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Full Length Research Paper

Skinfolds as prognosticators of nutritional status among adult undernourished males of India

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The objective of this work is to utilize skinfold thicknesses taken at various sites as indicators to infer the nutritional status of undernourished tribal males of India and to find the best prognosticator skin fold for assessing under nutrition. A cross-sectional study was conducted on 1435 adult males of India categorized on the basis of nutritional status (undernourished and normal), and age groups. Anthropometric measurements were taken on all subjects and adiposity indices were derived. Binomial logistic models were used to determine the odds for being underweight through each skinfold thickness when others were held constant. Nutritional status assessed was by body mass index (BMI) and mid upper arm circumference (MUAC) in association with various skinfold thicknesses showed higher odds for being underweight (1.54 and 1.42, respectively) when triceps skinfold was used as a predictor for controlling other skinfolds. In conclusion triceps skin fold thickness was followed by chest, calf posterior and subscapular skinfolds determined sub-nutritional status of the Indian undernourished population competently validating the role of simple- easy to take and non-invasive skinfold measurements in evaluation of nutritional status.

Key words: Undernourished, triceps, skinfold thickness, nutrition, males.

INTRODUCTION

Malnutrition, that is the most crucial keyword for nutrition-related research encompasses a wide range of deficiencies (protein-energy) and excesses (over weight-obesity), which are clearly associated with adverse health outcomes. However, one area of malnutrition that is, undernutrition continues to be a major public health problem in most of the developing countries including India (Meshram et al., 2011) despite their continued contribution towards overweight/ obesity burden of the globe. In India, nearly 20% of the adult populations are undernourished according to a 2009 report on nutraceuticals by global services firm Ernst and Young (Jason, 2011). This global epidemic stalks India's tribal residents the most as they are socially and economically vulnerable. India with its large and diverse tribal population witness's wide variations with respect to nutritional status and access to and utilization of nutrition and health services, leading to myopic interpretations of causal-effect notions pertaining to undernutrition.

Nutritional status as reflected by height, weight and other anthropometric measurements are true indicators of a population's health status as these anthropometric variables are closely related to a population's nutrition, genetic makeup, environmental characteristics, social and cultural conditions, lifestyle, functional status, etc. Anthropometric appraisal has always been an essential feature of nutritional evaluation for determining malnutrition, overweight, obese, muscular mass loss, and adipose tissue redistribution (Sanchez-Garcia et al., 2007; Monir et al., 2008). Skinfold thicknesses are important and valid anthropometric indicators of nutritional status, body composition and relative subcutaneous fat distribution (regional and total body fatness), especially in research settings (Bellisari and Roche, 2005; Sinha et al., 2008). Subcutaneous fat measured as double layer of fat and skin has a long history in nutrition-related research as these measures of subcutaneous fat are very specific

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to adipose tissue and can be measured noninvasively (Addo and Himes, 2010).

Assessment of the nutritional status with the help of a simple, easy and at the same time fairly accurate and quickly implemented method is the need of the hour. With extensive literature search, it was evident that most of the studies related to nutritional state of the undernourished have been based on BMI and mid-upper arm circumference along with its derivatives. Body mass index (BMI) is one of the most established anthropometric indicators used not only for assessment of adult nutritional status but also for the socio-economic condition of a population, especially in developing countries. Mid upper arm circumference (MUAC) is another anthropometric measure, is particularly effective in the determination of malnutrition among adults in developing countries (Shetty et al., 1994; James et al., 1994 ; Khongsdier, 2002; Kapoor et al., 2009). There has been much interest in the literature on the use of skinfolds and derivatives of these for nutritional assessment of muscle and fat body reserves along with its association to chronic (Shetty et al., 1994; Kapoor et al., 2010)

Hence, the objective of our research is to understand the role of skinfold thicknesses (taken at various sites over the body) as indicators, to infer the nutritional status of undernourished tribal males of India and to find the best prognosticator skinfold for assessing undernutrition.

MATERIALS AND METHODS

This study is based on a cross-sectional sample of 1435 males aged 20 to 99 years, obtained from 8 tribal populations and 2 caste population inhabiting different geographical areas of India as shown Map 1 and Table 1. The study comprised of 1571 subjects initially but due to the objectives undertaken, we restricted the study population to normal-weight and undernourished individuals and excluded subjects who were overweight and obese (BMI ≥ 24.99). For the sake of convenience, different age groups have been referred to as young males (20 to 30 years), middle aged males (31 to 60years), and older males (61 to 99years).

A written consent was taken from each subject who volunteered after explaining the study purpose. The study protocol was duly approved by the Institutional Ethical Clearance Committee. All anthropometric measurements were taken by trained anthropologists using standard techniques of Weiner and Lourie (1981). Stature, body weight, MUAC and skinfold thicknesses (triceps, biceps, mid-axillary, chest, abdomen, suprailiac, subscapular and front of thigh) were recorded to the nearest 0.1 cm, 0.5 kg, 0.1 cm and 0.2 mm respectively. Skinfold thicknesses were measured using Harpenden's skinfold calipers which exerted a constant pressure of 10 g/mm² over the contact surface. Grand mean thickness (GMT) was calculated as mean of all skinfold thicknesses measured and BMI was computed as weight (kg)/height² (m²). Durnin's age specific equations (1977) were used to calculate body density which was further used in Siri's equation (1961) to determine the total body fat.

Body fat % = (4.95/D - 4.50) × 100.

Nutritional status was evaluated using internationally accepted standard cut offs for BMI (World Health Organisation, 2003) and MUAC (James et al., 1994). The cut off values used are as follows:

Category	BMI (kg/ m²)	MUAC (cm)
Underweight	<18.5	<22.0
Normal	18.5 – 24.9	≥22.0

Statistical analysis

Data was statistically analyzed in SPSS 17.0. Basic data was presented as means and standard deviations. T-test was used to reveal the significant differences among variables among different age groups and chi-square test was used to assess the difference in the prevalence of undernutrition with age. Pearson's correlation coefficient(r) was used to demonstrate the univariate association and its direction among various variables with age and BMI. Binomial logistic regression models were applied and stratified to determine the odds for being underweight with MUAC and BMI as dependent variables individually, while skinfold thickness were taken as independent variables, controlling for others. The Hosmer and Lemeshow test was also used as a goodness-of-fit test.

RESULTS

Figure 1 summarized the anthropometric characteristics and obesity indices of young males (20 to 30 years) categorized as undernourished and normal. Independent t-test revealed significant differences in body weight, upper arm circumference, triceps skinfolds, biceps skinfolds, chest skinfolds, subscapular skinfolds, BMI, GMT and body fat percentage (p <0.001). The middle (31 to 60years) and old aged undernourished males (61 to 99 years) presented in Figures 2 and 3 respectively, had significantly lower weight, upper arm circumference, BMI, GMT, body fat percentage and skinfold thickness than their normal weight counterparts. The difference was non significant for biceps and midaxillary skinfold thicknesses in middle aged individuals. Figure 4 displays mean and standard deviation of basic anthropometric characteristics for combined data. Normal weight individuals had significantly higher values for all variables except for stature, GMT, BMI, biceps and midaxillary skinfold thickness.

Patterns of fat distribution at different skinfold sites among undernourished and normal weight tribal males are depicted in Figures 5 to 8. Figure 5 illustrated depletion of skinfold thicknesses at various sites namely suprailiac, front of thigh, calf posterior, subscapular and abdomen among undernourished; the decline was abrupt in triceps skinfold thickness. Figure 6 indicated biceps and midaxillary skinfold to be resistant to fat depletion despite of decline in other skinfold thicknesses. Figure 7 demonstrated decline in subcutaneous fat at all sites. The analysis of pooled data as shown in Figure 8, demonstrated biceps and midaxillary sites to be resistant (to change) in nature.

Table 2 showed the cross tabulation of nutritional status (BMI) and age. The prevalence of undernutrition increased with advancing age. Majority of underweight

Map 1. Distribution of subjects according to different ethnic groups on the Map of India.

Table 1. Key for understanding the map and size of sample population.

Variable			N	Key index number
Tribal populations		Car Nicobarese	164	1
		Nolias (Orissa)	155	2
		Rajis (Uttaranchal)	63	3
		Tadavi (Gujarat)	87	4
		Bhoatis (Uttarakhand)	182	5
		Desia Khonds (Orissa)	144	6
		Minas (Rajasthan)	160	7
		Saharias (Madhya Pradesh)	155	8
Caste populations	Rajputs	Haryana	122	9
		Himachal Pradesh	84	10

males were found in age group 61 to 99 years followed by 31 to 60 years and 20 to 30 years. Chi-square validated the significant difference (χ^2=6.28, p< 0.045) in proportion of underweight individuals distributed age wise.

Table 3 displayed correlation analysis of height, weight, skinfold thickness and adiposity indices with age and BMI. Significant decline was observed in various

Table 2. Cross tabulation and chi-square value for nutritional status and age.

Age (years)	Underweight (%)	Normal weight (%)	Chi-square value	Significance
20-30	49.11 (138)	50.89 (143)		
31-60	51.46 (457)	48.54 (431)	6.28	0.045 (df=2)
61-99	55.87 (157)	38.79 (109)		

Table 3. Correlation of age and BMI with various anthropometric and derived variables.

Variable	Age	BMI
Weight	-0.229**	0.882**
Stature	-0.335**	-0.086**
Triceps skinfold thickness	-0.110**	0.408**
Biceps skinfold thickness	-0.116**	0.019
Midaxillary skinfold thickness	-0.265**	-0.053
Chest skinfold thickness	-0.208**	0.296**
Abdomen skinfold thickness	-0.189**	0.223**
Suprailiac skinfold thickness	-0.157**	0.349**
Subscapular skinfold thickness	-0.214**	0.325**
Front of thigh skinfold thickness	-0.164**	0.366**
Calf posterior skinfold thickness	-0.213**	0.408**
BMI	-0.081**	1
GMT	-0.208**	0.439**
BF%	0.017	0.393**

Table 4. Binomial logistic regression analysis to identify risk for underweight (BMI).

Skinfold thickness	B	S.E.	Exp(B)	95% confidence intervals		p
				Lower	Upper	
Triceps	0.434	0.057	1.536	1.381	1.726	<0.001
Chest	0.383	0.056	1.472	1.315	1.635	<0.001
Calf posterior	0.363	0.051	1.124	1.026	1.211	0.004
Subscapular	0.178	0.056	1.115	1.012	1.226	0.027
Front of thigh	0.062	0.038	1.071	0.968	1.170	0.165
Abdomen	0.037	0.038	1.032	0.963	1.117	0.418
Midaxillary	0.108	0.049	0.931	0.837	1.023	0.166
Suprailiac	-0.117	0.048	0.891	0.827	0.958	0.002
Biceps	-0.078	0.040	0.855	0.791	0.918	<0.001
Age	0.003	0.004	1.003	0.995	1.012	0.476

Hosmer and Lemeshow test: Chi-square, 25.738; df, 8; Significance, 0.001.

anthropometric variables with progressing age except for body fat%. With increasing age, positive association of weight, GMT, body fat% and skinfold thickness (except biceps and midaxillary), with BMI that signifies significant decline in adiposity with decreasing BMI.

The binomial logistic regression analysis displayed in Table 4 indicated skinfold thicknesses as predictors of nutritional status evaluated on the basis of BMI, where each site was controlled for age and other skinfold thicknesses. The elevated adjusted odds of triceps skinfold (OR-1.54, CI 1.381-1.726) proved to be a better prognosticator of nutritional status trailed by chest, calf posterior and subscapular skinfold thickness sequentially. The odds of being underweight decreased with change in suprailiac (11%, CI 0.827-0.958) and biceps (15%, CI 0.791-0.918) skinfold thicknesses. Hosmer-Lemeshow tests for BMI and MUAC with different skinfold thicknesses resulted in values 25.738 (df=8, p<0.01) and 86.424 (df=8, p<0.001), respectively. Nutritional status assessed by MUAC in Table 5 also showed high odds for triceps skinfold to be a strong predictor of underweight (OR-1.42, CI 1.199-1.634) followed by subscapular, calf

Table 5. Binomial logistic regression analysis to identify risk for underweight (MUAC).

Skinfold thickness	B	Standard error	Exp(B)	95% confidence Intervals		p
				Lower	Upper	
Triceps	0.070	0.009	1.417	1.199	1.634	<0.001
Subscapular	0.047	0.008	1.359	1.214	1.537	<0.001
Calf posterior	0.023	0.005	1.183	1.068	1.339	0.003
Abdomen	0.005	0.006	1.093	0.979	1.198	0.086
Chest	0.034	0.007	1.062	1.015	1.459	<0.001
Biceps	0.001	0.005	0.997	0.913	1.096	0.956
Front of thigh	-0.011	0.007	0.980	0.884	1.130	0.755
Suprailiac	0.015	0.008	0.974	0.892	1.078	0.592
Midaxillary	-0.007	0.006	0.973	0.874	1.108	0.650
Age	-0.008	0.005	0.992	0.982	1.002	0.137

Hosmer and Lemeshow test: Chi-square, 86.424; df, 8; Significance, <0.001.

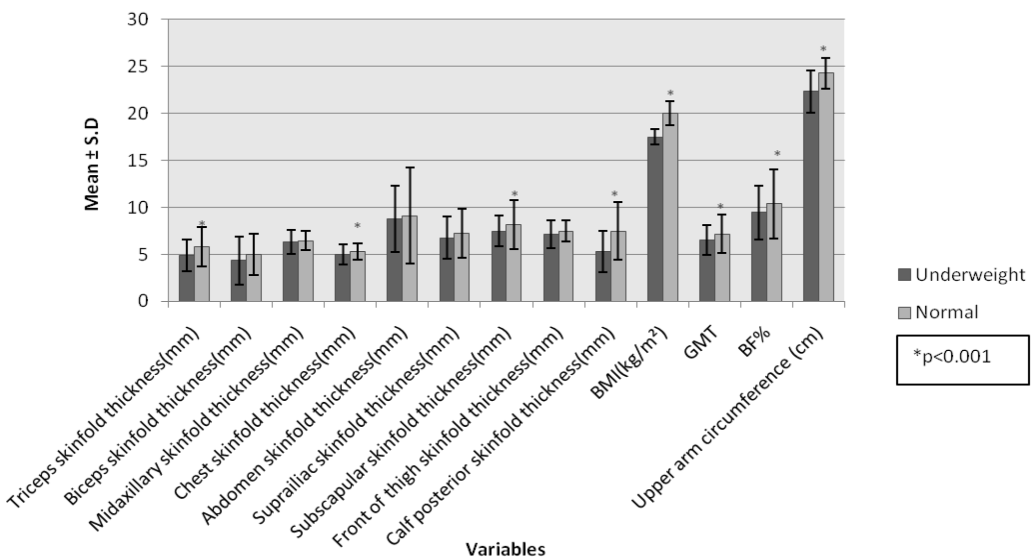

Figure 1. Descriptive characteristic of males aged 20 to 30 years along with t-test significance values.

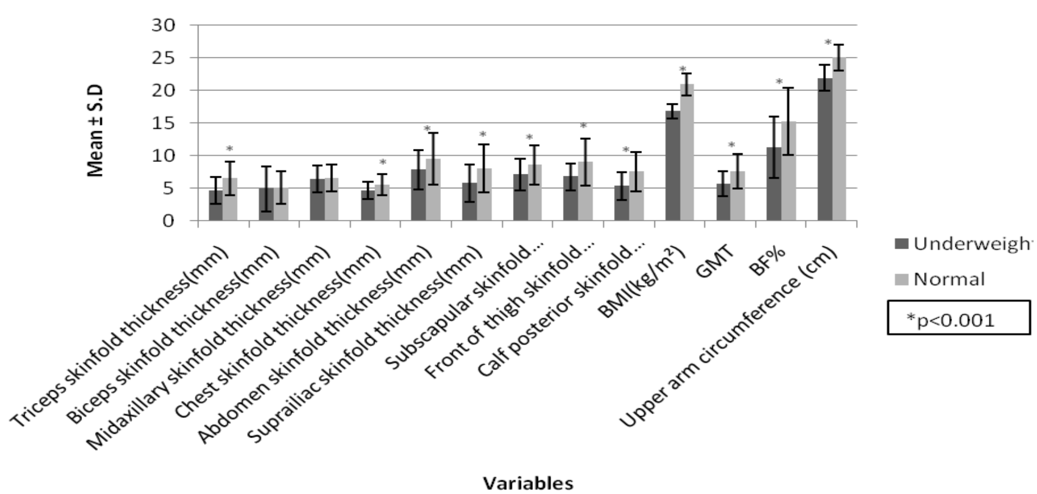

Figure 2. Descriptive characteristic of males aged 31 to 60 years along with t-test significance values.

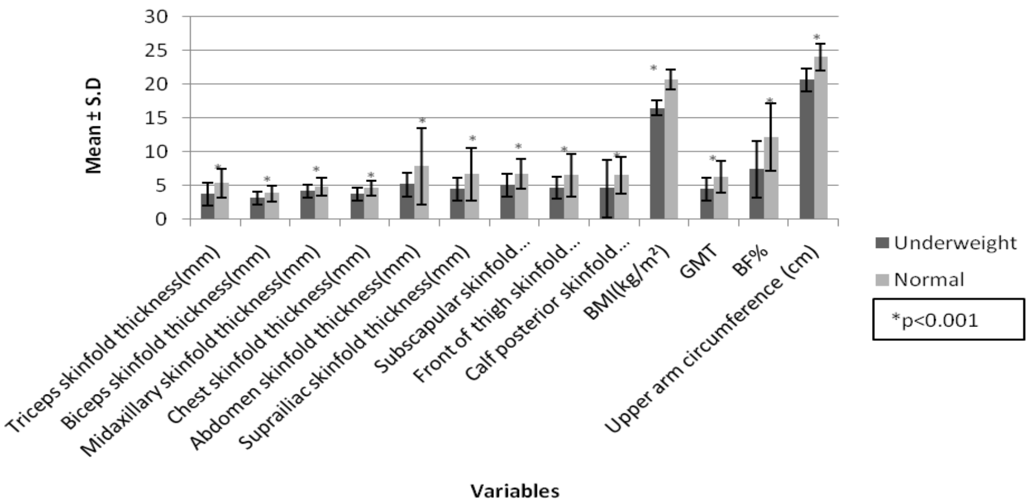

Figure 3. Descriptive characteristic of males aged 61 to 99 years along with t-test significance values

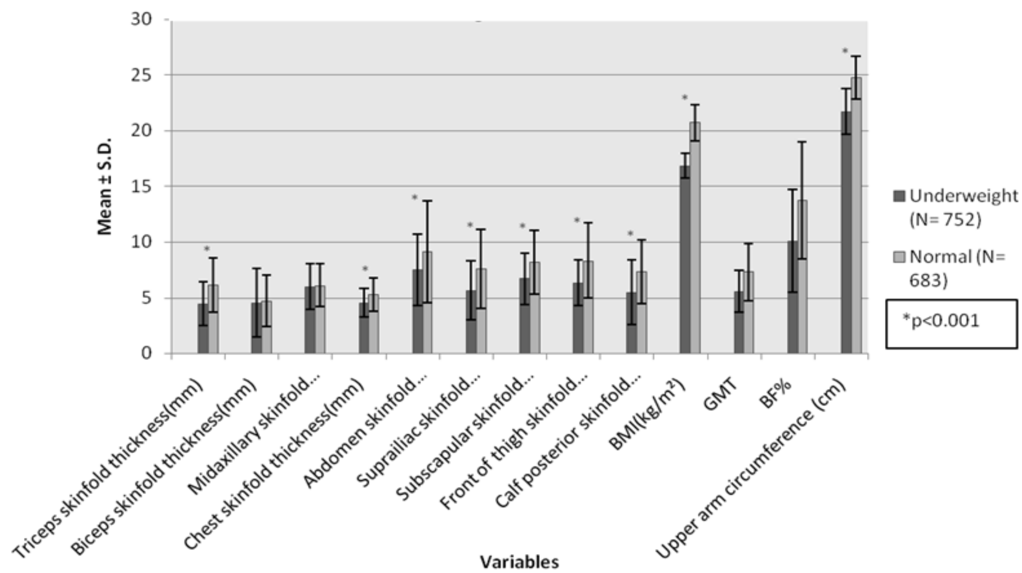

Figure 4. Descriptive characteristics of all the subjects (n=1435) along with t-test significance values.

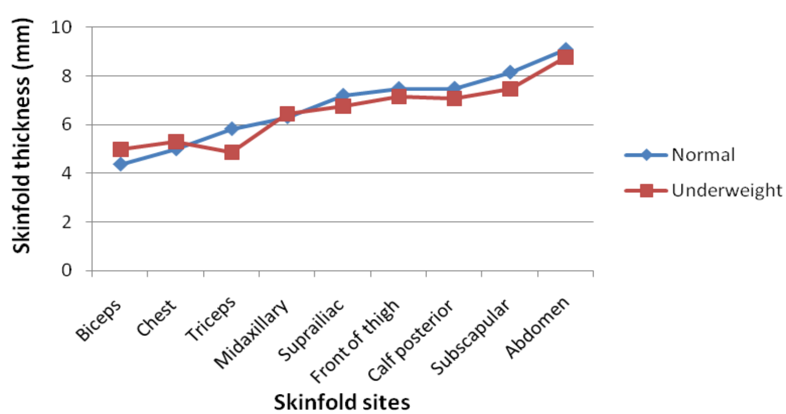

Figure 5. Fat distribution profile among males aged 20 to 30 years.

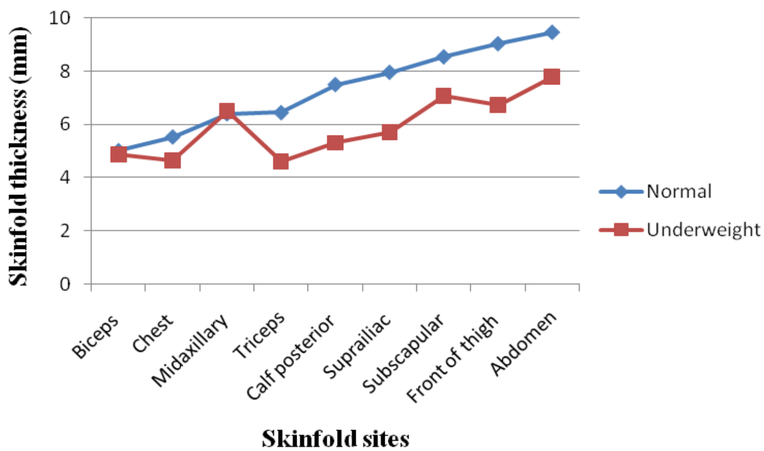

Figure 6. Fat distribution profile among males aged 31 to 60 years.

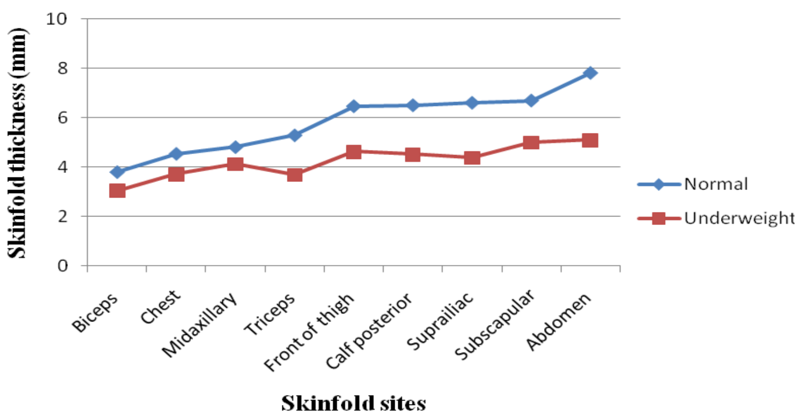

Figure 7. Fat distribution profile among males aged 61 to 99 years.

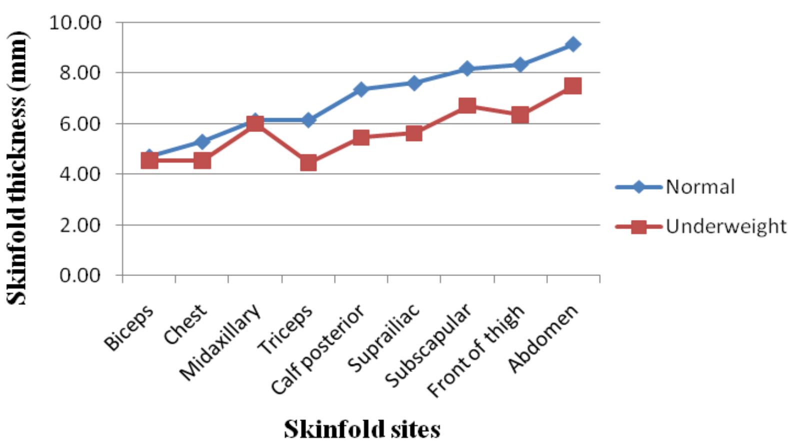

Figure 8. Fat distribution profile among males aged 20 to 99 years.

posterior and chest skinfold thickness respectively, after each site was adjusted for age and other skinfold thicknesses.

DISCUSSION AND CONCLUSION

The undeniable changes in the body's composition with old age bring about a plethora of physiological consequences affecting levels of function along with current and subsequent health of the individual. Though, malnutrition is an inevitable side effect of ageing, physiological changes associated with senescence can promote malnutrition which leads to nutrition related health problems (Hickson, 2006).

In the present study, frequency of underweight individuals increased with age. These results are in concordance with other studies, showing increased prevalence of malnutrition with age (Natarajan et al., 1995; Kapoor et al., 2010). This could be explained by escalating frailty, physical dependence (Stratton et al., 2004) and anorexia, which are common among the aging individuals and prevent them from getting requisite amount of the right food. Age-related decline in lean tissue affects immunosenescence which aggravates chronic conditions consequently disposing elderly to nutritional frailty. The prevalence of malnutrition is moreover influenced by varied socio-economic and psychological factors (Forster and Gariballa, 2005).

Anthropometric evaluation infers body size, amounts of skeletal muscle and fatness to be an essential feature of geriatric nutritional evaluation (Garcia et al., 2007). It displays disparity of body composition in a variety of health, nutritional and functionally-related milieu to monitor or depict individuals at risk (Chumlea et al., 1998). Differential and disordered body composition has different relationships to morbidity, disability and health status (Baumgartner, 2006). The present study revealed a significant decline in anthropometric variables among undernourished aged males. Decline in BMI was positively associated with skinfold thicknesses, GMT and body fat percentage (BF%), among underweight old aged individuals. This is in agreement with the finding that at the accepted cut-off of 18.5 kg/m^2 ; body fat content is reduced, varying from about 10 to 12% (Soares and Shetty, 1991) to as low as 6% (Shetty, 1984). In old, frail population, the altering muscle mass influences body weight and hence body mass index.

BMI and MUAC have been used as forecasters of subnutrition, intensively in numerous studies (Kapoor et al., 2009; Kapoor et al., 2010). But arm circumference, a sensitive measure of the loss of muscle mass in the elderly is related to greater degrees of malnutrition than BMI and is validated as nutritional screening tool for malnutrition in the elderly (Chumlea et al., 1998). Skinfold thickness has been used in myriad studies of nutritional status (Himes, 1980; Garn et al., 1991) based on the fact that the adipose fat storage is a function of positive energy balance. Skinfold thickness, however, stands in their own right as indices of fat and fatness and by difference of leanness (Norgan et al., 1995). Thickness of skinfolds among undernourished males may significantly contribute in the assessment of undernutrition as shown in the present study. Among undernourished individuals energy balance is negative which is reflected in depleted skinfold thicknesses (Singh, 2002). Similar trends have also been documented in the present study. The error in prediction of body fat by skinfold thickness is far less among undernourished than over nourished individuals (Womersley and Durnin, 1997). Triceps skinfold was found to be the best predictor of nutritional assessment among the Indian undernourished males whether classified by BMI or MUAC as it provides an estimate of body fat and the upper arm musculature (Burgert and Anderson, 1979).

Triceps skinfold along with chest, calf posterior and subscapular skinfolds can determine sub-nutritional status of a population competently when BMI and MUAC affirm the same. However, the same cannot be put to effect in the context of overweight individuals, as in the present study only few were overweight and excluded from the analysis which can be taken as a limitation of the study. The wide gap in the data base of nutritional assessment of the undernourished by skinfold thicknesses puts forward the need for further studies to validate the role of simple, easy to take and non invasive skinfold measurements in evaluation of nutritional status.

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