Mycobacterial Diseases

Tungdim, et al., Mycobact Dis 2015, 5:3
DOI: 10.4172/2161-1068.1000182

Research Article Open Access

# Outcome of Tuberculosis Treatment on Measures of Obesity and Adiposity Indices Among the Tribals of Northeast India

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**Received date:** April 28, 2015; **Accepted date:** May 18, 2015; **Published date:** May 25, 2015



**Abstract**

A cross sectional study was conducted among adult patients (N=280) between 20-40 years at different stages of tuberculosis (TB) treatment. The data was collected from the different DOTS centres in Manipur, Northeast India. Several anthropometric measurements and the indices of adiposity like body mass index (BMI), waist hip ratio (WHR), waist height ratio (WHtR) and grand mean thickness (GMT) were studied. Wasting of muscle mass and decrease in fat percentage because of chronic disease (TB) and overall improvement in these components with anti-tubercular treatment was observed. This study suggests that body composition is a useful marker to indicate temporal recovery of patients undergoing tuberculosis treatment and determine treatment outcome.

**Keywords:** Anti-tuberculosis treatment; Adiposity, Tribals; Northeast India

## Introduction

Tuberculosis (TB) is among the foremost infectious causes of mortality worldwide, with 2-3 million deaths reported each year. India is the second-most populous country in the world and one fourth of the global incident of TB cases occur in India annually. In 2012, out of the estimated global annual incidence of 8.6 million TB cases, 2.3 million were estimated to have occurred in India (TB India Annual Report 2014). The evidence of presence of tuberculosis was found in spines of Egyptian mummies dating from 5000 BC and the term 'consumption' has been virtually synonymous with tuberculosis and is often associated with severe wasting [1,2]. This wasting of soft tissues led to the speculation that the impact of this disease eventually extends beyond the lungs. The risk of developing tuberculosis was found to be more among tall and thin individuals than those who were short and heavy set [3-5]. It was also found that malnutrition predisposes a person to tuberculosis [6,7]. The extent to which such malnutrition contributes to the pathology of the disease still remains unclear [3].

It is difficult to identify those factors that make the most significant contribution to wasting in tuberculosis. Observations made at the time of diagnosis showed that metabolic rate, or resting energy expenditure, is increased [2]. However, by analogy energy expenditure is unlikely to be the sole driving force behind wasting in the catabolic phase; reduced energy intake is much more likely to be the primary driving force. Substrate handling may be perturbed by infections such as tuberculosis and it has been suggested that utilization of amino acids for protein synthesis may be impaired by pro-inflammatory cytokines. This phenomenon has been referred to as "anabolic block" [8]. Tuberculosis has a dramatic effect on nutritional state and such malnutrition undoubtedly contributes to the morbidity of the disease and may also lead to mortality, particularly in resource poor settings where nutritional state, even in the "healthy," may be parlous [9]. Weight gain and other improvements in nutritional indicators after effective chemotherapy for tuberculosis have been reported [1,6]. However, easily utilized and inexpensive markers to study the relationship between changes in adiposity indices and weight gain during the course of anti-tuberculosis therapy are the need of the hour to monitor the compliance of the patients and also see the treatment outcome during the long course of treatment.

Keeping this in mind the present study was carried out to examine the responsiveness of different nutritional status indices with anti-TB treatment and determine their treatment outcome.

## Materials and Methods

The present study was carried out in Manipur which lies in the North-Eastern region of the Indian Sub-continent, between 23°50' latitudes and 25°30' North and 93°10' and 94°30' East longitudes, bordering Myanmar in the East, Nagaland in the North, Assam and Mizoram in the West. According to the 2011 census, Manipur has a population of around 2,721,756 out of which the tribal population accounts for approximately 30% of the total population. In the tribal life the principal links for the whole society are based on kinship. Lineages, clans and other social groupings tend to be the main corporate units and they are often the principal units for land ownership, for economic production and consumption [10,11]. The tribals have their own traditional customs and customary laws. In Manipur two sharply distinct adaptive patterns- shifting cultivation (jhuming) and settled wet cultivation are practiced. In general, the tribal economic systems are basically self-sufficient and that these are subsistence economies but due to modernization and education, the quality of life has improved to a considerable extent. The staple food of the tribals of Manipur is rice. They also consume red meat in large amount and consume less milk and its products.

A cross sectional study was conducted on a total of 280 adult tribal males and females between 20-40 years of age who were suffering from tuberculosis from the different DOTS centers in Manipur. The sample was collected from the different tribes of Manipur *viz.*: Tangkhuls, Hmars, Kabuis, Kukis, Paites and Zous.

The ethnographic profiles of the studied population are as given below:

## Tangkhuls

The chieftainship is an age-old institution among the Tangkhuls. The chief is called 'Awunga' in Tangkhul dialect, which is equivalent to English word 'King'. The Tangkhuls were one of the most powerful tribes of the hills as far as the Chindwin. They occupy the Eastern hills of Manipur. In every village there is a hereditary chief. In rare cases, there are two or more chiefs in a village. Hungyo [12] in his study found that in Bungpa, "there are two chiefs representing the two clans of the village. In exceptional cases, the leaders of the clan groups, during their migration period, agreed to settle down in a particular place without submitting the leadership. In such cases, the leaders of the respective groups maintained their identity and hence we find two or more chiefs in a village. There are many big villages with several clans, which have one chief each. Therefore, the number and size of the clans in a village are not the criteria for having two or more chiefs in a village". The Tangkhuls strictly follow patriarchal and patrilineal.

## Hmars

The Hmars belongs to the Chin-Kuki-Mizo group. Their origin is traced back to 'khul' in Central China. The Hmars are mainly found in the South of Manipur [13]. The main source of livelihood of Hmars is agriculture. Hmars practice settled cultivation and forest constituted the main source of several products particularly timber, teak, pines, sal, oak, bamboo, etc. According to Lal Dena [14] "internally the economic activity of Hmars was marked by the absence of market oriented production. The process of distribution took the form of gift and counter gift and ceremonial exchange and the distribution involved channeling upward of products and services to socially determined allocative centers such as chiefs, priest and blacksmiths". The Hmars are hardworking people and have trade relation with Cacharis, Bengalis, etc. and the main items of exchange were cotton, chilly and later on orange and pineapple, which were exported in large quantities mainly through the Barak River.

According to Lal Dena [14], "as the Hmar society became more stable with settled agriculture as the mode of production, the position of chiefs became more and more deep-rooted in the society. Each Hmar village possessed a definite area of territory". It is assumed that at some stage, the communal ownership of land was the basic feature of the land tenure system among the Hmars and that it is the common property of the people and the chief and the councillors are trustees with the power to see the rightful use and distribution of land to each household for cultivation. The actual practice, however, presented a contrasting picture. The chief of the Hmar village called 'Lal' was a 'Maharaja' of a petty state [15]. The chief is in fact, the sole owner of the land and his rights can almost be compared with that of a Zamindar in other parts of the country. The villagers were something like tenants-at-will who paid 'Busung-Sadar' and rendered forced labour to the chiefs. The 'Busung-Sadar' is the practice of paying every year of certain specified quantity of rice (Busung) and of surrounding the forelegs of every animal (Sadar) shot or trapped within the chiefdom as rent and 'rendered forced labour' which involved building or rebuilding the chief's house and any other services whenever asked for without any wage [14].

## Kabuis

The Kabuis occupy the hills between Cachar and the valley of Manipur in the West. There are however, quite a number of Kabui villages in the valley. By and large, the Kabuis in the valley are more advanced than those living in the hills. Among the Kabuis of the plains many are found in white collared jobs. The tribe can be said to belong to two different groups namely, the Hill Kabuis and the Plain Kabuis. It is customary for a Kabui to seek his spouse outside his own clan. Intra-clan marriage is prohibited. The chief is called 'Khullakpa' in Kabui dialect. The 'Khullakpa' is the head of the village administration. The village administration consists of council of members headed by the 'Khullakpa' and the other members are 'Khunbu, Luplakpa and Mu (Medicine man)'. The chief is hereditary while the others are not. Divorce is permitted on account of barrenness or incompatible temperament between the spouses. Though many of the Kabuis have converted into Christianity, still many, retain their traditional beliefs and the worshipping place for them is called 'Haipei pui laa kai'. The Kabuis have different organization for the boys, girls and the aged persons. These are the so-called dormitories, which are the centers for various social and cultural trainings. The girls' dormitory is locally known as 'Luchu'. All the girls have to be a member of this organization before their marriage. The boys' dormitory is locally known as 'Khangchu'. All the boys of marriageable age are members of this organization and retain their membership till their marriage. At the time of wedding feast or the community feast, members of the boys' dormitory cook and look after the guests. The organization for the aged persons is locally known as 'Kengjapui' [16].

## Kukis

The Kukis follow the hereditary chieftainship. Stewart [17], had categorically stated that "the Kookis are naturally a migratory race, never occupying the same place for more than two, at the utmost three years". The Kukis were warlike people and hence they were engaged by the Maharaja of Manipur to safeguard the land bordering Myanmar in the East. It was during this time that they settled side by side with the Tangkhul Nagas. The Kukis are also concentrated in the South and Tengnoupal districts in Manipur and in parts of Nagaland and Assam. The chief is called 'Hausapu' in Kuki dialect. The Kukis belong to the Chin-Kuki-Mizo group.

## Paites

Paites belong to the Chin-Kuki-Mizo group. They are concentrated mostly in Churachandpur district. Unlike the other Chin-Kuki-Mizo tribes, the Paites organize themselves very well and excel in many fields. They are considered to be one of the most advanced tribe in India. The Paites were one of the first tribe to get converted into Christianity, which is considered to be one of the main reasons for their advancement. The Paites amend their customs and traditions to suit the modern society. The village administration is in the hands of the village chief and the chieftainship is hereditary. The chief is locally called 'Hausa'.

## Zous

The Zous are believed to have originated from 'Khul' (cave) in Central China and it was during this time that Zou (Zhou) dynasty ruled China from 1027 BC to 256 BC [18]. They are the descendents of the three brothers namely: Songthu, Songza and Zahong. Zous are the eldest of the Chin-Kuki-Mizo tribe. The Zous have their own customs and customary laws. Any Zou who is found guilty of a crime will be tried under the Zou custom. The United Zomi Organization (UZO) is a political body of the Zous and was formed in the year 1967. The Zous had their own script but lost them due to the course of migration. The lost script is now depicted by Mr. Siahzathang of Lamka, Churachandpur. The Zous are the only tribe who has their own script in the whole of Northeast India. The chieftainship among the Zous is hereditary. The chief is locally known as 'Hausa'. Zous are mainly found in the South and Chandel districts of Manipur while many of them are found in Myanmar [16].

The data for the present study was collected from the different district TB centres in Manipur from August 2000 to July 2001. The subjects were all new cases of pulmonary TB and were classified into three groups based on the stages of anti-tuberculosis treatment. All confirmed cases of pulmonary TB who had not started the TB treatment were termed as BST, all those who were confirmed as having taken treatment regularly for two months were grouped as 2MOT and those who were declared as having taken full treatment as ACT. The grouping of the patients was done in consultation with doctors. Certain guidelines were laid down for selecting the subjects who had TB and were willing to co-operate in the present study, (1) only those subjects who took their medicines regularly as confirmed by the doctors and/or health workers and also followed the dietary norms as advised by doctors, (2) only those subjects were retained in the sample who refrained from alcohol and smoking during the course of treatment, (3) only new cases who had pulmonary tuberculosis were taken, (4) none of the HIV+ve patients were retained in the sample. Exclusion criteria for the controls were as follows: previous anti-TB treatment, any form of disease and HIV+ve as confirmed by the doctors. None of the subjects were related to each other by birth or by marriage. Controls (CG) were healthy subjects with no history of tuberculosis, matched with cases for age, and selected from among the non-family neighbours of the patients. The volunteers who fitted into the guideline frame were included in the study. A well informed written consent from the subjects for their willingness to participate in the present study was taken before the measurements were taken. The study protocol was approved by the Institutional Ethics Committee of the Department of Anthropology, University of Delhi, India.

Each subject was measured for body weight, height, waist circumference, hip circumference; mid upper arm circumference and skinfold thickness at biceps, triceps, and subscapular and suprailiac sites using Holtain skinfold caliper to the nearest 0.2 mm. Body weight was measured to the nearest 0.1 kg using a beam balance scale with subjects wearing only light clothes and no shoes. The height was measured to the nearest 0.1 cm with a Harpenden anthropometer. The body circumferences were measured to the nearest 0.1 cm using a flexible steel tape. All the measurements were taken by following standard techniques. The various indices for assessing regional and general adiposity *viz.*: waist-to-hip ratio (WHR), Waist height ratio (WHtR) body mass index (BMI) calculated as body weight in kg divided by height in meter squared [BMI=wt(kg)/height($m^2$)] and grand mean thickness (GMT) were calculated. Percent body fat (PBF) was calculated using Siri's equation [19]:

$$PBF=(4.95/density-4.50) \times 100$$

Linear regression equations of Durnin & Womersley [20] were used to calculate body density. Fat mass (FM), fat free mass (FFM), fat mass index (FMI) and fat free mass index (FMI) were calculated using following standard equations:

$$FM (kg)=(PBF/100) \times Weight (kg)$$

$$FFM (kg)=Weight (kg)-FM (kg)$$

$$FMI (kg/m^2)=FM (kg)/height^2 (m^2)$$

$$FFMI (kg/m^2)=FFM (kg)/height^2 (m^2)$$

To study the sensitivity of various skinfold sites towards accumulation of fat as a consequence of TB treatment each skinfold thickness was expressed as percent of grand mean thickness (%GMT).

Descriptive statistics were done for bodyweight, height, WC, HC, MUAC, BMI, WHR, WHtR and GMT, FM, FFM, FMI, FFMI in subjects at different stages of TB treatment. The differences between the treatment groups in respect of the indicators of temporal recovery were tested by one way analysis of variance (ANOVA). LSD Post hoc test was also applied to investigate inters group differences. All data was analysed using SPSS 16.0 version.

## Result

Table 1 presents the means and standard deviations of body weight (BW), height, waist circumference (WC), mid upper arm circumference (MUAC), hip circumference (HC), body mass index (BMI), waist hip ratio (WHR), waist height ratio (WHtR), percent body fat (PBF), fat mass (FM), fat mass index (FMI), fat free mass (FFM), and fat free mass index (FFMI) among the TB patients in different stages of treatment. Among males, mean values of bodyweight, height, WC, BMI, WHR, PBF, WHtR, FM, FMI, FFM were found to be lowest among the TB patients who had not started treatment (BST) and increased gradually with treatment. However, the mean values of MUAC, hip circumference and FFMI though found to be least among TB patients after 2 months of treatment group and increased significantly after completion of treatment. In females mean values of bodyweight, height, WC, BMI, WHR, PBF, WHtR, FM, FMI, FFM and FFMI were found to be lowest among the TB patients who had not started treatment (BST) and increased gradually with treatment. However hip circumference increased from before starting treatment to two months of treatment and then showed decline till after completion of TB treatment.

| Variables | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | Mean ± SD | | | Mean ± SD | | |
| | BST (N=62) | 2MOT (N=39) | ACT (N=49) | BST (N=40) | 2MOT (N=50) | ACT (N=40) |
| BW (kg) | 46.84 ± 6.65 | 48.23 ± 5.38 | 51.67 ± 6.03 | 43.95 ± 6.34 | 45.92 ± 5.28 | 54.88 ± 5.23 |
| Ht (cm) | 161.60 ± 5.88 | 163.22 ± 5.58 | 163.38 ± 4.86 | 148.40 ±5.25 | 149.61 ± 5.01 | 154.90 ± 4.12 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **WC (cm)** | 64.64 ± 4.94 | 66.55 ± 4.78 | 66.25 ± 5.15 | 64.11 ± 4.56 | 68.10 ± 3.50 | 66.21 ± 5.04 |
| **MUAC (cm)** | 22.12 ± 2.38 | 22.07 ± 1.71 | 23.20 ± 2.64 | 21.85 ± 2.45 | 22.02 ± 1.95 | 22.40 ± 1.40 |
| **HC(cm)** | 78.83 ± 4.70 | 78.15 ± 3.39 | 79.49 ± 4.65 | 76.30 ± 4.83 | 77.90 ± 4.19 | 71.80 ± 3.77 |
| **BMI (kg/m$^2$)** | 17.91 ± 2.18 | 18.10 ± 1.79 | 19.35 ± 2.02 | 19.87 ± 1.80 | 20.47 ± 1.60 | 22.85 ± 1.67 |
| **WHR** | 0.82 ± 0.04 | 0.85 ± 0.05 | 0.83 ± 0.06 | 0.84 ± 0.03 | 0.88 ± 0.04 | 0.92 ± 0.07 |
| **GMT (mm)** | 5.68 ± 1.23 | 6.69 ± 1.69 | 6.88 ± 1.70 | 7.26 ± 0.69 | 7.42 ± 0.81 | 8.42 ± 0.76 |
| **WHtR** | 0.40 ± 0.03 | 0.41 ± 0.03 | 0.41 ± 0.03 | 0.43 ± 0.03 | 0.46 ± 0.03 | 0.43 ± 0.03 |
| **PBF** | 15.52 ± 2.95 | 17.65 ± 3.53 | 18.08 ± 3.30 | 19.14 ± 1.34 | 19.42 ± 1.49 | 21.20 ± 1.22 |
| **FM (kg)** | 7.28 ± 1.77 | 8.60 ± 2.30 | 9.40 ± 2.32 | 8.38 ± 1.12 | 8.92 ± 1.24 | 11.64 ± 1.29 |
| **FMI (kg/m$^2$)** | 2.79 ± 0.68 | 3.22 ± 0.83 | 3.51 ± 0.82 | 3.80 ± 0.35 | 3.97 ± 0.42 | 4.84 ± 0.45 |
| **FFM (kg)** | 39.56 ± 5.75 | 39.64 ± 3.94 | 42.28 ± 4.70 | 35.57 ± 5.39 | 37.00 ± 4.28 | 43.24 ± 4.18 |
| **FFMI (kg/m$^2$)** | 15.12 ± 1.84 | 14.88 ± 1.30 | 15.83 ± 1.59 | 16.07 ± 1.56 | 16.49 ± 1.34 | 18.00 ± 1.35 |

**Table 1:** Basic data and indices of adiposity among the subjects at different stages of TB treatment. BST: Before Starting Treatment; 2MOT: After completion of 2 months of Treatment; ACT: At the Completion of Treatment; BW: Body Weight; Ht: Height: WC: Waist Circumference; MUAC: Mid Upper Arm Circumference; HC: Hip Circumference; BMI: Body Mass Index; WHR: Waist Hip Ratio; GMT: Grand Mean Thickness; WHtR: Waist Height Ratio; PBF: Percent Body Fat; FM: Fat Mass; FMI: Fat Mass Index; FFM: Fat Free Mass; FFMI: Fat Free Mass Index.

The means and standard deviations of skinfold thickness at biceps, triceps, subscapular, suprailiac and grand mean thickness are given in Table 2. In males the skinfold thickness at all the sites and grand mean thickness showed increase in the mean values from before starting treatment group till two months of treatment group. BSF and SSSF then showed a decline till completion of treatment however TSF and SISF increased gradually among the group who had completed treatment.

In Table 2, among females the skinfold thickness at all the sites and grand mean thickness showed increase in the mean values from before starting treatment group till after completion of treatment group except with the bicep skinfold thickness (BSF) which showed decline from before starting treatment group till two months of treatment group and then increased gradually in after completion of treatment group.

| Variables | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | Mean ± S.D (mm) | | | Mean ± S.D (mm) | | |
| | BST (N=62) | 2MOT (N=39) | ACT (N=49) | BST (N=40) | 2MOT(N=50) | ACT(N=40) |
| **BSF** | 5.37 ± 1.57 | 5.69 ± 1.57 | 5.57 ± 1.73 | 5.09 ± 1.08 | 4.83 ± 0.98 | 6.54 ± 1.25 |
| **TSF** | 4.37 ± 1.87 | 5.16 ± 2.20 | 5.70 ± 1.87 | 7.37 ± 1.74 | 7.66 ± 1.31 | 8.33 ± 1.16 |
| **SSSF** | 6.98 ± 1.55 | 8.42 ± 2.33 | 8.40 ± 1.91 | 8.49 ± 1.01 | 8.47 ± 1.09 | 9.00 ± 0.85 |
| **SISF** | 5.99 ± 1.62 | 7.47 ± 2.63 | 7.86 ± 2.88 | 8.11 ± 1.35 | 8.71 ± 1.30 | 9.80 ± 1.47 |
| **GMT** | 5.68 ± 1.23 | 6.69 ± 1.69 | 6.88 ± 1.70 | 7.26 ± 0.69 | 7.42 ± 0.81 | 8.42 ± 0.76 |

**Table 2:** Skinfold thickness at different sites and grand mean thickness of the subjects at different stages of treatment. BST: Before Starting Treatment; 2MOT: After completion of 2 months of Treatment; ACT: At the Completion of Treatment; BSF: Bicep Skinfold Thickness; TSF: Tricep Skinfold Thickness; SSSF: Subscapular Skinfold Thickness; Suprailiac Skinfold Thickness; GMT: Grand Mean Thickness.

Table 3 displays the ANOVA test in anthropometric variables and adiposity indices between BST, 2MOT and ACT in TB patients. The ANOVA test showed significant differences for Body weight (F=39.93; p<0.00), height (F=6.39; p<0.01), WC (F=9.86; p<0.001), MUAC (F=4.28; p<0.05), HC (F=4.57; p<0.05), BMI (F=23.24; p<0.001), WHR (F=17.19; p<0.001), GMT (F=20.40; p<0.001), WHtR (F=10.87; p<0.001), PBF (F=18.95; p<0.001), FM (F=48.96; p<0.001), FMI (F=30.83; p<0.001), FFM (F=26.12; p<0.001), FFMI (F=14.70; p<0.001) among subjects at different stages of treatment.

Table 4 displays LSD post hoc test for anthropometric variables and adiposity indices between before starting treatment group to 2 months of treatment group, 2 months of treatment group to after completion of treatment group and before starting treatment group to after completion of treatment group. The LSD Post hoc test showed significant differences for waist circumference, BMI, WHR, GMT WHtR, PBF, FM, FMI between before starting treatment group to two months of treatment group. However Body weight, height, MUAC, HC, BMI, WHR, GMT, WHtR, FM, FMI, FFM, FFMI showed significant increase from two months of treatment group to after completion of treatment group. The overall response to treatment was evident in the significant increase (p<0.05) in the mean body weight, WC, HC, MUAC, BMI, WHR, GMT, PBF, FM, FMI, FFM, FFMI from the time of starting of TB treatment till completion of TB treatment [21].

| Variables | F- value | LSD Post hoc test | | |
|---|---|---|---|---|
| | | BST vs. 2MOT | 2MOT vs. ACT | BST vs. ACT |
| BW (kg) | 39.93*** | -1.28 | -6.18* | -7.41* |
| Ht (cm) | 6.39** | 0.85 | -3.10* | -1.35* |
| WC (cm) | 9.86*** | -2.99* | 1.19 | -1.80* |
| MUAC (cm) | 4.28* | -0.03 | -0.80* | -0.83* |
| HC (cm) | 4.57* | -0.17 | -1.98* | -1.81* |
| BMI (kg/m$^2$) | 23.24*** | -0.75* | -1.49* | -2.24* |
| WHR | 17.19*** | -0.04* | 0.10* | -0.05* |
| GMT (mm) | 20.40*** | -0.80* | -0.47* | -1.27* |
| WHtR | 10.87*** | -0.02* | 0.02* | -0.002 |
| PBF | 18.95*** | -1.70* | -0.84 | -2.54* |
| FM (kg) | 48.96*** | -1.07* | -1.63* | -2.70* |
| FMI (kg/m$^2$) | 30.83*** | -0.46* | -0.47* | -0.93* |
| FFM (kg) | 26.12*** | -0.16 | -4.55* | -4.71* |
| FFMI (kg/m$^2$) | 14.70*** | -0.29 | -1.02* | -1.31* |

**Table 3**: ANOVA with LSD Post hoc test of different anthropometric variables and adiposity indices among subjects. *p<0.05;**p<0.01;***p<0.001. BST: Before Starting Treatment; 2MOT: After completion of 2 months of Treatment; ACT: At the Completion of Treatment; BW: Body weight; Ht: Height: WC: Waist Circumference; MUAC: Mid Upper Arm Circumference; HC: Hip Circumference; BMI: Body Mass Index; WHR: Waist Hip Ratio; GMT: Grand Mean Thickness; WHtR: Waist Height Ratio; PBF: Percent Body Fat; FM: Fat Mass; FMI: Fat Mass Index; FFM: Fat Free Mass; FFMI: Fat Free Mass Index

| Variables | BST vs. 2MOT | 2MOT vs. ACT | BST vs. ACT |
|---|---|---|---|
| **BW (kg)** | -1.28 | -6.18* | -7.41* |
| **Ht (cm)** | 0.85 | -3.10* | -1.35* |
| **WC (cm)** | -2.99* | 1.19 | -1.80* |
| **MUAC (cm)** | -0.03 | -0.80* | -0.83* |
| **HC (cm)** | -0.17 | -1.98* | -1.81* |
| **BMI (kg/m$^2$)** | -0.75* | -1.49* | -2.24* |
| **WHR** | -0.04* | 0.10* | -0.05* |
| **GMT (mm)** | -0.80* | -0.47* | -1.27* |
| **WHtR** | -0.02* | 0.02* | -0.002 |
| **PBF** | -1.70* | -0.84 | -2.54* |
| **FM (kg)** | -1.07* | -1.63* | -2.70* |
| **FMI (kg/m$^2$)** | -0.46* | -0.47* | -0.93* |
| **FFM (kg)** | -0.16 | -4.55* | -4.71* |
| **FFMI (kg/m2)** | -0.29 | -1.02* | -1.31* |

**Table 4:** LSD Post hoc test of different anthropometric variables and adiposity indices among subjects between different stages of treatment. *p<0.05.

## Discussion and Conclusion

Malnutrition predisposes to tuberculosis, and tuberculosis causes ‘consumption’ [22]. Recent studies have investigated anthropometric and body composition characteristics as well as nutritional status of tuberculosis patients in several countries worldwide and found that, tuberculosis patients had significantly lower mean values of anthropometric and body composition characteristics. The frequency of under nutrition (BMI<18.5 kg/m$^2$) was also significantly higher among tuberculosis patients. Similar findings have been reported in earlier studies worldwide [23-28].

In the present investigation, there was clear evidence that TB patients before starting treatment had significantly lower mean values of anthropometric variables and adiposity indices. Thus, with TB, a depletion of fat and wastage of muscles has been noticed, which bring about a decrease in body weight as observed among patients who had not started their treatment. Similar findings were found in a study among 823,199 Navy recruits [3]. The study also found morbidity (TB) to be 3 times greater for underweight than for overweight men. In the present study it was further found that proper treatment and improved diet certainly showed an impact on the body weight and this corroborates with the findings of Harries et al., Hartz et al., Jackson AS [1,29,30].

In the present study body mass index (BMI) a widely used method to assess the fatness in human beings was noticed to be lowest among the subjects who had not started TB treatment, thereby indicating degeneration of the body’s soft tissues with chronic disease and the same was also found by Onwubalili and Van et al. [6,31]. This increase in BMI with treatment may be attributed to the increase in fat and muscle mass with proper medication as advised by doctors. The present findings was also supported by the study done by Tverdal [4], among 1717655 subjects, where he found that incidence of pulmonary TB decreased with increasing body mass index (BMI) for both sexes and all age groups, which was mainly attributed to be due to the weight component. Waist to hip circumference ratio (WHR) is an indicator of the degree of masculine distribution of adipose tissue: the higher the WHR, the more masculine the pattern of adipose tissue distribution and the greater the risk of diseases such as noninsulin dependent diabetes mellitus [32,33]. In the present study, the WHR was found to be least among TB patients (BST) and a significant increase was observed till two months of treatment (p<0.01). The increase in WHR with TB treatment has been brought by the more sensitive behaviour of suprailiac site for fat accumulation. This also suggests that a central deposition of adipose tissue is a response to stress acting through the adrenal cortex [34].

The present study also found that all the skinfold thicknesses were found to be least among TB patients (BST) and this could be a reflection of decreased energy stores due to depletion of fat with chronic disease. The situation changed during the course of treatment. A continuous increase in bodyweight with treatment can be attributed to increase in muscle mass as well as subcutaneous fat. The increase in BMI, an index of overweight/obesity and a simultaneous increase in the GMT of skinfold thicknesses with TB treatment which suggests that the increase in body weight may be due to increase in fatness. It was also observed that fat re-distribution started manifesting itself from the time treatment started and which displayed an overall increase with anti-tuberculosis treatment thereby indicating loss of trunkal as well as extremity fat from the time a person is diagnosed with the chronic disease [33-36].

The present study also showed increase in the mean values of grand mean thickness (GMT) and Fat mass Index with anti-tuberculosis treatment. The increase in fatness level is mainly due to improved health status and treatment compliance of the present subjects. The variability among patients especially those patients who were diagnosed cases but had not started treatment may be due to poor nutritional intake, lack of physical activity, anorexia, etc. which comes with chronic diseases [7,37]. There is no doubt that one of the symptom of tuberculosis is anorexia or loss of appetite which often cause a loss in body weight with a concomitant decrease in body fat which was noticeable in the present subjects. The decrease in energy intake might be due to less food intake or improper and or imbalanced diet. Energy intake can be influenced by less food availability, poor eating habits or anorexia. Thus, wasting of muscle mass and decrease in fat percentage with disease and overall temporal recovery in these components along with redistribution of fat with TB treatment was observed. It was also found that there was significant variation in the body composition during treatment. Thus, this indicates that selected anthropometric variables and various obesity and adiposity indices are strongly suggestive useful biomarkers to predict TB treatment outcome.

## Acknowledgements

The authors are grateful to the subjects who volunteered for the study. The authors are also thankful to (L) Dr. S.P. Khanna, the then Director, Delhi TB Centre for his cooperation and guidance before the start of the fieldwork. The financial assistances to Mary Grace Tungdim from Department of Science & Technology (WOS-A) and to Heemanshu Aurora from Department of Science & Technology (INSPIRE Fellowship) are sincerely acknowledged.

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