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Quetelet's Index and Body Fat Percentage Assessment in Indian Undergraduate Students

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ABSTRACT

Obesity is gradually becoming a global epidemic with more than 13% of the world's adult population classified as obese. The most significant anthropometric marker to classify individuals as obese is Body Mass Index [BMI]. Other body composition parameters like visceral fat have also been found to be good markers of predisposition of the individual to various metabolic disorders like coronary heart disease, diabetes mellitus, pulmonary problems and dyslipidemia. High subcutaneous fat levels however have been correlated with insulin resistance. A health camp was conducted at Shivaji College, University of Delhi, comprising of 140 students in the age group 17-21 years to measure their body parameters indicative of general health. Their BMI, total body fat, visceral fat, subcutaneous fat and skeletal muscle were recorded and analyzed. It was found that the sample population was primarily healthy, and consisted majorly of female participants (57.1%).There appears to be a difference in the pattern of distribution of certain body composition parameters with respect to the gender of participants. A larger population of females (17.5%) was found to be overweight/obese according to BMI when compared with males (10%).Correlation between BMI and other body parameters was also assessed through this study. A strong and significant positive correlation was obtained between BMI and visceral fat deposits, total body fat and subcutaneous fat of subjects under study. However, a negative correlation was obtained for BMI and skeletal muscle of the individuals.

Key Words: Body Mass Index, Obesity, Skeletal Muscle, Subcutaneous Fat, Total Fat percentage, Visceral Fat

INTRODUCTION

The WHO has defined obesity as a condition with excessive fat accumulation in the body to the extent that health and well-being are adversely affected (1, 2). Obesity is not a new phenomenon and clinical evidence of it has been dated far back in the ancient Indian *Ayurveda* studies as well as the Greco-Roman times though the scientific understanding of the ailment began in the 20th century (2,3).It has taken on epidemic proportions in the current era with worldwide projections of more than one billion overweight individuals across the world by 2030 (4). Obesity is fast replacing more traditional problems such as under-nutrition and infectious diseases as the most significant causes of ill-health. The co-morbidities of obesity include coronary heart disease, hypertension, stroke, non-insulin-dependent diabetes mellitus, and certain types of cancer, dyslipidemia, osteoarthritis and pulmonary diseases, including sleep apnea(5).Epidemiologic evidence supports the correlation between obesity and predisposition to disease risk early in life. Though obesity has such far reaching complications, it is majorly preventable and easily managed if detected at a younger age. Obesity and over-weightiness may differ in individuals based on the distribution of fat within the body as well as ethnicity of the individual. Presence of excess fat in the abdominal region has been shown to have a stronger association with diseases as compared to theother parts of the body (1,6).

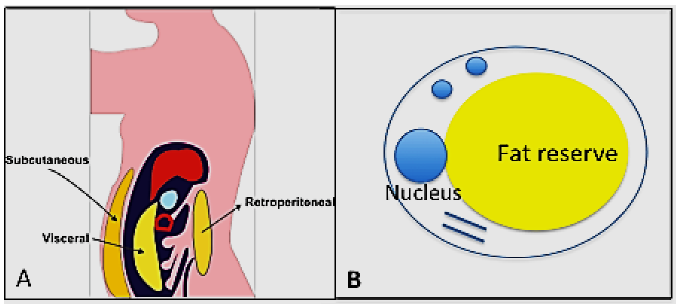

Figure I. A. Different types of fat deposits in the body with respect to their site of localization- visceral, subcutaneous & retroperitoneal; B. Structure of an a dipocyte (fat cell)

The adipose tissue is one of the largest and highly specialized connective tissues of the body and has been associated with varied functions in different systems including metabolic system and the immune system (6).Disturbance of the energy balance and deposition of excess fat is largely responsible for the manifestation of various diseases associated with obesity. The adipose tissue stores are broadly classified into two types based on their localization in the body (Figure I), viz. the visceral adipose tissue (VATs) (also known as the intra-abdominal adipose tissue, IAAT) and the subcutaneous adipose tissue (SATs).Visceral fat or extra abdominal fat that lies much below the layer of subcutaneous layer acts as a cushion around the body organs. Excess levels of this fat deposition have been proposed to cause a number of health concerns such as diabetes, hypertension, anxiety, depression, sexual dysfunction, hyperinsulinemia and coronary heart disease (7, 8, 9). The amount of visceral fat increases in an age dependent manner, in both men and women (7).It has also been shown to be clinically relevant with respect to metabolic complications and adverse health effects (8). The SATs are present under the epithelial layer, and their excessive presence in the abdominal region has been associated with a specific set of diseases. Excess total body fat (TBF) as a whole is also an indicator of unhealthy body status of an individual. Skeletal muscle (SM) content of the body and muscle specific force (force per unit physiological cross-sectional area of muscle) is indicative of the physical activity as well as the nutritional intake of the individual.

Timely assessment and awareness is essential for prevention and management of obesity and associated diseases. An inexpensive, non-invasive and effective method of assessing body composition (percentage of body weight composed of adipose and lean tissue) for epidemiological studies is the calculation of BMI of an individual. Adolphe Quetelet, mathematician and social statistician, observed that the weight of the average man was proportional to the square of the height (10). The ratio of body weight measured in kilograms when divided by the square of the height measured in meters was termed the Quetelet's Index and later renamed the Body Mass Index (BMI).Quetelet's Index is a widely utilized anthropometric estimate of general adiposity, however, the failure to identify differences in body composition and body fat distribution often limits its usefulness. Hence, other body parameters such as TBF%, VAT, SAT and SM have also been used as modes of determining obesity and fat distribution. The correlation between these body parameters and BMI is not steady and vary based on age group, physical activity levels and ethnicity of individuals. Some studies indicate a strong association of BMI-TBF%, while some others show negative association (11, 12, 13, 14). Association of the metabolically active VAT and various metabolic abnormalities and truncal SAT with insulin resistance certain populations (15, 16, 17) stress on the importance of analyzing all anthropometric variables in order to determine the health status of a population.

Classification of children and young adults on the basis of weight is complicated, as their height and body composition have not yet attained a stable status. It is also difficult to categorize individuals of high physical activity such as athletes, by their BMI, as it is taking into account the muscle weight of the individuals, rather than presence of excess fat. Thus, it is important to study the distribution of fat over the body in order to assess the health risks (18).Therefore, total body fat percentage, visceral and subcutaneous fat patterns may be equally or more effective than BMI in assessing fatness and obesity in physically active individual. SM content of the body and muscle specific force (force per unit physiological cross-sectional area of muscle) is also reduced in overweight obese individuals compared to their leaner counterparts. Studies have reported that individuals with higher BMI and adiposity have lower levels of skeletal muscle contractility (19).

METHODOLOGY

Data Collection

The study was conducted at Shivaji College, a constituent of the University of Delhi, New Delhi, India. A total of 140 students, of the age group 17-21 years, were included in this study. A health camp was organized by members of innovation project SHC-311 within the college premises and data was obtained by recording various body parameters of participants. Before proceeding to recording the body parameters, care was taken to record the personal detail such as age, gender, height and weight of each participant.

Anthropometric Measurements

For the calculation of BMI as weight (kg)/square of height (m^2), height and weight of the participants were measured. The height of the individuals was measured using height-measuring tape and weight was measured on Equinox digital weighing scale EB 9300. Weight was measured after removal of shoes while wearing light clothing. Height was measured without shoes in the standing position with the shoulders in relaxed position and arms hanging freely. Based on their BMI, the participants were classified as underweight, normal weight, overweight and obese [Refer to Table I].

Table I. Standard Values of Anthropometric Measurements Used in the Study

S. No.	Parameters	Low	Normal	High	Very High
1.	BMI (kg/m^2)	Underweight	Normal weight	Overweight	Obese
	All individuals	<18.5	18.5-24.99	≥25	≥30
2.	Total Body Fat (TBF %)				
	Male	< 10.0	10.0-19.99	20.0-24.99	≥25
	Female	<20.0	20.0-29.99	30.0-34.99	≥35
3.	Skeletal Muscle				
	Male	<33.3	33.3-39.3	39.4-44.0	>44.1
	Female	<24.3	24.3-30.3	30.4-35.3	>35.4
4.	Visceral Fat (cm^2)				
	All individuals	0.5-9.5	10-14.5	15.0-30.0	

(References: 20- 25, Omron Instruction Manual Body Composition Monitor Model HBF-375 Karada Scan)

Measurement of body fat (total body fat, visceral fat, subcutaneous fat and skeletal muscle) was done using the instrument Omron Karada Scan Body composition Monitor (HBF-375, Omron Health Care Co., Kyoto, Japan). The instrument works on the principle of biological impedance, which is a successful method for evaluating body composition. It is relatively simple, quick, non-invasive and does not require exposure to radioactivity or submersion in water. Hence, it is being used widely in various studies involving children as well as adults for assessment of body composition by a number of healthcare professionals and researchers worldwide (26-30).

Body tissues containing more water conduct electricity easily whereas fat tissue is a poor conductor. This feature is used to calculate body fat content. For measurement of body fat, it was imperative to begin with entering personal details of each participant such as age, gender and height. The subjects stood on footplate barefoot and grasped the two handgrips with arms. The posture of the individual was such that arms were straightened and an angle of 90° was maintained between arms and body. Precautions were taken to avoid errors such as shaking of the body, arms too bent, incorrectly positioned feet and incomplete contact of palms/soles with the electrodes.

Statistical Analysis

The subjects were grouped according to their anthropometric measurements and body composition parameters. Males and females were also grouped when the parameters showed a gender bias. The present study consisted of a single population consisting cross section of the age group 17-21 years. Basic descriptive statistics for subject data were expressed as mean ± standard deviation. Pearson's correlation coefficients (r) were calculated to assess the link and the degree of relation between BMI and selected body composition parameters. Statistical analysis was carried out using the SPSS version 16.0 software for Windows.

RESULTS

A. Assessment of body parameters for determining prevalence of obesity

The data collected from the 140 undergraduate participants (age ranging from 17-21) were analyzed for their health status using anthropometric measures. The participants were primarily females with as many as 57.1% female subjects.The participants were analyzed for various parameters of body composition like Quetelet's Index (BMI), Total Body Fat percentage,Visceral Adipose Tissue (VAT), Subcutaneous Adipose Tissue (SAT), Skeletal Muscles (SMs) were studied The representative data was plotted on a scatter plot of 5x5 grids constituting of all the parameters studied in the population (Figure II). The populationwas distributed as *low*, *normal*, *high* and *very high* groups on the basis of their values for a particular body parameter.

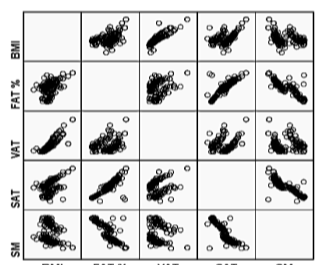

Figure II: Distribution of body parameters from collected data. All the parameters considered for analysis are shown in a scatter plot in a representation of the recorded data obtained from the current study

A total of 140 individuals were investigated as a part of the study and mean values of parameters used in our study are mentioned in Table II; 57.1 % of the participants were females (80 females and 60 males). The study sample represented a wide range of BMI values (11-35 kg/m^2). The range of fat percentage extended from 6.9-40.4.The visceral fat was comparatively restricted in extend and ranged from 0.5-14.5 cm^2. The subcutaneous fat represented a wide range of values (1.40-39.40 cm^2). The skeletal musculature in comparison had a narrow range of values (22.1-40).

Table II. Descriptive Statistics of the Anthropogenic Measurements and body parameters

Parameter	Mean ± S.D.	
	Males	Females
BMI (kg/m^2)	20.86 ± 2.99	21.48 ± 4.64
Fat %	15.66 ± 6.89	28.14 ± 5.22
VAT (cm^2)	4.13 ± 2.62	3.24 ± 2.78
SAT (cm^2)	10.58 ± 4.44	23.56 ± 5.75
SM	36.56 ± 2.36	26.97 ± 2.54

B. Body Mass Index (BMI)

Our data indicates that 60.7 % of the subjects screened were found to lie in the normal range, 24.3 % were underweight, and 12.1% subjects were overweight, while 2.9% was obese (Figure III a).The pooled data indicate that among the male participants 10% were overweight/obese (Figure III b), while among the female participants, 18.8% were overweight/obese (Figure IIIc).

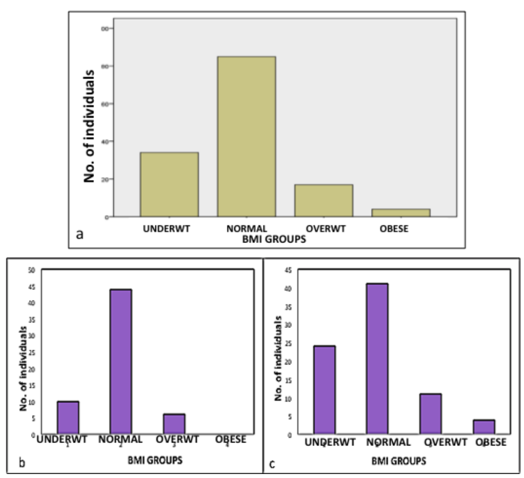

Figure III:Graphical representation of the distribution of (a) all individuals (b) males and (c) and females in the four pre-defined BMI groups [See Table I for the BMI ranges]

C. Total Body Fat %

The normal range of TBF % has been shown to differ in a gender-biased manner.The majority of male participants were found to range between low, normal and high levels of body fat (30% with low levels and 40% with normal levels and 23% with high levels; Figure IV a).

The female participants were found to predominantly belong to the normal, high and very high range of total body fat percentage (58.8% normal, 27.5% high and 8.8% very high; Figure IV b).

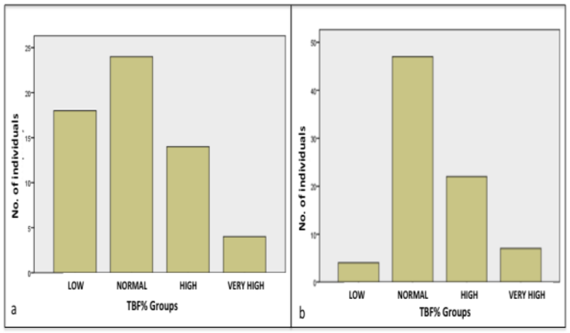

Figure IV:Distribution of Participants Based on Total Body Fat (TBF) %.a) Distribution of Male subjects into low, normal, high and very high TBF % groups. b) Distribution of female subjects into low, normal, high and very high TBF % groups.

D. Visceral Adipose Tissue

The VAT of individuals has shown to have no gender bias. The current study shows that 97% of the subjects have low visceral fat, and the rest have a normal VAT levels (Figure V). No individuals were shown to have a VAT composition in the *high* category.

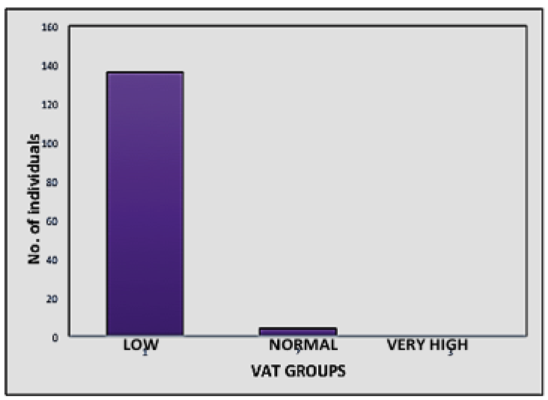

Figure V: Distribution of individuals in groups with respect to their visceral adipose tissue content. Group 1: Normal; Group 2: High; Group 3: Very high {No participants belong to this category in our study}

E. Skeletal Muscle

The male and female participants of the study were grouped into four sub-groups based on their levels of skeletal fat (refer to Table I). Amongst the female participants, 85% were found to have normal skeletal musculature, and 7.5% with high or very high skeletal musculature. The male participants had 76.6% individuals with normal skeletal musculature and 11.7% with high or very high skeletal musculature (Figures VI a & b).

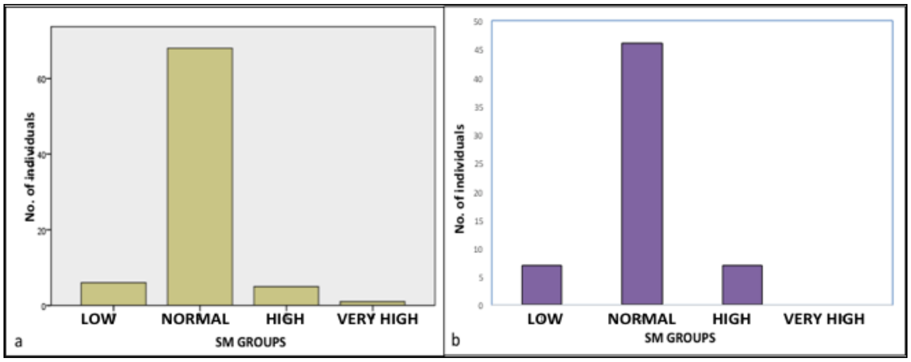

Figure VI**:** Distribution of individuals (a) Females and (b) Males in groups with respect to their skeletal muscle content {Group 1:Low; Group 2: Normal; Group 3: High; Group 4: Very high}.

F. Analysis of association between various body parameters

One of the main objectives of this study is to analyze the relationship of BMI and the various body parameters in the given population of young adults of Indian ethnicity and moderately high physical activity. Both BMI and body composition measurements have been shown to be useful indicators of obesity. A correlation between these parameters was attempted as a part of this study. Correlation between BMI and VAT/SAT/TBF% and SM was investigated in order to come to a conclusion. A relationship between VAT and TBF% was also attempted in order delineate any correlation between them.

The participants were divided into subgroups based on their BMI values. Further, their relationship with the above mentioned body parameters were tested by plotting their mean values against BMI values (Figure VII). All the body composition parameters (TBF%, VAT and SAT) with the exception of skeletal musculature appear to increase with increase in BMI ratios.

G. Correlation of the BMI-body composition parameters relationship

Our study shows that there was a strong and significant positive correlation between BMI and TBF% ($r = 0.80$, $p < 0.01$ in females; $r = 0.50$, $p < 0.01$ in males). A similar strong and significant positive correlation is observed between BMI and SAT ($r = 0.75$, $p < 0.01$ in females; $r = 0.61$, $p < 0.01$ in males). A negative and significant correlation was found between BMI and SM ($r = -0.54$, $p < 0.01$ in females; $r = -0.70$, $p < 0.01$ in males). The strongest and significant correlation was observed between BMI ratios and VATs ($r = 0.99$, $p < 0.01$ in males and $r = 0.87$, $p < 0.01$ in females). It was found that there is a positive and significant correlation between the parameters VAT and TBF%, ($r = 0.54$, $p < 0.01$, for males; $r = 0.75$, $p < 0.01$) for females (Table III).

H. Relationship between BMI-body composition parameters

The association between BMI and TBF% was also analyzed in a scatter plot and it not only showed a increasing trend for both males and females, but also a definite difference in pattern of distribution based on their respective BMI ratios and TBF% (Figure VIII). The association between BMI and SAT was also analyzed in a scatter plot and it showed an increasing trend for both males and females, as well as a definite difference in pattern of distribution based on their

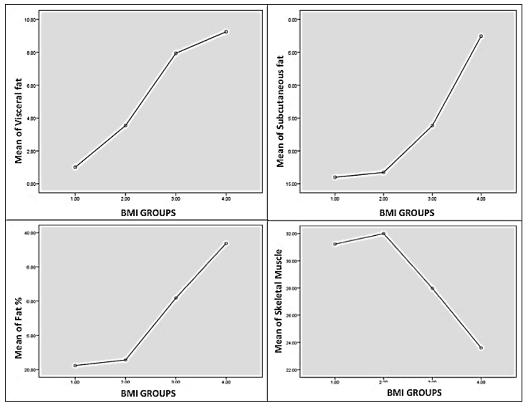

Figure VII: Plots between BMI groups with mean of Visceral fat, Subcutaneous fat, Fat % and skeletal muscle (Categories of BMI: 1- underweight, 2-normal weight, 3-overweight, 4- obese).

Table III. Correlation between BMI and various body composition parameters

Parameter	Male	Female	Whole
BMI vs TBF%	0.50**	0.80**	NA
BMI vs SAT	0.61**	0.75**	NA
BMI vs SM	-0.70**	-0.54**	NA
BMI vs VAT	0.99**	0.87**	0.87**
VAT vs TBF %	0.54**	0.75**	0.32**

** Correlation is significant at the 0.01 level (2-tailed).

respective BMI ratios and SAT. The association between BMI and SAT was further analyzed in a scatter plot and it appears to be the only body parameter that has a decreasing trend with respect to each other, for both male and female participants (Figure 8). The association between BMI and VATs was further analyzed in a scatter plot and it showed an increasing trend for all participants, however based on the values of BMI ratios and VAT levels recorded a distinctive difference in the pattern of distribution based on their respective genders (Figure 8). Total body fat comprises of visceral fat and subcutaneous fat.

It was found that there is a strong and significant correlation between the two parameters, (r = 0.54, p< 0.01, for males; r = 0.75, p< 0.01) for females; Figure 8).

When the entire population was assessed for correlation between the parameters, a lower correlation coefficient was observed (3.21).

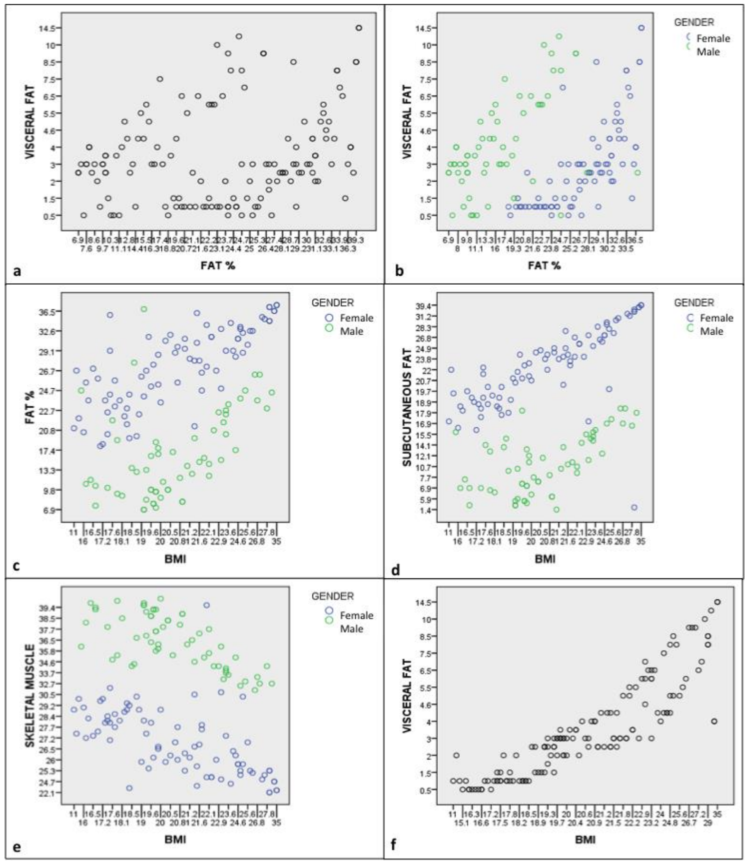

Figure VIII: BMI and relationship with body composition parameters viz. (a-b) scatter plot between visceral fat and total body fat(all individuals, subgroups of males and females); c) Scatter plot between total body fat and BMI (subgroups of males and females); d) Scatter plot between subcutaneous fat and BMI (subgroups of males and females); (e) Scatter plot between skeletal muscle and BMI (subgroups of males and females);f) Scatter plot between visceral fat and BMI.

DISCUSSION

The current study comprised of young individuals with ages ranging between 17-21, and a higher proportion of female participants as compared to males. The assessment of their health status was carried out by analyzing the data for the various body parameters including BMI, TBF%, VAT, SAT and SM. The population was primarily found to constitute of normal range BMI individuals, but substantial subjects were also found in the below normal and overweight category. When analyzed on the basis of gender, it was found that though both participants had majority of normal BMI ratio values, in the case of females, higher number individuals existed at both extremities (more underweight as well as overweight/obese individuals as compared to their male counterparts). The assessment of the TBF% of the participants indicates that there was distinctive difference in distribution patterns between males and females. The number of males with very high TBF% was negligible as compared to the males with low or normal levels of TBF%. In stark contrast, the females had primarily individuals in normal, high and very high categories of TBF%. This indicates that the male participants hadhealthierfat composition as compared to the females. The presence of visceral adipose tissue has no gender bias and all participants of the study had either normal or low levels of VATs, thus no definite predisposition to diseases associated with high VAT. The skeletal musculature of both the male and female participants was found to be primarily normal, with a higher percentage of males having high musculature as compare to females, indicating more athletic activities carried out by the males.

This study was aimed at exploring if BMI as an anthropometric measurement is indicative of the status of the various other body composition parameters, in the currently selected population of Indian undergraduate students with moderate to high levels of physical activity. It was observed that the increase in BMI was correlative to the increase in in the TBF%, the VAT and the SAT content. However, increase in BMI showed a concomitant decrease in skeletal musculature. This inverse pattern between BMI and SM is expected, as individuals with more s musculature would ideally be carrying out more physical activity, and hence a lower chance of obesity as well as high BMI. The increase in TBF% and SAT were shown to exhibit a sudden linear spike in values with increase from normal BMI to higher BMI ratios. In the case of visceral fat, there is a gradual increase of VAT with increasing BMI. Skeletal muscles are to be highest in individuals with normal BMI, followed by a sharp decline with the increase of BMI. Further correlation studies were also carried out between the above mentioned parameters and a similar trend was observed, hence showing a strong, significant and positive association was found between BMI and the other body parameters. The association between TBF% and VAT was also found to be strongly positive and significant. BMI and SM were shown to have a strong and significant negative correlation as expected.

Our study thus shows that we have analyzed a primarily healthy group of young adults, however a significant proportion of individuals were also identified with possible weight related predicaments in the near future. The results of this study also indicate that though BMI can be used to correlate with most body parameters for a similar population to a significant extent, however the relationship is not linear throughout the spectra. Hence additional body composition parameters must be also taken into account when carrying out such studies.

In order to manage and prevent obesity, it is important to understand the mechanisms and modes by which obesity may occur. Based on the localization of excess fat, overweight and obese persons can be categorized under two groups: android and gynecoid (6,31,32). Obesity of the male type is android and is associated with excess adipose tissue distribution in the upper thoracic body and results in apple shape structure. Female type or gynecoid obesity is characterized by fat deposition in the lower body that is thighs and hips and leads to pear shaped body. Android type obesity predisposes to cardiovascular disorders, insulin resistance, strokes and high blood pressure (19,31).

The adipocytes or fat cells in the adipose tissue secrete hormones known as adipokines (33; Figure IX). The visceral fat that surrounds the abdomen releases adipokines like visfatin, which can lead to inflammation in visceral fat and is associated with increased cardiovascular diseases (33, 34). Obesity suppresses the good adipokines, which help in maintaining body weight and also exert anti-inflammatory action. It also increases secretion of bad adipokine –resistin which can lead to insulin resistance and hence can lead to type-2 diabetes. It has also been reported that VATs may induce the more adipocytokinesthan the SATs. Hence, as VAT increases, diseases related to metabolism also increase, along with an increase in incidence and severity of excess subcutaneous fat (35).

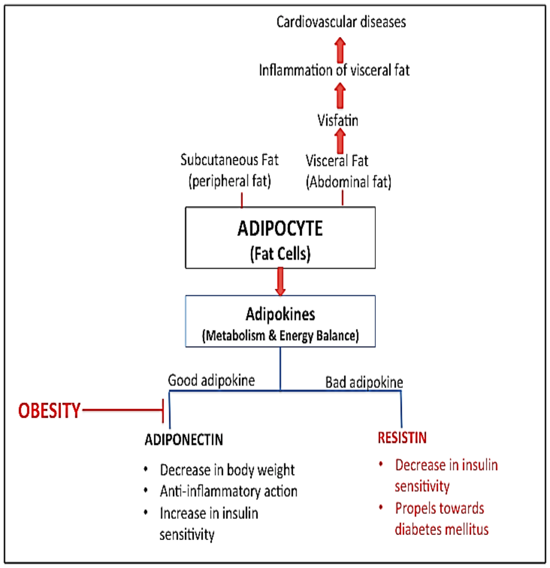

Figure IX: Role of adipocytes/fat cells in producing good and bad a dipokines. Obesity inhibits positive effects of a diponectin (good adipokine). Visceral fat cells produce vis fatin that causes inflammation of visceral fat and leads to cardiovascular diseases.

The root cause of increasing obesity in the younger generation is due to major lifestyle changes that include sedentary habits, excessive use of technology and unhealthy diet intake (36). The traditional lifestyle which included physical activity on a day-to-day basis for carrying out meager jobs has been given up. Body weight can be maintained by decreasing fat and increasing muscle mass. This can be done by decreasing the intake of unhealthy food and increasing the physical activity levels on a daily basis. One of the objectives of this study was also to spread awareness amongst the youth regarding their lifestyle habits that are making way for health challenges in the future.

CONCLUSIONS

Our study has revealed that individuals with a high BMI level also show marked increase in their visceral fat deposits. There is a profound correlation between high levels of BMI and increase in total body fat. These parameters can be easily used to measure basic parameters predicting future health of an individual. Since we have dealt with age groups of 17-21, these statistics are alarming as they put these individuals at high risk of disorders. The objective of conducting this health camp was to increase awareness amongst the youth and it is our future objective to counsel them about the disorders that maybe awaiting them.

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