat at a given site and in its distribution over the body surface, it is accepted that the thickness of subcutaneous fat provides a better index of relative fatness than body weight.[6]

The subcutaneous adipose tissue is adherent to the dermis but is joined to the deep fascia by loose areolar tissue so that a skinfold can be lifted up between the thumb and forefinger. The thickness of the fold of skin and subcutaneous tissue can be measured by applying a caliper to either side of it and this technique has been used to give an estimate of body fat.[19,36,41,44] The measurement of skinfold thickness to estimate body fat has now become a standard anthropometric technique and is an invaluable field procedure which can be applied to large numbers of subjects.

Brozek and Keys[3] were the first to use the relationship between skinfold thickness and body density for assessing fat content though Booth[2] and Sloan [42,43] made refinements to this technique.

The correlation coefficients for total skinfold thickness and body density in young adult men was — 0.835 which is very significant ($P < 0.001$ [17,33]). Other anthropometric measurements (as circumference of arm or thigh) did not give as high correlations as skinfolds with density.

Skinfold thickness measured by pinch caliper correlated quite highly with fat thickness under the skin at the same sites as determined by surgical incision $r = 0.82$[22] and by means of X-ray $r = 0.61—0.90$.[7,10,23,24,45] A study by Forbes et al[21] using ^{40}K showed that the correlation coefficient of fat content against average skinfold thickness was 0.80 for males. When the thickness at 3 or more sites were averaged, the correlation coefficients ranged from 0.74—0.91.[5,38,50] Skinfold thickness even at one site (triceps or subscapular) was a fairly good predicator of total fatness $r = 0.65—0.93$.[9] Inclusion of body weight with skinfold thickness did not improve the estimation of total body fatness.[16,28]

Taking all these factors into consideration it was decided to estimate body fat in our subjects using skinfold thickness as it is apparent that skinfold measurements are not inferior in consistency to the classical body measurements and since they compare favourably with most physiological variables. Since there is a wide discrepancy between the skinfold thickness of age matched males and females, this study was confined to only males.

A significant reduction in skinfold thickness and estimated body fat has been demonstrated following physical training.[32] Thompson[46,47] showed significant changes in skinfold measurements among college team players even during a single season of training. Long distance running has been found to require an energy expenditure as much as 6000 K cal per day[12,13] and this demand on the metabolic system seems to offer little opportunity for the deposition of excess adipose tissue.

Based on these observations it was decided to investigate the total body fat content of trained male athletes selected from the national training pools at the height of their training programme and to compare this with similar data obtained from sedentary male University students of about the same average age (age matched) and living in almost the same conditions and having a somewhat similar diet. These University students were not participating in any organised physical training programme. The sports that these athletes participated in were athletics (track and field), swimming and rugger.

2. Materials and Methods

Skinfold thickness was measured using the Harpenden skinfold caliper, described by Tanner.[44] The caliper used was a new model Harpenden skinfold caliper (British Indicator Ltd, St. Albans, Herts.) where one complete revolution of the pointer on the scale was equivalent to 20 mm and which exerted a constant pressure of 10 gm/sq mm.

There is a lack of agreement on the number and location of points at which the skinfolds have been or should be measured. Richer[37] measured it at 20 different sites and Matiegka et al[31] at 7 sites. As the relationship between body density and the logarithm of the sum of the four skinfolds is apparently linear in form[18] and as the incorporation of height, body weight or limb circumference caused no improvement in the standard error, only the four sites stipulated by Durnin and Womersely[18] were used to estimate skinfold thickness.

Calculations were made using the logarithm of each skinfold thickness rather than the actual measurement because the S. E. of the estimate of density using the logarithm of the skinfold was lower than those for the raw measurements.[18]

Edwards et al[19] suggested the substraction of 1.8mm which is the thickness of a double layer of skin, but Durnin and Womersely[18] showed that no significant alteration was obtained in the S. E. of the estimate of density where a deduction of 1.8 mm was made from each measurement of skinfold thickness. Hence no correction was made for skin thickness.

The four sites at which skinfold thickness was measured were identical with those described by Weiner and Lourie.[48]

1. Triceps—at the mid posterior point of the muscle between the tip of the acromion and the olecranon process. The skinfold being lifted parallel to the long axis of the arm.

2. Biceps— over the midpoint of the muscle belly.

3. Subscapular— just below the tip of the inferior angle of the scapula, the fold being picked up parallel to the natural cleavage line of the skin i. e. at an angle of 45° to the vertical.

41. Suprailiac—just above the iliac crest in the midaxillary line.

At these 4 sites the skinfold was pinched up firmly between the thumb and forefinger, taking care that no underlyng muscle was included, and the caliper was applied to the fold a little below the fingers. As the error of measurement is much greater between observers[19] all measurements were made by the author. All measurements were made on the right side of the body with the subject standing in a relaxed position as described by Consolazio[11], although Womersely and Durnin[49] showed no statistical difference between measurements on either side of the body. Three recordings were made at each site and the average utilised to estimate body density. Adequate time was allowed between measurements so that the tissues would regain their normal configuration.

Linear regression equations for the different age groups stated below, were used for prediction of body density from the logarithm of the sum of the skinfold thickness at 4 sites as advocated by Durnin and Womersely.[18]

Body density = C — M x Logarithm total skinfold

Age		17 — 19 yrs	20 — 29 yrs	30 — 39 yrs
C	=	0.1620	1.1631	1.1422
M	=	0.0630	0.0632	0.0544

The standard error using the regression equation is 4%.[17]

Body fat was calculated from density using the equation given by Siri[40] which is predicated on the basis of a known and constant density of the non-fat solids in the body.

$$\% \text{ Fat} = \left(\frac{4.95}{D}\right) - 4.50 \times 100$$

The S. E. using the Siri equation is 3.5% and for all practical purposes this error is within acceptable limits. No significant difference is known to arise from the use of the equation of Brozek et al.[8]

Though derived measurements using formulae always have more error than direct measurements, the above method was employed in this paper for the estimation of the fat content of the athletes and non-athletes because the apparatus for making direct measurements was not available in Sri Lanka.

3. Results

The total skinfold, body density and total body fat content are calculated separately for each event.

Table 1 presents the age, height and weight characteristics of those tested.

Table 2 shows the mean skinfold measurements for all groups.

TABLE 1. Age, height and weight characteristics of athletes and non-athletes

		Age (years)			Height (cm)			Weight (kg)		
	N	Mean	S.D	Range	Mean	S.D.	Range	Mean	S.D.	Range
Swimmers	17	18.4	3.6	15-24	169.5	8.2	155-177.5	59.4	8.8	49-73
7 a side rugger	9	23.4	1.7	21-27	169	6.3	160.6-180.6	64.6	7.2	56-76
Club rugger	18	21.5	4.2	18.29	168.5	5.5	161.3-176.9	61.5	8.8	52-73.5
Field events	24	25.0	2.4	21-30	170.5	5.7	162.5-178.8	69.5	0.3	54-94
National sprinters	25	24.4	2.7	19-30	168.2	5.5	156.3-177.5	57.2	5.7	44-66
Public Schools	20	18.5	2.1	15-24	165.5	5.1	150-173.8	49.7	4.2	42.5-60
Army	26	22.8	2.1	20-27	170.9	6.0	163.8-181.3	58.4	4.3	51-66
Army Long Distance	21	25.2	2.2	22-29	164.8	4.9	161.9-171.2	51.1	4.9	43-58.5
Long Distance (Non-service personnel)	19	23.2	3.4	17-30	164.0	4.9	166.9-173.1	53.0	5.2	45-63.5
Sedentary	200	23.4	2.3	18-28	165.4	6.2	150.0-180.0	53.4	6.8	40-72.3

TABLE 2. Mean Skinfold Measurements (mm)

		Triceps			Biceps			Subscapularis			Suprailiac			Total Skinfold		
	N	Mean	S.D	Range	Mean	S.D	Range	Mean	S.D	Range	Mean	S. D	Range	Mean	S. D	Range
Swimmers	17	7.0	2.1	5.1-10.5	3.3	1.3	2.4-6.1	6.9	1.5	5.0-8.7	7.1	1.8	4.2-9 0	24.2	5.5	19.5-33.8
7 a side rugger	9	6.2	2.9	3.9-13.6	2.8	0.4	2.5-3.8	8.5	1.7	6.1--10.6	7.4	3.2	4.4-14.9	24.9	7.6	17.9-42.7
Club rugger	18	7.2	2.2	4.5-11.7	3.2	0.68	2.7-4.8	9.3	3.3	6.9-17.2	8.2	2.7	5.2-13.7	27.8	8.4	20.8-47.4
Field events	24	7.5	2.5	4.3-13.3	3.0	0.8	2.0-5.7	9.8	2.6	6.0-16.4	7.7	3.6	5.1-21.1	28.0	8.0	18.7-46.5
National sprinters	25	5.9	2.1	3.1-10.2	2.9	0.5	2.0-3.9	8.0	1.8	5.0-11.9	6.5	2.3	3.9-10.8	23.3	5.7	14.4-34.3
Public Schools	20	4.9	0.9	3.4-6.5	2.6	0.4	2.0-3.6	6.6	1.2	4.7-8.3	5.1	0.7	3.0-5.8	19.1	2.2	13.5-21.7
Army sprinters	26	5.1	1.8	3.0-7.7	2.4	0.3	2.0-3.0	7.2	1.2	5.1-9.5	5.5	1.4	3.1-8.8	20.3	4.0	14-27.1
Army long distance	21	4.2	1.0	3.0-6.7	2.3	0.2	1.9-2.6	6.2	1.1	4.8-8.4	4.5	0.9	3.3-6.7	17.2	2.3	13.2-20.4
Long distance (Non-service personnel)	19	5.8	1.5	3.9-9.3	2.8	0.4	2.1-3.4	5.7	1.8	4.4-10.7	5.3	1.7	3.4-10.1	21.4	4.5	15.6-30.7
Sedentary	200	8.9	3.7	3.8-20.8	3.3	1.0	2.1-6.7	10.9	4.0	5.0-25.7	9.0	4.2	3.4-23.4	32.1	11.5	15.0-72.9

Table 3 is a comparison of body density values and estimated body fat among athletes and non-athletes.

TABLE 3. Comparison of estimated body density values and body fat among athletes and non-athletes.

	Body density × 10² (kg/m³)				Fat (% body weight)			P (t-test)
	N	Mean	S.D.	Range	Mean	S.D.	Range	
Swimmers	17	1.0755	5.9	1.0656-1.0822	10.3	2.5	7.4-14.5	< 0.1
7 a side rugger	9	1.0757	7.6	1.059-1.0839	10.1	3.2	6.7-16.7	< 0.1
Club rugger	18	1.0723	6.8	1.0572-1.079	11.6	3.0	8.7-18.2	< 0.1
Field events	24	1.0723	8.1	1.0515-1.0827	11.7	3.5	7.2-20.8	< 0.1
National sprinters	25	1.0768	6.1	1.0661-1.0898	9.8	2.6	4.2-14.3	< 0.0001
Public Schools	20	1.0816	3.4	1.0779-1.0908	7.7	1.4	3.8-9.2	< 0.00001
Army sprinters	26	1.0810	5.4	1.0726-1.0907	7.9	2.3	3.8-11.5	< 0.00001
Army long distance	21	1.0853	3.6	1.0804-1.0922	6.1	1.5	3.2-8.2	< 0.00001
Long distance (non-service personnel)	19	1.0801	6.1	1.0691-1.08062	8.5	2.4	3.8-13.0	< 0.0001
Sedentary	200	1.0694	9.6	1.0454-1.0888	12.9	4.1	4.7-23.5	

A study of the dietary habits showed that the diet of the athletes was very similar to that of the sedentary group. In many instances, the athletes and non-athletes lived in the same hostel and ate the same food. Almost all of them had two rice meals each day, but their diet was inadequate in proteins. Except for the rugger players and the swimmers who came from upper middleclass families, only a few could afford an egg and a glass of milk each day. On an average they consumed less than ¼ lb of beef or fish per day.

The most reproducible site for skinfold was the biceps, while the skinfold thickness at the subscapular and suprailiac sites was far greater than at the other sites, which was also the observation of Tanner and Whitehouse.[45] Though Ruiz et al[39] reported that lack of precision in identifying the triceps midpoint could lead to large random variations in skinfold thickness and Womersely and Durnin[49] observed that the greatest variation was at the triceps site, this was not what was observed in the present study.

3.1 Swimming

A total of 17 male swimmers who constituted the Sri Lanka pool were examined just prior to the Indo-Ceylon Meet.

These 17 swimmers were Ceylon's best swimmers and were the youngest group examined (mean age 18.4 yrs). Their duration of training was 1¾ hours per day. In spite of their rigid training schedules their total body fat content was high (10.3 %)

3.2 Rugger

A total of 27 rugby players were examined.

3.2.1. *Seven a Side Rugger* — 9 players comprised the Sri Lanka team for the international Seven a side rugby tournament held in Hongkong. All of them were employed, some of them being executives and they trained for 1½ hours each day.

3.2.2. *Club Rugger* — These 18 players represented a leading Colombo rugby club — the Colombo Hockey and Football Club — (CH and FC). All were employed in the private sector and training was restricted to 1½ hours each day.

The total body fat content of these 27 rugby players was high and there was no significant difference ($P<0.1$ >0.05) between the fat content of these players and the sedentary individuals.

3.3 Athletes

A total of 135 athletes were examined. These athletes had represented Sri Lanka in international meets, some held Ceylon records, others were winners of the AAA meet, the Junior Nationals, the Ceylon Schools or Army meet.

Of these athletes 24 had won field events like the Discus, Puttshot and Javelin. Of the remaining 111 athletes, 71 were sprinters who had as their favoured event the 100 m, 200 m, 400m, 800 m, flat or hurdles. They comprised 26 army sprinters, 20 Public schools sprinters and 25 national sprinters who were non-service personnel.

40 athletes were long distance runners who specialized in the 1500m, 3000 m, 5000 m, 10,000m or the marathon road race — 26 miles. 21 of these athletes were from the army while the other 19 were non-service personnel. The sprinters, Army athletes, public schools athletes, long distance runners and those athletes who participated in the field events are considered separately.

3.3.1. *Field events* — They were the heaviest of the athletes, (mean wt. 69.5 kg). Their fat content was the highest (mean 11.7 %) among the athletes and showed no significant difference ($P<0.01$—0.05) from the sedentary group. This was probably because their training involved more or less static exercises and they did not participate in any running or endurance training.

3.3.2. *National Sprinters* — Most of them were employed in the mercantile sector, doing desk jobs and their period of training was only 1½ hours per day. Their total body fat content (9.8 %) though highest among the runners was significantly lower ($P<0.0001$) than the sedentary group.

3.3.3. *Public Schools*–These young schoolboys (mean age 18.5 yrs) trained for about 1½ hours each day. Their total body fat content (7.7 %) was even lower than the national and army sprinters and was very significantly lower ($P < 0.00001$) than the sedentary groups, probably due to their greater physical activity and higher metabolic needs.

3.3.4. *Army sprinters* — Compared to the national sprinters, their mean fat content was lower (7.9 %) probably because their duration of training was almost double that of the other sprinters.

3.3.5. *National long distance runners* — Although long distance runners are known to have the lowest fat content among athletes, these national runners had fat content higher than most sprinters— a reflection of their poor training which was only 1½ hours each day. These athletes almost all of whom were employed and doing desk jobs had very little time for endurance training.

3.3.6. *Army long distance runners* — Their body weight were the lowest (mean 51.1 ± 4.0 kg) and their fat content was also the lowest (mean 6.1 %) being very significantly lower ($P<0.00001$) than the sedentary groups. Their duration of training was at least 3 hours each day.

Although these army long distance runners ate the same food and lived in the same barracks as the army sprinters, their fat content was significantly lower on account of the endurance training.

4. Discussion

The body fat content depends on dietary habits and physical activity. Variations in states of nutrition, and in physical activity alters markedly the composition of body fat. Brozek[4] observed that matched for age and height, the physically active men were heavier than inactive men, their S. G. was higher and their estimated fat content lower.

Various figures have been given for the total body fat content of normal men. Hunt and Giles[27] reported that the reference man had 14 % fat. Brozek[4] estimated that the average value for fat percentage in men 25 years old was 13.1 %. Pascale et al[34] sampled 88 men with an average age of 22 years and reported a mean fat content of 13.8 %. Lesser et al[30] found that the average body fat content for men aged 17-39 years who were representative of the urban U. S. population was 18.3 % (range 9.7-27.3 %). Costill et al[14] reported a body fat content of 16.3 % among sedentary college students.

No figures are available for the total body fat content of Ceylonese males whose diet is so completely different from their counterparts in the western world. The present study shows that the total body fat content of sedentary Ceylonese males (mean 12.9 %) is far lower than that reported by workers in other countries. The fat content of the athletes is even lower.

It is known that exercising any group of muscles leads to a mobilisation of fatty acids from fat deposits throughout the body,[25] since exercising muscle utilizes fatty acids as its principal source of fuel.[51] Variations of body density and fat content among athletic groups has shown some relationship to the nature of the sport. Endurance athletes (marathoners) are known to have less body fat than other athletic groups.[15,26] Many top olympic marathon runners have a body fat value below 6%. Costill et al[14] found the mean fat content of 114 marathoners to be 7.5%.

In our series, though the army long distance runners had a comparable fat content (mean 6.1%), the long distance runners who were non-service personnel showed a much higher fat content (8.5%).

Pugh et al[35] showed a relatively high body fat content (22.2%) among 10 channel swimmers. Our swimmers most of whom were not long distance swimmers showed a mean fat content of 10.3%.

Football players were also observed to have considerably more body fat. Behnke et al[1] observed a fat content which ranged from 10-24% among football players, while Costill et al[14] reported a fat content of 15.4% in 75 football players. Though no figures are available for rugger players, rugger is a sport which is very similar to football, and our rugger players had much lesser values for their body fat content. The higher body fat content in rugger players and swimmers is probably due to their richer diet for most of them were from the upper middle class.

It is generally accepted for European men that 20% body fat represents mild obesity. No standards for obesity are available in Sri Lanka, but by these western standards, one athlete in the field events and 8 from the sedentary group could be classified as mildly obese.

5. Comment

The total body fat content of the sedentary students is far greater than that of the age matched athletes. It appears that the young sedentary man with a higher total body fat content is an increasingly common variety of physical type in Sri Lanka and may account for the increasing incidence of coronary heart disease among the young in this country.

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