



DXA And Walk Analysis - As A Probability Tool To T2dm In Near Future

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Abstract

Introduction: India is relatively young country as compared to western or far eastern countries. After 40 years of age nearly all are prone to prediabetes and then diabetes due to rapid epidemiological transition and positive familial history as shown by CURES STUDY from south India. Prediabetes and Diabetes are positively co-related to central abdominal fat. It is already proved that android pattern of fat distribution is co-related with prediabetes and diabetes not gynoid fat in the subject. Visceral Adipose Tissue (VAT) is the fat accumulated in viscera and muscles. Subcutaneous Adipose Tissue (SAT) is the fat accumulation in subcutaneous region of whole body. This adiposity feature is the main risk factor for prediabetes which further leads to diabetes and then sarcopenia and frailty. Dual X-ray Absorptiometry (DXA) calculates fat in the form of VAT, SAT very readily and effectively by an affordable, less harmful and non-invasive tool as compared to CT scan and MRI scan.

So, DXA can diagnose prediabetes in time, then this endemic can be preventable. This study is a part of my ethically approved large study of sarcopenia and walk test in TYPE 2 DIABETES MILLETUS (T2 DM).

Method: This is a cross-sectional-study of 46-patients (23 normal-subjects and 23 T2DM patients), taken from diabetic-clinic of department-of-medicine KGMU-UP. T2DM patients (n = 23) with history more than 5 years with mean HBA1C of 7.5 and compared with normal persons (n = 23). DXA is used to calculate BMI, VAT, SAT, FMI (FAT MASS INDEX), LMI (LEAN MASS INDEX), FMR-A/G- FAT MASS RATIO (ANDROID/GYNOID), FMR-T/L - FAT MASS RATIO (TRUCK/LIMB RATIO) in T2DM patients (n = 23) with history more than 5 years with mean HBA1C of 7.5 and compared with normal persons (n = 23).

Result: Across both sexes demonstrated an increase in adiposity measures (BMI, FM, FMI, VAT) peaking in the 50 -< 60 yrs age category, with lean mass indices remaining comparatively uniform across age. This pattern suggests that, within the case group, middle age was associated with greater fat accumulation-especially visceral fat-without substantial loss of lean tissue BMI mean at 50 years of age. BMI of case (T2DM) in male is calculated as 27.4 ± 1.9 and in female as 28.9 ± 3.4 , BMI of normal subject in male is calculated as 26 ± 4.4 and in female as 27.5 ± 4.4 . FMI of case (T2DM) in male is calculated as 8.19 ± 2.54 and in female as 10.34 ± 2.74 , FMI of normal subject in male is calculated as 5.3 ± 3.1 and in female as 8.3 ± 3.1 . LMI of case (T2DM) in male is calculated as 18.06 ± 2.64 and in female as 16.13 ± 1.56 , LMI of normal subject in male is calculated as 20.8 ± 2.4 and in female as 19.6 ± 1.9 . FMR-A/G of case (T2DM) in male is calculated as 1 and in female as 1, FMR-A/G of normal subject in male is calculated as 1.02 and in female as 0.76. FMR-T/L of case (T2DM) in male is calculated as 3 and in female as 1.14, FMR-T/L of normal subject in male is calculated as 2.6 and in female as 1.35.

Conclusions: In a nutshell, we found in this study there is a mirror (inverse $\propto$) relation between normal subjects and T2DM patients after 55 years of age as far as the graph is concerned in body parameters (BMI, FMI, LMI, FMR-A/G AND FMR-T/L). North Indians (from 40 to 70 years in 46 patients-23 each) of urban and rural background has been found to have deranged body parameters (BMI, FMI, LMI, FMR-A/G AND FMR-T/L) that causes T2DM in later life. In addition, this study reports LMI reference values with regard to fat mass quantities, showing a positive association with increasing FMI percentiles and BMI categories.

Public health awareness after proper screening by DXA, government sponsored Diabetes campaign in the form of screening of vulnerable population in specific age group from 40 years (positive family history and epidemiological history) via DXA diagnosing T2DM in the form of prediabetes and later diabetes, interventions should target modifiable risk factors to slow down the diabetes epidemic in this population.

Keywords: DEXA; T2DM; Walk Tests; Left Cerebral Dominance

Introduction

Visceral-obesity is based on our body's four molecular-level components-water, fat, protein, and minerals body components [1]. Human-body is a model of three-compartments, fat-mass (FM), lean-mass (LM), and bone-mineral-content (BMC), these three are analysed by Dual-X-ray-absorptiometry (DXA) [2-6].

Asian-Indians have an increased susceptibility and rising prevalence to T2DM (T2DM) and insulin-resistance compared with Europeans [7-13] with lower BMIs than Europeans [14] but greater waist-to-hip ratios and abdominal-fat [14,15] than Europeans. Android/apple shaped fat distribution is common in men is the fat on the abdomen have significant correlation with metabolic syndromes. Gynoid/pear shaped has fat distribution is common in female is the fat on thighs and buttocks is non-significant on metabolic syndromes. Therefore, liposuction or weight-loss surgeries causes loss of Visceral-fat [16] proves beneficial effect in the incidence of metabolic syndromes in android shaped humans.

There are very few studies on fat distribution in South Asian Indians [17,18] and virtually none comparing diabetic and non-diabetic subjects in north Indian population. Also, we get western parameters in DXA machines, thus it is the need of hour to get exact north Indian parameters for further studies in the subject. Thus, the first objective of this study was to measure body fat distribution in North Indians in normal and T2DM.

DXA is used to measure total body fat [19] and central abdominal fat [20]. The association of Visceral-fat and central abdominal fat measured by DXA has been studied in Asian-Indian [21] but specifically not been studied in North-Indian population. Thus, the second objective of our study was to correlate visceral and central abdominal fat with each other and with anthropometric parameters in North-Indian normal population and Type-2 DM cases to predict T2DM in near future which remains a gap in knowledge until now what we have from various references and so here in this study we have filled those gaps to predict T2DM in various ages.

Material Methods

This is a cross-sectional-study of 46-patients (23 normal-subjects and 23 T2DM patients) of different age groups, taken from

diabetic-clinic of department-of-medicine KGMU-UP that is in specially North India. T2DM patients (n = 23) with history more than 5 years with mean HBA1C of 7.5 and compared with normal persons (n = 23). Normal subjects and self-reported diabetic patients were taken for this study and convenient sampling done. Self-reported diabetic patients were classified as known diabetic subjects. Ethical approval was taken from KGMU university The study protocol was reviewed and approved by the Institutional Ethics Committee of KGMU. Written informed consent was obtained from all participants before data collection. The study was conducted following ethical guidelines to ensure participant safety and data confidentiality.

DEXA scans

DEXA-procedure was done at the Department-of-Radiodiagnosis, KGMU-Lucknow-UP {Osteosis (Model-number HTB-1003 SERIAL-NUMBER 2201009 MANUFACTURER-POSCOM-Co-LTD)}. Central-abdominal-fat was calculated by the construction of an abdominal-window as described by Carey, *et al.* [38]. The upper margin of this window was fixed at the lower-border of the second-lumbar-vertebra (L2) and the lower-margin at the lower-border of the fourth-lumbar-vertebra (L4). The lateral-margins were fixed in alignment with the outer edges of the ribcage so as to exclude most of the lateral-subcutaneous-fat.

Statistical-analysis

Various fat measures and anthropometric variables as independent variables were performed. All analyses were done using Windows-based SPSS Statistical Package (version 10.0; SPSS-Chicago-IL), and *P* values <0.05 were considered significant.

Results

As shown in table 1, the case-group (n = 23) exhibited age-related differences in body composition among men and women. In men, those aged 50 -< 60 years (n = 5) had the highest mean-BMI ($27.4 \pm 1.9 \text{ kg/m}^2$) and visceral-adipose-tissue (VAT) mass ($1020.7 \pm 270.4 \text{ g}$), whereas the youngest (40 -< 50yrs, n = 2) and oldest (60 -< 80yrs, n = 2) subgroups showed lower BMI (26.1 ± 2.5 and $25.6 \pm 3.1 \text{ kg/m}^2$, respectively) and VAT-mass (784.8 ± 342.3 and $710.4 \pm 195.7 \text{ g}$). Lean-mass-indices were relatively stable across ages ($\text{LMI} \sim 18 \text{ kg/m}^2$), but the peak-fat-mass-index (FMI) oc-

occurred in the 50 -< 60yrs subgroup ($8.19 \pm 2.54\text{kg/m}^2$), indicating greater adiposity in middle-aged men (Table 1). Appendicular FMI declined with age in men-highest in the youngest subgroup ($2.83 \pm 0.81\text{kg/m}^2$) and lowest in the oldest ($1.09 \pm 1.07\text{kg/m}^2$)-whereas appendicular-LMI remained around 18kg/m^2 across all groups. Among women, middle-aged participants (50 -< 60yrs, n = 6) similarly exhibited the highest-BMI ($28.9 \pm 3.4\text{kg/m}^2$), total-fat-mass ($27.8 \pm 8.1\text{kg}$), and VAT-mass ($1161.3 \pm 283.7\text{g}$). Younger women (40 -< 50yrs, n = 3) had the lowest-BMI ($25.1 \pm 2.7\text{kg/m}^2$) and VAT-mass ($706.0 \pm 440.9\text{g}$), while those in the oldest bracket (60 -< 80yrs, n = 5) showed intermediate values. Despite these differences, percent lean mass remained high across all female age groups (approximately 82-85%), reflecting preserved muscle compartment relative to fat (Table 1). Women's appendicular-FMI peaked in the 50 -< 60yrs category ($5.11 \pm 2.47\text{kg/m}^2$) and was lower in both younger and older groups, with appendicular-LMI similarly uniform ($16.13\text{-}17.82\text{kg/m}^2$).

Overall, both sexes demonstrated an increase in adiposity measures (BMI, FM, FMI, VAT) peaking in the 50 -< 60yrs age category, with lean mass indices remaining comparatively uniform across age. This pattern suggests that, within the Case-group, middle age was associated with greater fat accumulation-especially visceral-fat-without substantial loss of lean-tissue (Table 1).

In table 2, the control-group (n = 23) demonstrated distinct age-related trends in body composition for both sexes.

- **Men:** Those aged 50 -< 60years (n = 5) exhibited the highest mean-BMI ($26.0 \pm 4.4\text{kg/m}^2$), fat mass ($15.3 \pm 9.2\text{kg}$), and visceral-adipose-tissue (VAT) mass ($769.4 \pm 404.2\text{g}$). Younger-men (40 -< 50yrs, n = 3) had lower-BMI ($24.1 \pm 1.1\text{kg/m}^2$) and VAT-mass ($586.7 \pm 296.0\text{g}$), while the oldest subgroup (60 -< 80yrs, n = 7) showed intermediate-values (BMI $26.5 \pm 4.3\text{kg/m}^2$; VAT-mass $659.9 \pm 360.8\text{g}$). Lean-mass-indices (LMI) increased slightly with age, from $19.4 \pm 2.5\text{kg/m}^2$ in the youngest to $20.6 \pm 2.4\text{kg/m}^2$ in the oldest-subgroup, reflecting modest gains in lean tissue relative to body size (Table 2). Appendicular-FMI rose with age, from $0.80 \pm 0.34\text{kg/m}^2$ in the 40 -< 50yrs bracket to $2.27 \pm 1.17\text{kg/m}^2$ in the 60 -< 80yrs group, whereas appendicular-LMI remained uniformly high ($\sim 20\text{-}21\text{kg/m}^2$) across all male subgroups.

- **Women:** In the 40 -< 50yrs bracket (n = 2), women had a mean BMI of $30.3 \pm 8.5\text{kg/m}^2$ and VAT mass of $974.0 \pm 401.6\text{g}$ -higher than their 50 -< 60yrs counterparts (n = 6; BMI $27.5 \pm 4.4\text{kg/m}^2$; VAT $918.5 \pm 290.3\text{g}$). No female participants fell into the 60 -< 80yrs category. Both FMI and %FM were elevated in the younger female subgroup ($9.3 \pm 5.8\text{kg/m}^2$; $30.4 \pm 8.8\%$) compared to the middle-aged group ($8.3 \pm 3.1\text{kg/m}^2$; $29.3 \pm 9.5\%$), while lean mass percentages (%LM) remained lower ($69.6 \pm 8.8\%$ vs. $70.7 \pm 9.5\%$) (Table 2). Appendicular FMI was also higher in younger women ($4.00 \pm 2.64\text{kg/m}^2$) than in those aged 50 -< 60yrs ($3.19 \pm 1.67\text{kg/m}^2$), with appendicular LMI similarly consistent ($\sim 19\text{-}22\text{kg/m}^2$) across the control female subgroups.

Overall, control-group men showed peak adiposity in mid-age with gradual increases in lean mass index, whereas women exhibited higher fat accumulation in the younger age bracket with stable lean mass proportions. These patterns underscore age- and sex-specific differences in fat distribution and body composition within the control population (Table 2).

Comparison of case and control-group

Comparing the case (Table 1) and control (Table 2) groups reveals several noteworthy differences in body composition across age and sex:

Men

- **BMI and overall adiposity:** In every age bracket, men in the Case-group had higher mean BMI than controls. For instance, the 50 -< 60yrs case-men averaged $27.4 \pm 1.9\text{kg/m}^2$ versus $26.0 \pm 4.4\text{kg/m}^2$ in controls (Table 1 and 2).
- **Visceral-fat:** Case-men also carried more visceral adipose tissue (VAT) at each age. The 50 -< 60yrs subgroup had a mean VAT mass of $1020.7 \pm 270.4\text{g}$ (Table 1) compared with $769.4 \pm 404.2\text{g}$ in controls (Table 2).
- **Lean mass index (LMI):** Control-men exhibited slightly higher LMI than case-men in the younger bracket (40 -< 50yrs: 19.4 ± 2.5 vs. $18.34 \pm 4.18\text{kg/m}^2$), suggesting relatively greater preservation of lean tissue in controls at younger ages.

- **Appendicular-indices:** Case-men had markedly higher appendicular FMI across all brackets (e.g., 1.32 ± 0.65 vs. $1.05 \pm 0.21 \text{ kg/m}^2$ in 50 -< 60yrs), whereas controls showed lower values (1.05 ± 0.21 vs. $0.80 \pm 0.34 \text{ kg/m}^2$ in 40 -< 50yrs). Appendicular LMI was broadly similar between groups in mid-age but edged lower in cases at older ages (18.06 ± 2.64 vs. $20.8 \pm 2.4 \text{ kg/m}^2$ in 50 -< 60yrs).

Women

- **BMI and fat mass:** Case-women aged 50 -< 60yrs had a mean BMI of $28.9 \pm 3.4 \text{ kg/m}^2$ (Table 1) versus $27.5 \pm 4.4 \text{ kg/m}^2$ in controls (Table 2). Their fat mass ($27.8 \pm 8.1 \text{ kg}$ vs $19.4 \pm 7.9 \text{ kg}$) and FMI (10.34 ± 2.74 vs. $8.3 \pm 3.1 \text{ kg/m}^2$) were also higher, indicating greater total adiposity.
- **Visceral-fat:** Although control-women aged 40 -< 50yrs showed elevated VAT ($974.0 \pm 401.6 \text{ g}$) compared to case-women ($706.0 \pm 440.9 \text{ g}$), in the predominant 50 -< 60yrs bracket the Case-group had higher VAT mass (1161.3 ± 283.7 vs. $918.5 \pm 290.3 \text{ g}$).
- **Lean-proportion:** Percent lean mass (%LM) was marginally higher in case-women (e.g., $81.8 \pm 5.2\%$ vs. $70.7 \pm 9.5\%$ in 50 -< 60yrs), reflecting that despite greater fat deposition, lean tissue remained proportionally robust (Tables 1 and 2).
- **Appendicular-indices:** Case-women exhibited higher appendicular FMI in mid-age (5.11 ± 2.47 vs $3.19 \pm 1.67 \text{ kg/m}^2$ in 50 -< 60yrs) and retained similar appendicular LMI to controls (16.13 ± 1.56 vs $19.6 \pm 1.9 \text{ kg/m}^2$), indicating that additional fat was also distributed peripherally.

Overall

Across both sexes, the Case-group tended toward greater adiposity-particularly Visceral-fat- than controls in corresponding age brackets, while lean mass indices were broadly similar or slightly lower in cases. Moreover, appendicular FMI was consistently higher in cases (reflecting greater limb fat deposition), whereas appendicular LMI remained comparable between groups, underscoring that excess adiposity in cases extended to the appendicular compartment. These distinctions suggest that participants classified as "case" exhibited a higher tendency for fat accumulation overall and peripherally, especially in the 50 -< 60yrs range, relative to their age-matched controls.

Figure 1 (Male): Across ages 45 to 70 years, all FMI percentiles in the case-group men rise from age 45, peak at around age 55, and then decline by age 70. The median (50th percentile) FMI increases from about 7.4 kg/m^2 at 45yrs to roughly 8.2 kg/m^2 at 55yrs before falling back to $\sim 6.8 \text{ kg/m}^2$ at 70yrs. Similarly, the upper percentiles (90th and 97th) climb from ~ 10.5 and 12.0 kg/m^2 at 45yrs to ~ 11.5 and 13.0 kg/m^2 at 55yrs, then taper off modestly. The lower percentiles (3rd and 10th) mirror this pattern on a smaller scale. Together, these curves indicate that fat-mass relative to height in case-group men is highest in the mid-50s and decreases thereafter, with variability (spread between percentiles) greatest around age 55.

Figure 1 (Female): In the case-group women, FMI percentiles show an even more pronounced midlife peak. The 50th percentile jumps from $\sim 7.4 \text{ kg/m}^2$ at 45yrs up to $\sim 10.3 \text{ kg/m}^2$ at 55yrs before declining to $\sim 7.9 \text{ kg/m}^2$ at 70yrs. The top end (90th and 97th percentiles) rises sharply- reaching ~ 13.9 and 15.5 kg/m^2 by age 55-then falls to ~ 11.4 and 13.1 kg/m^2 by 70yrs. The lower curves likewise increase steeply between 45 and 55yrs. This pattern suggests that women in the Case-group accumulate fat more rapidly into midlife, creating wider percentile spreads at age 55, followed by a reduction in FMI in later years.

Fat mass/Height² vs. age in Control-group (Male): (Figure 2)

All male FMI percentiles dip slightly from age 45 to 55 and then rebound by age 70, with the median (50th) rising from $\sim 3.7 \text{ kg/m}^2$ at 45yrs to $\sim 5.3 \text{ kg/m}^2$ at 55yrs before falling back to $\sim 4.1 \text{ kg/m}^2$ at 70yrs. The upper percentiles peak most sharply at 55yrs (97th: $\sim 11.2 \rightarrow 7.9 \text{ kg/m}^2$ by 70yrs), while the lower percentiles (3rd, 10th) show minimal variation, indicating that mid-life brings a transient increase in Visceral-fat relative to height, particularly among those at the higher end of the distribution.

Fat mass/Height² vs. age in Control-group (Female): (Figure 2)

Female FMI percentiles steadily decline with age. The median drops gradually from $\sim 9.3 \text{ kg/m}^2$ at 45yrs to $\sim 8.3 \text{ kg/m}^2$ at 55yrs. The highest percentiles (90th, 97th) decrease from ~ 16.8 and 20.2 kg/m^2 at 45yrs to ~ 12.4 and 14.2 kg/m^2 at 55yrs, while the lower percentiles (3rd, 10th) rise modestly, reflecting a compression of variability. Overall, women in the Control-group lose relative fat mass after mid-life, and the spread between leaner and fatter individuals narrows with age.

Lean Mass/Height² vs. age in Case-group (Male): (Figure 3)

Across ages 45 to 70, case-group men show a small mid-life dip in lean-mass index (LMI) followed by recovery by age 70. The median (50th percentile) LMI declines slightly from ~18.3kg/m² at 45yrs to ~18.1kg/m² at 55yrs, then rises to ~18.8kg/m² by 70yrs. The upper percentiles (90th, 97th) mirror this: highest at 45yrs (~23.7 and 26.2kg/m²), decreasing through 55yrs (~21.5 and 23.1kg/m²), then plateauing. Conversely, the lower percentiles (3rd, 10th) increase steadily with age-from ~10.5 and 13.1kg/m² at 45yrs to ~14.6 and 15.9kg/m² by 70yrs-indicating that lean mass relative to height becomes more uniform across individuals as they age. Overall, while the highest-muscle-mass men experience a slight loss in mid-life before stabilizing, those at the lower end gain LMI, compressing variability by later years.

Lean Mass/Height² vs. age in Case-group (Female): (Figure 3)

In women, LMI percentiles decline from mid-40s into the mid-50s, then rebound by age 70. The median falls from ~17.2kg/m² at 45yrs to ~16.1kg/m² at 55yrs before increasing to ~17.8kg/m² at 70yrs. Upper percentiles (90th, 97th) follow suit-decreasing from ~19.4 and 20.5kg/m² at 45yrs to ~18.2 and 19.1kg/m² at 55yrs, then rising sharply to ~21.4 and 23.1kg/m² by 70yrs. Lower percentiles (3rd, 10th) gradually decrease through age 70, from ~13.9 and 15.0kg/m² at 45yrs down to ~12.7 and 14.3kg/m². This pattern suggests that female lean mass relative to height dips in mid-life but recovers in older age, with the spread between leaner and more muscular individuals widening again by 70yrs.

Lean Mass/Height² vs. age in Control-group (Male): (Figure 4)

Control-group men show a subtle mid-life rise in lean-mass index followed by a slight decline by age 70. The median (50th percentile) LMI increases from about 19.4kg/m² at 45yrs to 20.8kg/m² at 55yrs, then dips marginally to 20.6kg/m² by 70yrs. The upper percentiles (90th, 97th) peak at 55yrs (~23.2 and 27.1kg/m²) before decreasing, whereas the lower percentiles (3rd, 10th) fall to their lowest at mid-life (~0.5 and 1.4kg/m²) and then rise again by 70yrs (~0.4 and 1.6kg/m²). Altogether, this suggests that lean tissue relative to height is greatest around age 55 for the most muscular men, while those at the lower end recover some lean-mass index by later years, narrowing variability.

Lean Mass/Height² vs. age in Control-group (Female): (Figure 4)

Control-group women exhibit a steady decline in LMI with age. The median falls from about 21.6kg/m² at 45yrs to 19.6kg/m² at 55yrs. Upper percentiles similarly drop-from roughly 19.4 and 20.3kg/m² at the 90th and 97th percentiles down to ~18.2 and 15.9kg/m²-while lower percentiles also decrease modestly. This uniform downward shift indicates that lean-mass relative to height diminishes across the board in women after mid-life, with the spread between leaner and more muscular individuals remaining relatively constant.

Fat mass ratio Android/Gynoid vs age in Case-group (Male): (Figure 5)

In case-group men, the Android/Gynoid fat-mass ratio steadily increased with age across all percentiles. The median (50th percentile) rose from approximately 0.8 at age 45 to about 1.0 by age 55 and reached roughly 1.2 by age 70. Upper centiles (90th and 97th) showed even steeper growth-climbing from ~1.1 and 1.3 at 45yrs to ~1.4 and 1.5 at 55yrs, then to ~2.0 and 2.3 by 70yrs-indicating that men with the highest ratios experienced the greatest central fat accumulation over time. Lower percentiles (3rd and 10th) also trended upward (from ~0.4- 0.6 at 45yrs to ~0.5-0.6 at 55yrs and ~0.1-0.3 at 70yrs), albeit with smaller absolute changes. Overall, this pattern demonstrates an age-related shift toward a more central (android) fat distribution in men, with variability widening at older ages.

Fat mass ratio Android/Gynoid vs age in Case-group (Female): (Figure 5)

Among case-group women, Android/Gynoid ratios also increased across the lifespan but with a slightly different profile. The median rose from about 0.9 at 45yrs to 1.0 at 55yrs and then to ~1.2 by 70yrs. The top percentiles climbed from roughly 1.1-1.3 at 45yrs to ~1.4-1.6 at 55yrs and up to ~2.0-2.3 at 70yrs, indicating pronounced central fat gain among the highest-ratio individuals. Lower percentiles increased more modestly-from ~0.5-0.6 at 45yrs to ~0.6 at 55yrs and ~0.3-0.4 by 70yrs-suggesting that even women with relatively gynoid-weighted fat distributions shifted toward more central adiposity in later life. Together, these curves highlight a clear trend of increasing Android/Gynoid fat-mass ratio

with age in both sexes, with the steepest rises seen in those at the upper end of the distribution.

Fat Mass Ratio Android/Gynoid vs. age in Control-group (Male): (Figure 6)

In control-group men, the median (50th percentile) Android/Gynoid ratio decreases slightly from ~1.13 at age 45 to ~1.02 by age 55, then rises modestly to ~1.04 at 70yrs, reflecting a small mid-life dip before partial recovery. Upper centiles (90th, 97th) follow a downward trajectory, indicating that men with the highest central adiposity experienced the greatest relative decline—from ~1.37 and 1.48 at 45yrs to ~1.30 and 1.45 at 55yrs, then to ~1.24 and 1.33 at 70yrs. Lower percentiles (3rd, 10th) mirror this U-shaped pattern: both dip to their lowest at 55yrs (~0.60 and 0.73) before increasing by age 70 (~0.74 and 0.84). Overall, men in the Control-group show a slight redistribution away from android-dominant fat in mid-life with a trend back toward centralization at older ages, and variability in ratio narrows most around age 55.

Fat Mass Ratio Android/Gynoid vs. age in Control-group (Female): (Figure 6)

Among control-group women, the median ratio rises steadily from ~0.74 at age 45 to ~0.76 at 55yrs, and to ~0.78 by age 70, indicating progressive central fat accumulation over time. Upper percentiles (90th, 97th) also increase—from ~0.84 and 0.89 at 45yrs to ~0.88 and 0.92 at 55yrs, reaching ~0.92 and 0.98 at 70yrs—showing consistent growth in central adiposity among those with higher ratios. Lower percentiles (3rd, 10th) decrease marginally from ~0.60-0.64 at 45yrs to ~0.58-0.64 at 55yrs and ~0.58-0.64 at 70yrs, indicating a slight widening of variability as leaner individuals maintain or lose gynoid-dominant distribution. Overall, women in the Control-group exhibit a clear trend toward increasing Android/Gynoid ratio with age, reflecting a gradual shift toward central fat deposition.

Fat Mass Ratio Trunk/Limbs vs. age in Case-group (Male): (Figure 7)

Case-group men showed a marked increase in central (trunk) relative to peripheral (limb) fat with age. The median (50th percentile) ratio rose from ~1.4 at age 45 to ~3.0 at age 55 and to ~3.9 by age 70, indicating progressive trunk fat accumulation versus limb fat. The upper percentiles (90th, 97th) climbed steeply—from ~2.0

and 2.3 at 45yrs to ~4.2 and 4.8 at 55yrs, reaching ~7.8 and 9.7 at 70yrs—highlighting that men with the greatest central fat disproportionately increased trunk storage over time. Lower percentiles (3rd, 10th) exhibited a U-shaped pattern, peaking at age 55 (1.2-1.8) then falling by age 70 (-1.9 to -0.1), reflecting that leanest men saw a mid-life shift toward trunk fat but some limb recovery in later years. Overall, men in the Case-group accumulated trunk fat relative to limbs steadily with aging, especially at the higher end of the distribution.

Fat Mass Ratio Trunk/Limbs vs. age in Case-group (Female): (Figure 7)

In case-group women, the median trunk/limb ratio remained flat from 45 to 55yrs (~1.14) before rising to ~1.40 at 70yrs, indicating relatively stable central vs. peripheral fat until older age. Upper centiles (90th, 97th) increased substantially—from ~1.27 and 1.33 at 45yrs to ~1.66 and 1.91 at 55yrs, and up to ~1.82 and 2.02 at 70yrs—showing pronounced central fat gain among those with highest ratios. Lower percentiles (3rd, 10th) experienced a drop at mid-life (from ~0.95-1.01 at 45yrs to ~0.38-0.63 at 55yrs) then recovered by 70yrs (~0.77-0.97), suggesting that women with lowest ratios briefly shifted toward trunk fat at mid-life before rebalancing. Together, these curves reveal that, although most women maintained a stable trunk/limb balance through mid-life, older age brought increased centralization of fat, particularly in those with originally higher ratios.

Fat Mass Ratio Trunk/Limbs vs. age in Control-group (Male): (Figure 8)

Control-group men exhibit a U-shaped pattern in trunk/limb ratio. The median (50th percentile) falls from ~3.8 at age 45 to ~2.6 at 55yrs, then rebounds to ~3.4 by 70yrs, indicating an initial mid-life shift toward relatively more limb fat before renewed centralization in later years. Upper centiles (90th, 97th) decline markedly from ~5.4 and 6.5 at 45yrs to ~4.2 and 4.8 at 55yrs, plateauing thereafter—suggesting high-ratio men lose relative trunk fat through mid-life before slight regain. Lower centiles (3rd, 10th) mirror this U-shape, dipping to ~0.1-0.9 at 55yrs and rising to ~1.9-2.4 by age 70. Overall, men show transient peripheral redistribution in mid-adulthood, followed by a shift back toward central fat deposition in older age.

Fat Mass Ratio Trunk/Limbs vs. age in Control-group (Female): (Figure 8)

Control-group women display a monotonic increase in the trunk/limb ratio with age. The median gradually rises from ~1.27 at age 45 to ~1.39 by 55yrs and ~1.77 at 70yrs, reflecting steadily increasing central fat relative to limb fat. Upper centiles (90th, 97th) climb prominently-from ~1.42 and 1.49 at 45yrs to ~1.66 and 1.91 at 55yrs, and up to ~2.47 and 2.90 by 70yrs-indicating substantial central fat gains among those most predisposed. Lower centiles (3rd, 10th) decrease from ~0.96-1.01 at 45yrs to ~0.38-0.63 at 55yrs, then recover partially to ~0.74-0.97 at 70yrs, suggesting a mid-life dip in centralization among leanest women but an overall upward trend later. Together, these curves highlight a progressive increase in trunk fat storage relative to limbs across female adulthood.

Discussion

The present study on 46 north Indian population aged 40-70 years, age and sex related reference values for total and regional body composition parameters and VAT, were obtained by Osteosis DXA scans. In addition, this study firstly reported in North Indians LMI reference values with regard to different FM quantities, showing a positive association with increasing FMI percentiles. Moreover, LMI and appendicular LMI reference values are provided for different BMI categories. It is well established that reference values should take age, sex, and ethnicity into account [22], and should be population- and technique-specific²³ with same DXA device and software [23]. In the United States [24-27], DXA devices are from Hologic Inc. (Bedford, MA, USA) [24-18] and iDXA [29], show only descriptive percentile values [30]. The recommended reference values of body composition parameters are those based on the American NHANES cohort [31]. Whether those reference values are applicable to populations outside America is unclear [31], but comparison with the LEAD cohort, suggest that they might not be representative for Indians. Therefore, reference values for Osteosis DXA scans were created, based on these parameters. A study from south Indian single city revealed prediabetic prevalence is more in Asians as compared to Caucasians due to raised serum level of insulin along with insulin resistance. This insulin resistance is due to family history and rapid epidemiological transition, so prediabetics are more than those ethnic groups (Pima, Micronesians and north Americans [32-37].

Both sexes demonstrated an increase in adiposity measures (BMI, FM, FMI, VAT) peaking in the 50-60yrs age category, median at 55 years, with lean mass indices remaining comparatively uniform across age. This pattern suggests that, within the Case-group, middle age was associated with greater fat accumulation-especially Visceral-fat-without substantial loss of lean tissue (Table 1).

Control-group men showed peak adiposity in mid-age with gradual increases in lean mass index, whereas women exhibited higher fat accumulation in the younger age bracket with stable lean mass proportions. These patterns underscore age and sex-specific differences in fat distribution and body composition within the control population (Table 2).

Men

- **BMI and overall adiposity:** In every age bracket, men in the Case-group had higher mean BMI than controls.
- **Visceral-fat:** Case-men also carried more visceral adipose tissue (VAT) at each age.
- **Lean mass index (LMI):** Control-men exhibited slightly higher LMI than case-men in the younger suggesting relatively greater preservation of lean tissue in controls at younger ages.
- **Appendicular-indices:** Case-men had markedly higher appendicular FMI across all ages.

Women

- **BMI and fat mass:** Case-women aged 50 -< 60yrs had a mean BMI, fat mass and FMI were also higher, indicating greater total adiposity.
- **Visceral-fat:** Although control-women aged 40 -< 50yrs showed higher VAT mass.
- **Lean-proportion:** Percent lean mass (%LM) was marginally higher in case reflecting that despite greater fat deposition, lean tissue remained proportionally robust.
- **Appendicular-indices:** Case-women exhibited higher appendicular FMI in mid-age indicating that additional fat was also distributed peripherally.

	Age (yrs)		
	40 to <50	50 to <60	60 to <80
Men			
N	2	5	2
Height (cm)	158.4 ± 12.6	162.9 ± 9.6	156.4 ± 4.8
Weight (kg)	64.3 ± 14.9	70.1 ± 8.5	62.4 ± 11.0
BMI (kg/m ²)	26.1 ± 2.5	27.4 ± 1.9	25.6 ± 3.1
FM (kg)	18.4 ± 6.1	21.8 ± 4.5	16.6 ± 3.9
LM (kg)	45.9 ± 11.2	48.2 ± 7.3	45.8 ± 5.4
%FM	28.5 ± 5.3	31.8 ± 4.7	26.3 ± 4.9
%LM	71.5 ± 5.3	68.2 ± 4.7	73.7 ± 4.9
Appendicular FMI (kg/m ²)	2.83 ± 0.81	1.32 ± 0.65	1.09 ± 1.07
FMI (kg/m ²)	7.36 ± 2.45	8.19 ± 2.54	6.79 ± 1.98
LMI (kg/m ²)	18.34 ± 4.18	18.06 ± 2.64	18.78 ± 2.23
VAT mass (g)	784.8 ± 342.3	1020.7 ± 270.4	710.4 ± 195.7
VAT volume (cm ³)	852.8 ± 372.2	1109.5 ± 293.9	772.2 ± 213.0
Women			
N	3	6	5
Height (cm)	150.0 ± 7.2	156.7 ± 7.4	155.7 ± 6.7
Weight (kg)	55.8 ± 12.8	70.9 ± 9.2	62.4 ± 11.0
BMI (kg/m ²)	25.1 ± 2.7	28.9 ± 3.4	25.8 ± 3.1
FM (kg)	17.5 ± 9.6	27.8 ± 8.1	19.2 ± 6.4
LM (kg)	38.3 ± 3.9	43.1 ± 4.1	43.2 ± 9.1
%FM	14.7 ± 3.8	18.2 ± 5.2	16.7 ± 4.9
%LM	85.3 ± 3.8	81.8 ± 5.2	83.3 ± 4.9
Appendicular FMI (kg/m ²)	3.48 ± 2.15	5.11 ± 2.47	3.31 ± 0.86
FMI (kg/m ²)	7.36 ± 4.04	10.34 ± 2.74	7.92 ± 2.73
LMI (kg/m ²)	17.17 ± 1.75	16.13 ± 1.56	17.82 ± 2.75
VAT mass (g)	706.0 ± 440.9	1161.3 ± 283.7	800.2 ± 249.1
VAT volume (cm ³)	767.0 ± 479.6	1262.3 ± 308.2	869.9 ± 271.5

Table 1: Descriptive Characteristic of Study Population (Case group $n = 23$).

As shown in Table 1, the case group ($n = 23$) exhibited age-related differences in body composition among both men and women. In men, those aged 50 –< 60 years ($n = 5$) had the highest mean BMI ($27.4 \pm 1.9 \text{ kg/m}^2$) and visceral adipose tissue (VAT) mass ($1020.7 \pm 270.4 \text{ g}$), whereas the youngest (40 –< 50 yrs, $n = 2$) and oldest (60 –< 80 yrs, $n = 2$) subgroups showed lower BMI (26.1 ± 2.5 and $25.6 \pm 3.1 \text{ kg/m}^2$, respectively) and VAT mass (784.8 ± 342.3 and $710.4 \pm 195.7 \text{ g}$). Lean mass indices were relatively stable across ages (LMI ~18 kg/m^2), but the peak fat mass index (FMI) occurred in the 50 –< 60 yrs subgroup ($8.19 \pm 2.54 \text{ kg/m}^2$), indicating greater adiposity in middle-aged men (Table 1). Appendicular FMI declined with age in men- highest in the youngest subgroup ($2.83 \pm 0.81 \text{ kg/m}^2$) and lowest in the oldest ($1.09 \pm 1.07 \text{ kg/m}^2$)-whereas appendicular LMI remained around 18 kg/m^2 across all groups. Among women, middle-aged participants (50 –< 60 yrs, $n = 6$) similarly exhibited the highest BMI ($28.9 \pm 3.4 \text{ kg/m}^2$), total fat mass ($27.8 \pm 8.1 \text{ kg}$), and VAT mass ($1161.3 \pm 283.7 \text{ g}$). Younger women (40 –< 50 yrs, $n = 3$) had the lowest BMI ($25.1 \pm 2.7 \text{ kg/m}^2$) and VAT mass ($706.0 \pm 440.9 \text{ g}$), while those in the oldest bracket (60 –< 80 yrs, $n = 5$) showed intermediate values. Despite these differences, percent lean mass remained high across all female age groups (approximately 82–85%), reflecting preserved muscle compartment relative to fat (Table 1). Women's appendicular FMI peaked in the 50 –< 60 yrs category ($5.11 \pm 2.47 \text{ kg/m}^2$) and was lower in both younger and older groups, with appendicular LMI similarly uniform (16.13– 17.82 kg/m^2).

	Age (yrs)		
	40 to <50	50 to <60	60 to <80
Men			
N	3	5	7
Height (cm)	163.3 ± 8.3	169.6 ± 7.1	166.8 ± 6.7
Weight (kg)	64.2 ± 4.5	75.5 ± 18.8	73.3 ± 11.9
BMI (kg/m ²)	24.1 ± 1.1	26.0 ± 4.4	26.5 ± 4.3
FM (kg)	9.7 ± 3.4	15.3 ± 9.2	12.2 ± 6.0
LM (kg)	54.5 ± 7.9	60.2 ± 10.0	61.1 ± 7.0
%FM	15.1 ± 5.2	18.8 ± 9.6	17.8 ± 7.1
%LM	84.9 ± 5.2	81.2 ± 9.6	82.2 ± 7.1
Appendicular FMI (kg/m ²)	0.80 ± 0.34	1.05 ± 0.21	2.27 ± 1.17
FMI (kg/m ²)	3.7 ± 1.7	5.3 ± 3.1	4.1 ± 2.0
LMI (kg/m ²)	19.4 ± 2.5	20.8 ± 2.4	20.6 ± 2.4
VAT mass (g)	586.7 ± 296.0	769.4 ± 404.2	659.9 ± 360.8
VAT volume (cm ³)	637.7 ± 322.2	836.2 ± 439.3	696.7 ± 381.6
Women			
N	2	6	0
Height (cm)	153.5 ± 0.7	152.8 ± 7.6	
Weight (kg)	71.5 ± 20.5	64.4 ± 12.7	
BMI (kg/m ²)	30.3 ± 8.5	27.5 ± 4.4	
FM (kg)	21.8 ± 14.0	19.4 ± 7.9	
LM (kg)	49.7 ± 6.6	45.0 ± 5.9	
%FM	30.4 ± 8.8	29.3 ± 9.5	
%LM	69.6 ± 8.8	70.7 ± 9.5	
Appendicular FMI (kg/m ²)	4.00 ± 2.64	3.19 ± 1.67	
FMI (kg/m ²)	9.3 ± 5.8	8.3 ± 3.1	
LMI (kg/m ²)	21.6 ± 2.9	19.6 ± 1.9	
VAT mass (g)	974.0 ± 401.6	918.5 ± 290.3	
VAT volume (cm ³)	1059.0 ± 437.0	998.5 ± 315.7	

Table 2: Descriptive Characteristic of Study Population (Control group n = 23).
In table 2, the control group (n = 23) demonstrated distinct age-related trends in body composition for both sexes.

Overall

Across both sexes, the Case-group tended toward greater adiposity-particularly Visceral-fat- than controls in corresponding age brackets, while lean mass indices were broadly similar or slightly lower in cases. Moreover, appendicular FMI was consistently higher in cases (reflecting greater limb fat deposition), whereas appendicular LMI remained comparable between groups, underscoring that excess adiposity in cases extended to the appendicular compartment. These distinctions suggest that participants classified as “case” exhibited a higher tendency for fat accumulation overall and peripherally, especially in the 50 -< 60yrs range, relative to their age-matched controls.

FM parameters

Fat mass/Height² vs. age

In Case-group: (Figure 1): In T2DM analysis data, significant sex differences were found in almost all parameters, which supports the need for sex specific reference values.

- **Male:** Across ages 45 to 70 years, all FMI percentiles in the case-group men rise from age 45, peak at around age 55, and then decline by age 70. The median (50th percentile) FMI increases at 55yrs. Indicate that fat-mass relative to height in case-group men is highest in the mid-50s and decreases thereafter, with variability (spread between percentiles) greatest around age 55.
- **Female:** In the case-group women, FMI percentiles show an even more pronounced midlife peak. The lower curves likewise increase steeply between 45 and 55yrs. This pattern suggests that women in the Case-group accumulate fat more rapidly into midlife, creating wider percentile spreads at age 55, followed by a reduction in FMI in later years.

In Control-group: (Figure 2)

- **Male:** All male FMI percentiles dip slightly from age 45 to 55 and then rebound by age 70 indicating that mid-life brings a transient increase in Visceral-fat relative to height, particularly among those at the higher end of the distribution.
- **Female:** All female FMI percentiles steadily decline with age. Overall, women in the Control-group lose relative fat mass after mid-life, and the spread between leaner and fatter individuals narrows with age.

Lean Mass/Height² vs. age

In Case-group: (Figure 3)

- **Male:** Small mid-life dip from 45 to 70 lean-mass index (LMI) followed by recovery by age 70. Indicating that lean mass relative to height becomes more uniform across individuals as they age. Overall, while the highest-muscle-mass men experience a slight loss in mid-life before stabilizing, those at the lower end gain LMI, compressing variability by later years.
- **Female:** Decline from mid-40s into the mid-50s, then rebound by age 70. This pattern suggests that female lean mass relative to height dips in mid-life but recovers in older age, with the spread between leaner and more muscular individuals widening again by 70yrs.

In Control-group: (Figure 4)

- **Male:** Subtle mid-life rise in lean-mass index followed by a slight decline by age 70. This suggests that lean tissue relative to height is greatest around age 55 for the most muscular men, while those at the lower end recover some lean-mass index by later years, narrowing variability.
- **Female:** Steady decline in LMI with age. This uniform downward shift indicates that lean- mass relative to height diminishes across the board in women after mid-life, with the spread between leaner and more muscular individuals remaining relatively constant.

Fat mass ratio Android/Gynoid vs age

Case-group: Figure 5

- **Male:** Steadily increased with age across all percentiles. Indicating that men with the highest ratios experienced the greatest central fat accumulation over time. Lower percentiles (3rd and 10th) also trended upward albeit with smaller absolute changes. Overall, this pattern demonstrates an age-related shift toward a more central (android) fat distribution in men, with variability widening at older ages.
- **Female:** Increased across the lifespan but with a slightly different profile. Suggesting that even women with relatively gynoid-weighted fat distributions shifted toward more central adiposity in later life. Together, these curves highlight a clear

trend of increasing Android/Gynoid fat-mass ratio with age in both sexes, with the steepest rises seen in those at the upper end of the distribution.

Control-group: Figure 6

- **Male:** The median (50th percentile) Android/Gynoid ratio decreases slightly reflecting a small mid-life dip before partial recovery. Upper percentiles (90th, 97th) follow a downward trajectory, indicating that men with the highest central adiposity experienced the greatest relative decline. Lower percentiles (3rd, 10th) mirror this U-shaped pattern: both dip to their lowest at 55yrs. Overall, men in the Control-group show a slight redistribution away from android-dominant fat in mid-life with a trend back toward centralization at older ages, and variability in ratio narrows most around age 55.
- **Female:** Median ratio rises steadily, indicating progressive central fat accumulation over time. Upper percentiles (90th, 97th) also increase showing consistent growth in central adiposity among those with higher ratios. Lower percentiles (3rd, 10th) decrease marginally indicating a slight widening of variability as leaner individuals maintain or lose gynoid-dominant distribution. Overall, women in the Control-group exhibit a clear trend toward increasing Android/Gynoid ratio with age, reflecting a gradual shift toward central fat deposition.

Fat Mass Ratio Trunk/Limbs vs. age

Case-group: Figure 7

- **Male:** Marked increase in central (trunk) relative to peripheral (limb) fat with age, reflecting that leanest men saw a mid-life shift toward trunk fat but some limb recovery in later years. Overall, men in the Case-group accumulated trunk fat relative to limbs steadily with aging, especially at the higher end of the distribution.
- **Female:** The median trunk/limb ratio remained flat from 45 to 55yrs before rising at 70yrs, indicating relatively stable central vs. peripheral fat until older age suggesting that women with lowest ratios briefly shifted toward trunk fat at mid-

life before rebalancing. Together, these curves reveal that, although most women maintained a stable trunk/limb balance through mid-life, older age brought increased centralization of fat, particularly in those with originally higher ratios.

Control-group: Figure 8

- **Male:** Exhibit a U-shaped pattern in trunk/limb ratio. The median (50th percentile) falls then rebounds by 70yrs, indicating an initial mid-life shift toward relatively more limb fat before renewed centralization in later years. Upper percentiles (90th, 97th) decline markedly suggesting high-ratio men lose relative trunk fat through mid-life before slight regain. Overall, men show transient peripheral redistribution in mid-adulthood, followed by a shift back toward central fat deposition in older age.
- **Female:** Display a monotonic increase in the trunk/limb ratio with age. The median gradually rises at age 45 to 70, reflecting steadily increasing central fat relative to limb fat. Upper centiles (90th, 97th) climb prominently indicating substantial central fat gains among those most predisposed. Lower centiles (3rd, 10th) decrease then recover partially, suggesting a mid-life dip in centralization among leanest women but an overall upward trend later. Together, these curves highlight a progressive increase in trunk fat storage relative to limbs across female adulthood.

Limitations

Less population sample size is the main limitation in this study but this study is considered as a pilot-study to justify early age DXA-study to predict T2DM in later life, on the basis of VAT, SAT, FMI AND LMI. As there is a single center study from south India has come up the similar results in nearly all aspect but different from the other ethnic groups in world [33-37].

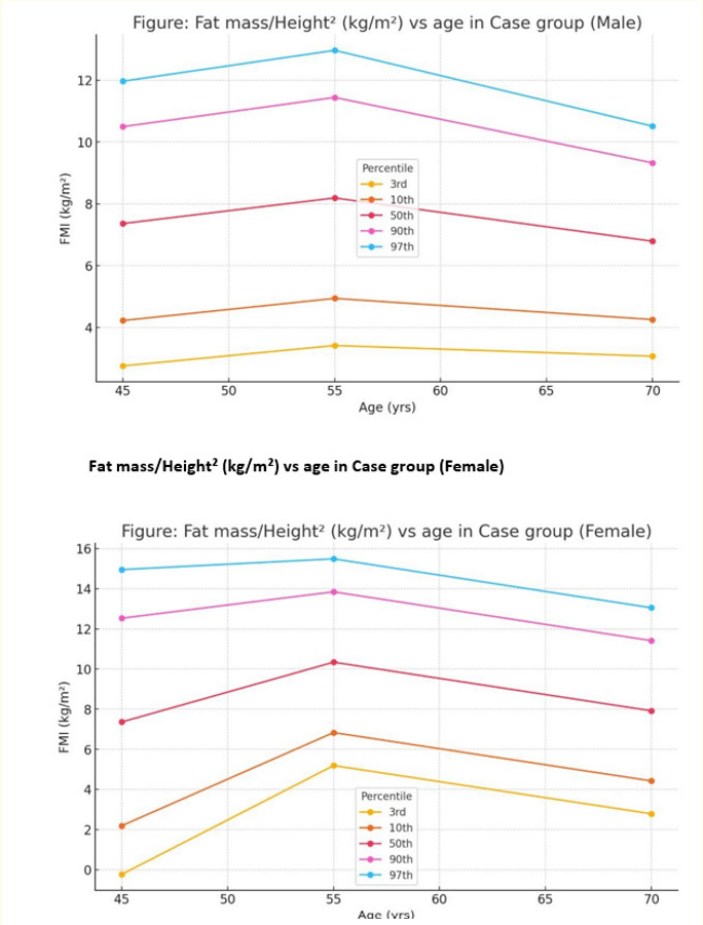
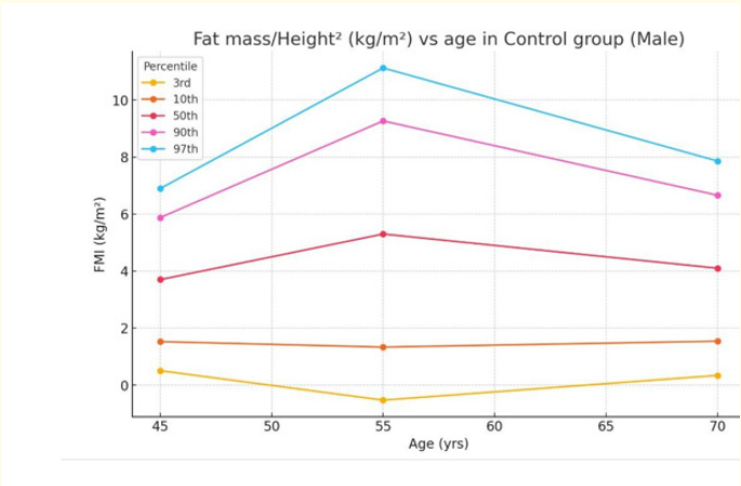


Figure 1: Fat mass/Height² (kg/m²) vs age in Case group (Male).



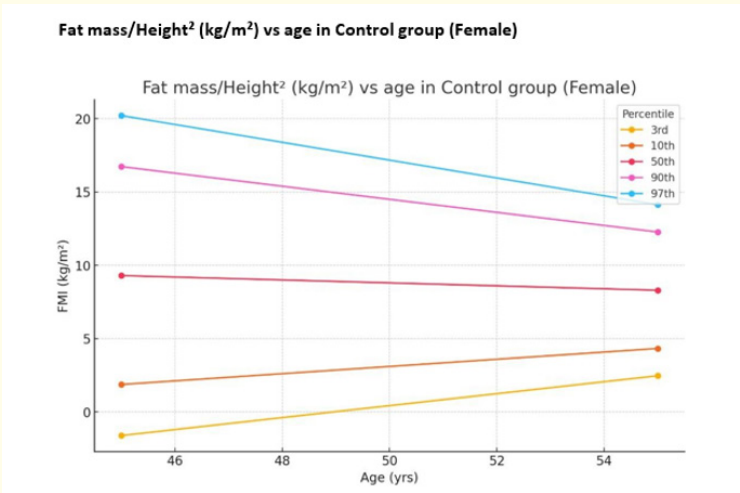


Figure 2: Fat mass/Height² (kg/m²) vs age in Control group (Male).

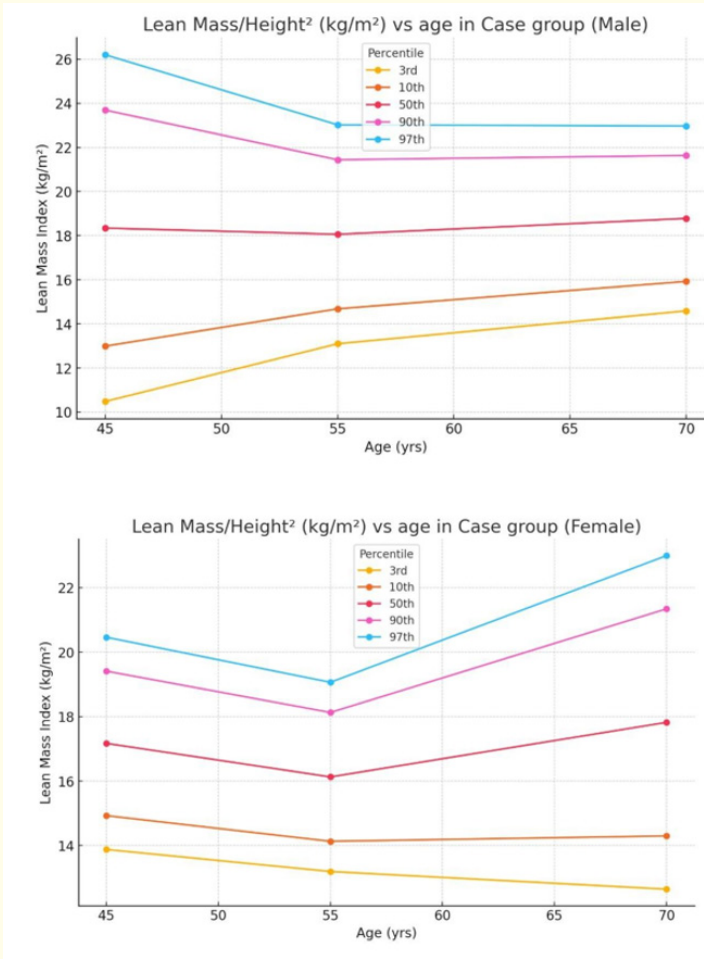


Figure 3: Lean Mass/Height² (kg/m²) vs age in Case group (Male).

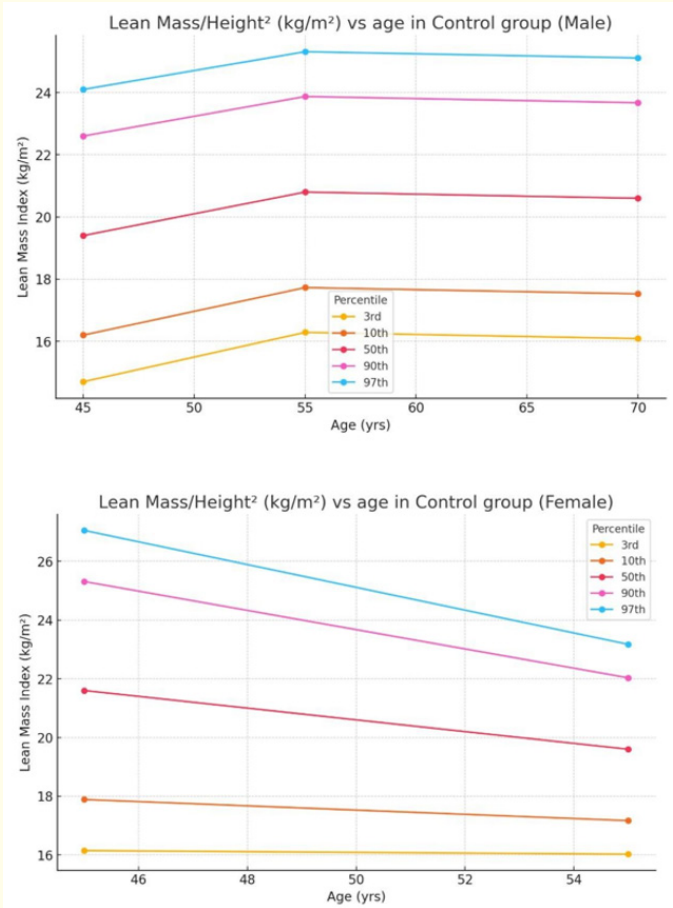
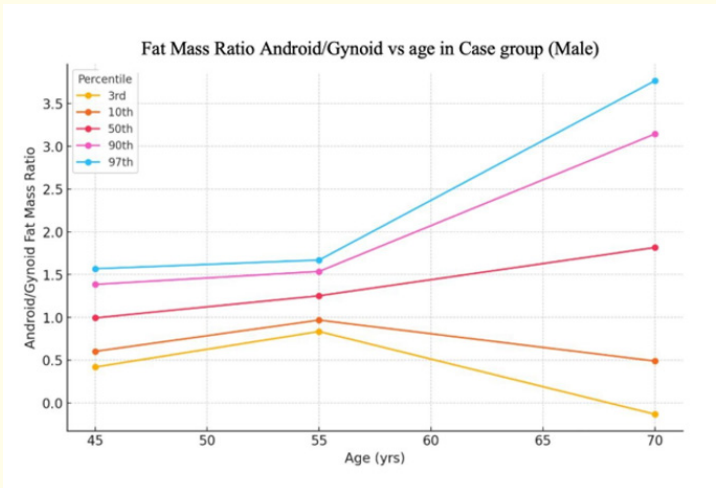


Figure 4: Lean Mass/Height² (kg/m²) vs age in Control group (Male).



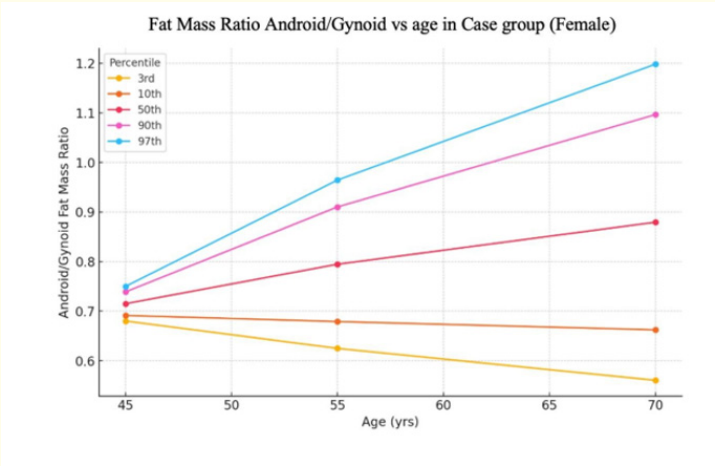


Figure 5: Fat Mass Ratio Android/Gynoid vs age in Case group.

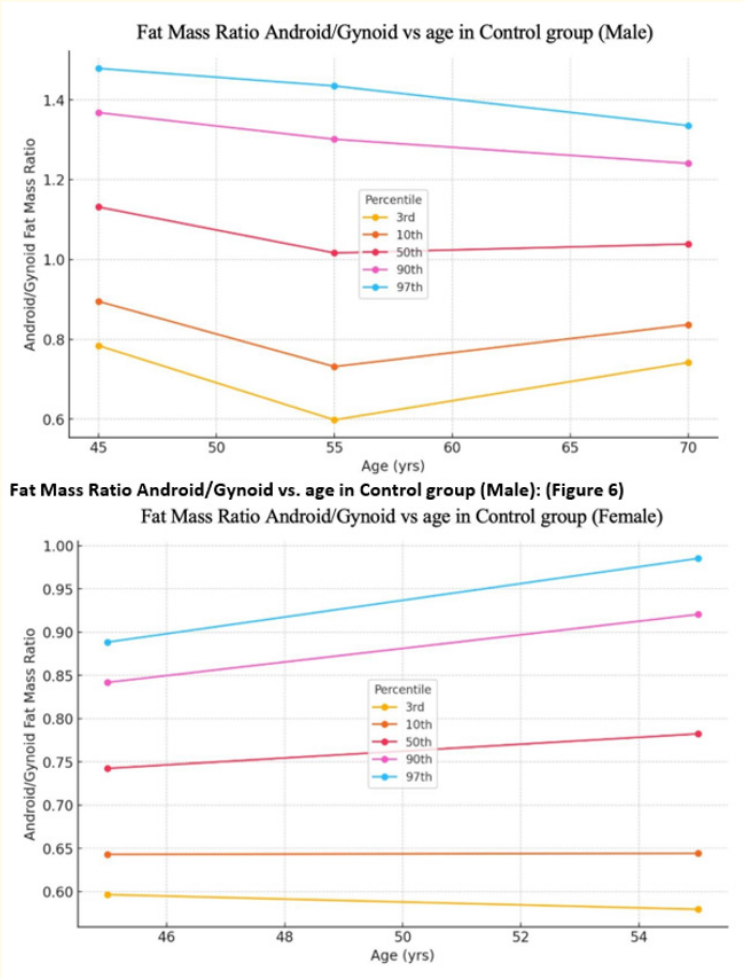


Figure 6: Fat Mass Ratio Android/Gynoid vs age in Control group.

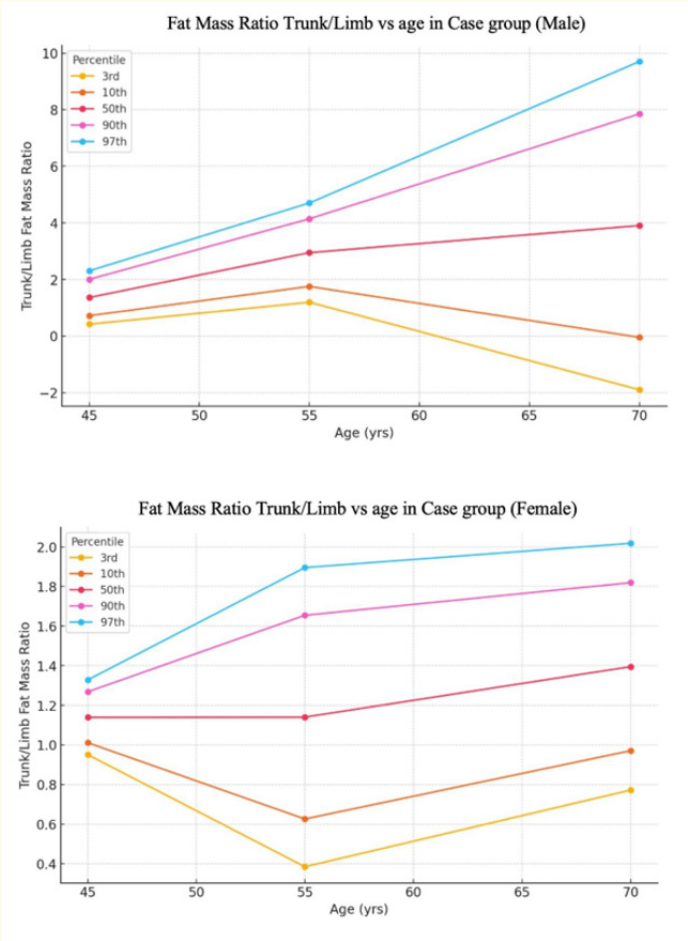
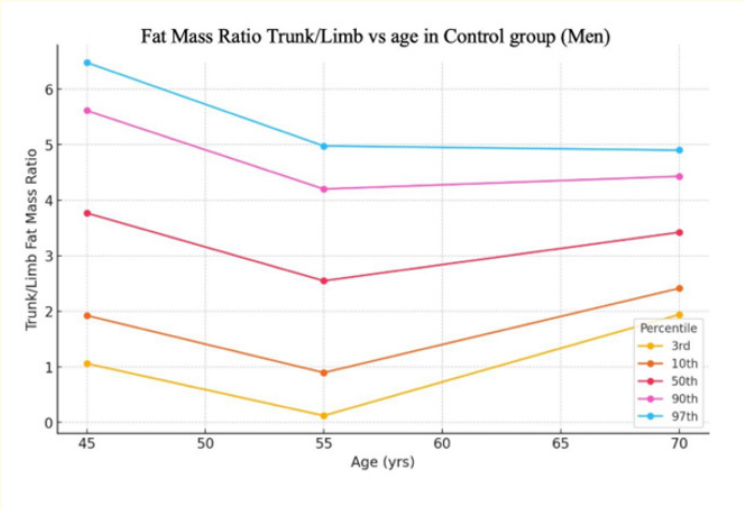


Figure 7: Fat Mass Ratio Trunk/Limbs vs age in Case group.



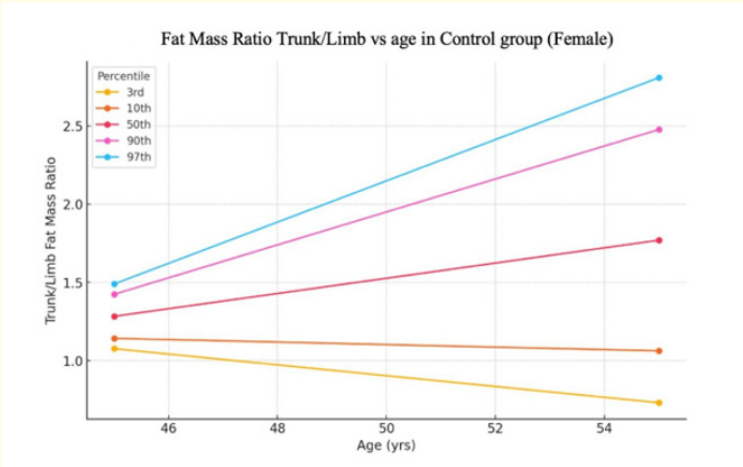


Figure 8: Fat Mass Ratio Trunk/Limbs vs age in Control group.

Conclusion

Across both sexes, the graph of case (T2DM) group behaves nearly inversely proportional to the graph of Control-group as far as FMI, LMI, FMR (A/G) and FMR (T/L) is concerned. So, we can conclude that these DXA parameters follow a thumb rule of inverse proportional between case (T2DM) and control (normal) group. The Case-group tended toward greater adiposity (VAT) than controls in corresponding age brackets, while lean mass indices were broadly similar or slightly lower in cases according to age and 55 years of age is the median cut off in both the groups. Moreover, appendicular FMI was consistently higher in cases (reflecting greater limb fat deposition), whereas appendicular LMI remained comparable between groups, underscoring that excess adiposity in cases extended to the appendicular compartment. These distinctions suggest that participants classified as “case” exhibited a higher tendency for fat accumulation overall and peripherally, especially in the 50 -< 60yrs range, relative to their age-matched controls.

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