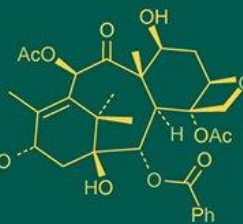
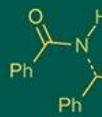


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Correlation of macronutrient distribution with body fat compartments and anthropometric markers among middle-aged adults in Chhatrapati Sambhajanagar

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Abstract

Changing food consumption patterns and increasing obesity rates require evidence specific to the context on the relationship between dietary macronutrient distribution and localized body fat deposition and general anthropometric markers in urban Indian populations. This study examines the correlation of macronutrient intake and energy distribution with body fat compartments (subcutaneous and visceral) and traditional anthropometric markers (BMI, waist circumference, and waist-hip ratio) among middle-aged adults. A cross-sectional observational study was conducted among 44 adult participants (75% male, 25% female) predominantly aged 39-58 years in Chhatrapati Sambhajanagar. Dietary data were gathered via 24-hour dietary recall and evaluated using the Indian Food Composition Tables. Statistical analyses utilized Pearson correlation coefficients, independent samples t-tests, and one-way ANOVA. The dietary profile revealed a stark skew toward high-fat, low-protein distribution compared to national guidelines (Fat $\approx$ 45.8%, Carbohydrates $\approx$ 42.1%, Protein $\approx$ 8.3%). Anthropometrically, 97.7% of the cohort fell into overweight and 100% of participants with valid data demonstrated high metabolic risk thresholds for waist-hip ratio. Pearson correlation analysis indicated that the proportion of energy from carbohydrates (%E-Carb) was strongly and positively correlated with Total Body Fat% ($r = +0.460$, $p = 0.003$) and Subcutaneous Fat ($r = +0.385$, $p = 0.014$). Conversely, fat energy proportion (%E-Fat) inversely correlated with Total Body Fat% ($r = -0.462$, $p = 0.003$) and subcutaneous fat ($r = -0.369$, $p = 0.019$). Visceral fat paradoxically correlated positively with absolute protein intake ($r = +0.316$, $p = 0.047$) and % E-Protein ($r = +0.379$, $p = 0.016$). Strikingly, global markers such as BMI, waist circumference, and WHR showed no statistically significant direct correlations with any dietary macronutrient variable ($p > 0.05$). These findings emphasise the importance of going beyond simple weight measurements to develop personalised nutrition interventions that target central obesity and metabolic syndrome.

Keywords: Macronutrients, body fat compartments, subcutaneous fat, visceral fat, anthropometry, central obesity

1. Introduction

The global burden of non-communicable diseases (NCDs) is significantly increased by obesity and related metabolic disorders, which have emerged as major public health problems. The World Health Organization, WHO, 2024^[24] reports that during the past few decades, the prevalence of overweight and obesity has significantly increased, which has led to an increase in the incidence of cardiovascular disease, type 2 diabetes, hypertension, and some types of cancer. Body composition and metabolic health have been found to be significantly influenced by dietary patterns, especially the amount and quality of macronutrient intake (Mozaffarian *et al.*, 2018; Ludwig *et al.*, 2021)^[7, 6].

Macronutrients fats, proteins, and carbohydrates—are essential for energy metabolism, controlling body weight, and fat accumulation. New research indicates that the distribution of dietary macronutrients may affect body fat composition and regional fat accumulation in addition to total body weight (Hall *et al.*, 2019)^[3]. Insulin sensitivity, appetite control, lipid metabolism, and energy expenditure can all be impacted by changes in protein, fat, and carbohydrate intake, which can have an impact on obesity-related outcomes (Hu *et al.*, 2018; Bray & Heisel, 2020)^[5, 2].

The most popular metric for determining overweight and obesity in epidemiological research is still body mass index (BMI) (WHO, 2000) ^[11]. However, BMI offers no insight into the distribution of body fat and does not differentiate between lean body mass and fat mass (Heymsfield *et al.*, 2016) ^[4]. Visceral adiposity is a better indicator of cardiometabolic risk than total adiposity, according to a growing body of studies (Ng AC, *et al.*, 2012) ^[9]. Insulin resistance, chronic inflammation, dyslipidaemia, hypertension, and an elevated risk of metabolic syndrome and cardiovascular disease are all linked to excess visceral fat (Fox *et al.*, 2007; Neeland *et al.*, 2019) ^[20, 21]. In order to evaluate central obesity and associated health risks, anthropometric measurements like waist circumference (WC) and waist-to-hip ratio (WHR) are commonly utilised (WHO, 2011) ^[11].

Among South Asian ethnicities, the importance of body fat distribution is especially clear. In comparison to Western populations, the "Asian Indian Phenotype" is defined by greater insulin resistance at lower BMI levels, higher body fat percentage, and increased abdominal adiposity (Misra & Khurana, 2008; Deepa *et al.*, 2009) ^[13, 14]. Even when traditional BMI classifications show normal or very slightly elevated body weight, this distinctive phenotype puts Indians at an increased risk of developing metabolic diseases. For an appropriate assessment of the health hazards associated with obesity in Indian communities, body fat compartments, especially visceral and subcutaneous fat, must be evaluated.

Increased consumption of energy-dense meals, refined carbohydrates, saturated fats, and processed goods, along with a decrease in physical activity, are the hallmarks of India's present rapid dietary shift (Popkin *et al.*, 2020) ^[15]. The prevalence of overweight, obesity, and metabolic syndrome among urban individuals has increased as a result of these lifestyle modifications (Luhar *et al.*, 2020) ^[16]. Despite this tendency, comparatively few research have looked at the connection between certain body fat compartments in urban Indian populations and the distribution of dietary macronutrients.

The relationship between macronutrient intake and obesity has been the subject of conflicting findings in earlier studies. While some research have found connections between dietary fat intake and changes in body composition (Astrup *et al.*, 2011) ^[1], others have linked higher carbohydrate consumption to increased body fat accumulation and obesity risk (Seidemann *et al.*, 2018) ^[17]. In a similar vein, dietary protein has been demonstrated to affect energy balance, satiety, and body composition, though its connection to visceral fat is still unclear (Leidy *et al.*, 2015) ^[18]. These discrepancies emphasise the necessity of population-specific research that takes regional food habits and metabolic traits into consideration.

Therefore, the present study aimed to examine the correlation between dietary macronutrient distribution and body fat compartments, including subcutaneous fat and visceral fat, as well as conventional anthropometric markers such as BMI, waist circumference, and waist-to-hip ratio among middle-aged adults in Chhatrapati Sambhajnagar, Maharashtra. Understanding these relationships may contribute to the development of targeted nutritional interventions for preventing obesity, central adiposity, and associated metabolic disorders in urban Indian populations.

2. Materials and Methods

2.1 Study Design and Population

This study utilized a cross-sectional observational design to explore dietary intake patterns and anthropometric measurements captured at a single point in time. Data were collected from 44 adult participants through a structured nutrition practical survey conducted in Chhatrapati Sambhajnagar. The sample included both male and female participants ranging in age from 18 to 58 years. To safeguard data integrity against metabolic confounding, individuals diagnosed with clinical disorders directly altering macronutrient metabolism, as well as pregnant or lactating women, were excluded from the study sample.

2.2 Dietary Assessment and Nutrient Conversion

Dietary behavior was quantified using the 24-hour dietary recall (24HDR) interview technique, where participants detailed all food items, snacks, and beverages consumed over the preceding 24 hours. To translate these descriptive portion sizes into precise macronutrient quantities (grams of carbohydrates, proteins, and fats), the food intake data were systematically processed using the country-specific Indian Food Composition Tables (IFCT, 2017) ^[19], published by the National Institute of Nutrition (NIN), Hyderabad ^[8]. Total energy contribution from each macronutrient was calculated using standard physiological fuel values, allowing researchers to evaluate the precise percentage energy distribution for carbohydrate (%E-C), protein (%E-P), and fat (%E-F).

2.3 Anthropometric and Compartmental Fat Measurements

Standardized, non-invasive protocols were executed to record the following metrics:

- **Weight and Height:** Captured using a calibrated electronic weighing scale and a vertical stadiometer to determine skeletal stature.
- **Body Mass Index (BMI):** Calculated via the standard equation:

$$\text{BMI} = \text{Weight (kg)} / \text{Height (m)}^2$$

Values were interpreted alongside standard World Health Organization (WHO) reference thresholds.

- **Waist Circumference (WC):** Measured with a flexible, non-stretchable tape at the horizontal midpoint between the lower rib margin and the superior border of the iliac crest, recorded to the nearest 0.1 cm.
- **Hip Circumference (HC):** Recorded at the widest horizontal aspect of the gluteal region to the nearest 0.1 cm.
- **Waist-Hip Ratio (WHR):** Derived using the formula:

$\text{WHR} = \text{Waist Circumference (cm)} / \text{Hip Circumference (cm)}$
Metabolic risk was classified using sex-specific WHO cutoff lines (≥ 0.90 for men; ≥ 0.85 for women).

- **Compartmental Fat Analysis:** Estimates for Total Body Fat Percentage (Fat%), Subcutaneous Fat, and Visceral Fat were cataloged across the dataset to serve as primary body composition outcomes.

2.4 Statistical Analysis

All data organization and statistical analyses were performed using Microsoft Excel, while analytical

procedures were cross-verified using established biomedical statistical software and platforms. Descriptive statistics are presented as Mean $\pm$ Standard Deviation (SD), along with median values and observed ranges.

To explore continuous relationships, bivariate Pearson Correlation Coefficients (r) were generated across dietary variables and body parameters, utilizing pairwise deletion to isolate missing data points seamlessly. Independent samples t -tests were implemented to evaluate structural differences between genders and across dichotomized high/low macronutrient intake tiers separated by a median split. Finally, one-way Analysis of Variance (ANOVA) was deployed to test for variations in macronutrient consumption patterns across different BMI clinical categories. Statistical significance was established *a priori* at $p < 0.05$, with highly significant markers anchored at $p < 0.01$.

3. Results

3.1 Demographic and Socioeconomic Profiling

The final analytical cohort comprised 44 adults, showing a gender distribution of 75% male ($n = 33$) and 25% female (n

$= 11$). Age distribution skewed heavily toward middle-aged profiles: 50% of participants belonged to the 49-58 years age bracket, 30% were in the 39-48 years tier, 16% were in the 29-38 years range, and 5% fell within the younger 18-28 years category.

Socioeconomic and literacy indicators revealed a highly educated sample: 68% were graduates and 16% possessed post-graduate degrees. Occupationally, the cohort was balanced between business owners (32%) and private sector employees (32%), followed by homemakers/unemployed individuals (18%), agricultural workers (11%), and public sector personnel (7%). Collectively, this occupational distribution reflects a predominantly sedentary to moderately active urban lifestyle, which strongly influences daily energy expenditure dynamics.

3.2 General Anthropometric Status and Prevalent Central Obesity

Descriptive analysis revealed an exceptionally high prevalence of excess adiposity across the study sample (Table 1).

Table 1: Descriptive Statistics of Key Anthropometric and Body Fat Parameters

Parameter	Sample (n)	Mean $\pm$ SD	Median	Minimum	Maximum
Weight (kg)	44	82.38 $\pm$ 11.69	82.25	58.40	130.00
BMI (kg/m ²)	43	31.06 $\pm$ 4.01	30.90	24.68	45.51
Waist Circumference (cm)	44	102.70 $\pm$ 6.32	103.00	90.00	122.00
Hip Circumference (cm)	43	102.91 $\pm$ 6.19	105.00	90.00	115.00
Waist-Hip Ratio (WHR)	42	0.96 $\pm$ 0.04	0.95	0.85	1.00
Total Body Fat (%)	40	37.59 $\pm$ 3.81	38.00	27.00	43.51

According to the standard WHO BMI classification, 67.4% ($n = 29$) of participants were categorized as obese (BMI ≥ 30), while 30.2% ($n = 13$) were classified as overweight (BMI 25-29.9). Only 2.3% ($n = 1$) of participants had a normal BMI profile (BMI < 25).

Analysis of waist circumference indicated that 32% of participants were within the 100-105 cm range, whereas 20% fell within the 105-110 cm category. Importantly, waist-hip ratio (WHR) assessment demonstrated that all participants with valid measurements ($n = 42$) were categorized as having high metabolic risk according to gender-specific cutoff values.

Gender-stratified comparisons performed using independent sample t -tests revealed significant structural differences between males and females (Table 2). Male participants exhibited significantly greater body weight (85.32 $\pm$ 11.53 kg vs. 73.58 $\pm$ 7.00 kg; $p = 0.003$) and larger waist circumference (103.91 $\pm$ 6.35 cm vs. 99.09 $\pm$ 4.87 cm; $p = 0.027$) compared with female participants. However, broader adiposity indicators, including BMI, WHR, and Total Body Fat%, did not differ significantly between genders, suggesting a relatively similar degree of overall adiposity across the study population.

Table 2: Body Composition Parameters by Gender (Independent Samples t -test)

Parameter	Male (($n = 33$))	Female (($n = 11$))	t -value
Weight (kg)	(85.32 $\pm$ 11.53)	(73.58 $\pm$ 7.00)	3.171
BMI (kg/m ²)	(31.28 $\pm$ 4.18)	(30.35 $\pm$ 3.47)	0.640
Waist Circumference (cm)	(103.91 $\pm$ 6.35)	(99.09 $\pm$ 4.87)	2.295
Waist-Hip Ratio (WHR)	(0.96 $\pm$ 0.04)	(0.96 $\pm$ 0.05)	0.065
Total Fat%	(37.71 $\pm$ 3.72)	(37.21 $\pm$ 4.27)	0.357

(Note: ns = not statistically significant)

3.3 Macronutrient Intake Profiles and Dietary Skew

Evaluation of the 24-hour dietary recall data demonstrated a marked deviation from the macronutrient distribution ranges recommended by the Indian Council of Medical Research (ICMR). Total daily energy intake was predominantly derived from fat, contributing approximately 45.8% of total energy intake, which exceeded the recommended range of 15-30%.

In contrast, carbohydrates contributed approximately 42.1%

of total daily energy intake, substantially lower than the recommended 55-65% range. Protein intake was also found to be inadequate, accounting for only approximately 8.3% of total energy intake compared with the recommended 10-15%.

Overall, the dietary pattern observed among participants reflected a high-fat, low-protein nutritional profile with comparatively insufficient carbohydrate contribution relative to standard dietary guidelines.

3.4 Correlational Analysis: Macronutrients vs. Fat Compartments

Bivariate Pearson Correlation testing generated a detailed

matrix mapping dietary distribution against specific physiological storage compartments (Table 3).

Table 3: Pearson Correlation Matrix Between Macronutrients and Adiposity Markers

Body Adiposity Marker	Protein (g)	Carbohydrates (g)	Fat (g)	%E-Protein	%E-Carbohydrate	%E-Fat
BMI	0.049	0.125	0.082	0.172	0.010	-0.060
Waist Circumference	0.166	0.249	0.218	0.259	0.224	-0.250
Waist-Hip Ratio (WHR)	0.208	0.126	0.196	-0.008	0.228	-0.178
Total Body Fat%	0.181	0.251	0.342*	0.261	0.460**	0.462**
Subcutaneous Fat	0.219	0.341*	0.341*	0.220	0.385*	-0.369*
Visceral Fat	0.097	0.316*	0.184	0.379*	0.250	-0.306

(Note: * $p < 0.05$ significant cells; $p < 0.01$ highly significant cells).

Isolation of the statistically significant correlations revealed several key relationships (Table 4):

Table 4: Deconstruction of Significant Dietary and Compartmental Relationships

Variable 1	Variable 2	r-value	p-value	Significance	Clinical Directional Interpretation
Total Fat%	%E-Carbohydrate	+ 0.460	0.003	Highly Sig (**)	Expanding carbohydrate energy shares correlates with elevated total body fat.
Total Fat%	%E-Fat	-0.462	0.003	Highly Sig (**)	Higher relative fat energy shares maps to lowered body fat metrics via carbohydrate displacement.
Subcutaneous Fat	Carbohydrates (g/d)	+ 0.341	0.031	Significant (*)	Elevated mass intake of carbohydrates tracks with expanded subcutaneous deposition.
Subcutaneous Fat	%E-Carbohydrate	+ 0.385	0.014	Significant (*)	Increasing carbohydrate energy share shifts fat storage into subcutaneous tissue.
Subcutaneous Fat	%E-Fat	-0.369	0.019	Significant (*)	Increasing relative fat energy share tracks with a reduction in subcutaneous fat.
Visceral Fat	Protein (g/d)	+ 0.316	0.047	Significant (*)	Absolute protein intake quantities covary directly with visceral compartment fat.
Visceral Fat	%E-Protein	+ 0.379	0.016	Significant (*)	Elevated relative protein energy percentage links to increased visceral fat mass.

Traditional external anthropometric markers—specifically BMI, Waist Circumference, and WHR—demonstrated no statistically significant correlation with any absolute or relative macronutrient variable ($p > 0.05$).

Furthermore, when partitioning the sample into High vs. Low intake groups using a median split, independent samples t-tests confirmed that no macronutrient category could differentiate or produce a statistically significant change in standard BMI, WC, or WHR values (all $p > 0.05$). Similarly, running a one-way ANOVA across distinct BMI classes (Normal vs. Overweight vs. Obese) showed that mean consumption patterns of total Energy ($p = 0.508$), Carbohydrates ($p = 0.327$), Protein ($p = 0.382$), and Fats ($p = 0.941$) remained statistically uniform across all weight groups.

4. Discussion

4.1 The Anthropometric Paradox and Ceiling Effects

The anthropometric data collected from this urban cohort in Chhatrapati Sambhajinagar reveals a widespread public health challenge: an alarming 97.7% of the sample fell into either overweight or obese categories. This clustering mirrors findings from large-scale national epidemiologic surveys, such as the *ICMR-INDIAB* and *NFHS-5* studies, which document a rising prevalence of obesity among middle-aged urban Indians.

A particularly striking finding was that 100% of the participants presented with high-risk waist-hip ratios, confirming widespread central adiposity. This uniform inflation of WHR values introduces a statistical phenomenon known as a ceiling effect. When an entire study population exhibits universally high-risk central

obesity metrics, cross-sectional variations in dietary habits cannot generate statistically significant differences or correlations with these markers. This dynamic explains why traditional external markers like BMI, waist circumference, and WHR failed to show direct correlation with dietary intake variables in this cohort, highlighting that tracking superficial weight metrics alone can obscure more nuanced internal metabolic alterations.

4.2 Carbohydrate Overloading and Compartmental Fat Partitioning

While external anthropometric markers remained statistically unaffected, internal body fat compartments showed strong, significant correlations with dietary energy distribution. The highly significant positive correlation between %E-Carbohydrate and Total Body Fat% ($r = +0.460$, $p = 0.003$), alongside its positive link to Subcutaneous Fat ($r = +0.385$, $p = 0.014$), provides clear clinical evidence supporting the Carbohydrate-Insulin Model of Obesity.

According to this model, diets high in rapidly digestible, low-quality carbohydrates typical of urban Indian food patterns dominated by polished cereals and refined wheat trigger sustained postprandial insulin spikes. Insulin acts as a potent driver of lipogenesis, actively directing circulating energy substrates away from metabolic oxidation in lean tissues and channeling them directly into adipose tissue storage.

The inverse relationships observed between %E-Fat and both Total Body Fat ($r = -0.462$) and Subcutaneous Fat ($r = -0.369$) further support the carbohydrate displacement hypothesis. In this specific cohort, a higher relative energy

share from fats corresponds to a reduction in total carbohydrate load. This shift lowers systemic lipogenic insulin stimulation, slowing down fat accumulation pathways.

4.3 Suboptimal Protein Intake and Visceral Fat Confounding

The dietary data also highlighted a clear nutritional imbalance: a mean protein energy contribution of just 8.3%, which falls substantially below national health recommendations. This sub-perceptual protein intake can trigger a biological mechanism known as the Protein Leverage Hypothesis. This hypothesis suggests that humans possess a strong appetite drive to meet specific protein targets. When dietary protein density is low as observed in carbohydrate-heavy, cereal-based food cultures individuals often unconsciously overconsume total energy in an effort to reach their physiological protein requirements, directly promoting weight gain.

Paradoxically, the data revealed significant positive correlations between absolute protein intake ($r = +0.316$), %E-Protein ($r = +0.379$), and visceral fat deposition. While higher protein intake is traditionally associated with beneficial changes in lean mass and improved satiety, this unexpected positive link to visceral fat likely stems from confounding dietary habits rather than a direct cause-and-effect relationship. In urban Indian settings, individuals with higher protein intake often consume it alongside energy-dense, ultra-processed savory snacks or fried foods. This means the apparent link between protein and visceral fat may actually be driven by the high-fat, high-calorie food matrices in which that protein is consumed, a pattern that warrants deeper longitudinal investigation.

Overall, these findings demonstrate that obesity and central adiposity within the Asian Indian phenotype are driven by a complex mix of lifestyle factors. Reliance on superficial parameters like BMI or weight categories fails to capture these underlying metabolic realities. To effectively address these health challenges, public health interventions must prioritize improving carbohydrate quality, increasing dietary protein density, and reducing the consumption of refined grains.

5. Conclusion

The results of this study show that middle-aged adults in Chhatrapati Sambhajnagar have a serious public health risk. 97.7% of participants were classified as overweight or obese, indicating an extraordinarily high prevalence of excess body weight. Additionally, all participants with appropriate measures showed waist-hip ratios suggestive of central adiposity and heightened metabolic risk. The results of the dietary assessment showed a significant imbalance in the distribution of macronutrients, with a high contribution of fat (45.8%) and carbohydrates to total energy intake and a low consumption of protein (about 8.3%), significantly departing from national dietary recommendations.

The distribution of dietary macronutrients was found to be more significantly correlated with particular body fat compartments than with traditional anthropometric measures, according to correlation analysis. Higher percentages of energy derived from carbohydrates (%E-Carb) were positively and significantly correlated with both subcutaneous fat accumulation ($p = 0.014$) and total body fat percentage ($p = 0.003$), indicating the possible involvement

of metabolic pathways driven by carbohydrates in the deposition of adipose tissue. Conversely, there were no statistically significant relationships found between individual macronutrient consumption factors and conventional anthropometric measures like body mass index (BMI), waist circumference, or waist-hip ratio. These results suggest that changes in compartmental fat storage and body fat composition may take place independently of changes identified by traditional weight-based assessments. Therefore, rather than depending solely on standard anthropometric measures, measurement of body fat compartments may offer a more sensitive and informative method for assessing the impact of food patterns on obesity-related health risks.

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8. Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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