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Original Research

Exploring diversity in Non-Alcoholic Fatty Liver Disease (NAFLD) among lean, overweight, and obese patients: A Multicenter study from India.

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Abstract

Background: One common chronic liver illness is non-alcoholic fatty liver disease (NAFLD) affecting individuals across various body weights. Traditionally associated with obesity, NAFLD is now increasingly observed in overweight and lean individuals as well. This research investigates the clinical, metabolic, dietary pattern, and socio-demographic differences of NAFLD in lean, overweight, and obese individuals across various centers in two Indian states.

Methodology: Conducted as a cross-sectional observational study with 154 NAFLD patients aged 18-65 years across four centers [Odisha (OD) -3; Uttar Pradesh (UP) -1], the research utilized a self-administered questionnaire to gather socio-economic, biochemical, and clinical data. Data analysis involved Chi-square tests at a 0.05 significance level. Trail Registration: CTRI/2024/04/065699.

Result: The majority of NAFLD cases were found in obese patients (37.01% in Odisha and 35.06% in UP). Overweight NAFLD was more common in UP (10.39%), while lean NAFLD was more prevalent in Odisha (7.14%). Obesity was significantly associated with diabetes in both states (p=0.020). Constipation was notable in overweight and obese groups (p=0.001 and p=0.027), and bloating was more frequent in overweight individuals (p=0.064). Loss of appetite was significant among lean NAFLD patients. Biochemical parameters and food consumption across ten food groups showed no significant variation.

Conclusion: Overall, NAFLD was more common among obese patients, highlighting the need for tailored dietary interventions based on body type.

Keywords: Dyslipidemia; Diabetes; NAFLD; India; Diversity; Lean.

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Introduction

Non-alcoholic fatty Liver Disease (NAFLD) is a rapidly growing global public health problem that includes a range of liver diseases marked by excessive fat deposition without a strong alcohol intake history approaching 30%. Though historically it is linked to obesity, the primary cause of NAFLD is changing, revealing a range of phenotypes that impact people in different body weight ranges. Previous studies have underscored the risk factors associated with NAFLD in India, including obesity, elevated fasting blood sugar, and dyslipidemia, all of which are correlated with metabolic syndrome Obesity, particularly central obesity, has been identified as a significant risk factor for NAFLD in the Indian population, with a higher prevalence of central obesity among Asians compared to Western populations, even at lower Body Mass Index (BMI) levels High levels of fasting blood sugar, serum glutamate pyruvate transaminase (SGPT), triglycerides, and very low-density lipoprotein (VLDL) are also significantly associated with NAFLD in India. [1] [2]

The prevalence of NAFLD varies across different regions of India (16-32%), with higher rates observed in eastern coastal areas compared to northern central regions. Factors such as obesity and metabolic syndrome (MeS) contribute significantly to the higher prevalence in the eastern coastal regions[3, 4]. Some regional studies in South Asian countries report even higher rates up to 49.8% of prevalence, indicating a significant public health concern[5]. Thus, understanding the regional variations in NAFLD prevalence and identifying the underlying factors contributing to these differences is crucial for developing targeted interventions. Interestingly, overweight individuals constitute a notable portion of NAFLD cases, approximately one in five. Among these patients, those with MeS tend to experience more severe liver issues [6].

Lean NAFLD is defined as NAFLD in individuals with a BMI between 18.5 and 22.9 kg/m², overweight NAFLD refers to overweight individuals with a BMI between 23-25 kg/m^2 in Asians and Obese NAFLD Individuals with a BMI >25 kg/m^2. Those patients are more likely to have severe forms of the disease and are often associated with other metabolic conditions such as diabetes, hypertension, and dyslipidemia [7, 8].

The objective of this study was to explore the clinical, metabolic, and socio-demographic variations of NAFLD in lean, overweight, and obese individuals in various centers of two different states of India, and to determine the major factors that affect disease progression and severity in each phenotype. Also, this study was designed to provide comprehensive insights into the dietary patterns of NAFLD patients, which could potentially inform the development of targeted dietary interventions for NAFLD management.

Methods

Research Design & Study Setting: This study was a hospital-based **cross-sectional study**, conducted across four multispecialty hospitals located in two Indian states (three in Odisha and one in Uttar Pradesh) from 16th April to 20th July 2024.

Inclusion Criteria: Adult age group (18-65yrs); Diagnosed case of NAFLD by physicians. And Patients with informed consent.

Exclusion Criteria: NAFLD patients having Cirrhosis/ hepatocellular carcinoma (HCC); Pregnant and lactating women; People with other causes of liver diseases (Alcoholic, Viral, Genetic, Hepatic viruses A-E, etc.); Patients consuming alcohol more than 20g/day (male) and 10g/day (female) and Those on drugs (Metformin, Tamoxifen, amiodarone, Methotrexate, Glitazones).

Sample Size: The study aimed to enroll a diverse sample of NAFLD patients (n = 154), with 78 individuals from Odisha and 76 from UP. Therefore, the sample size was based on the projected prevalence of NAFLD in the OPDs and the average weekly patient flow during the 3-month recruitment period. This pragmatic decision ensured that the sample adequately represented the range of NAFLD presentations encountered in real-world clinical practice across multiple centers in India.

Questionnaire Development: A custom-designed questionnaire was developed in consultation with experts in Hepatology, Food and Nutrition, and Statistics, and subsequently, it was pilot-tested (n=46) to evaluate its reliability, leading to further adjustments. The revised questionnaire was employed for the main data collection and was divided into six segments:
Demographic Characteristics, including age, gender, marital status, family type, income, and education level, were collected.

Anthropometric Measurements: Anthropometric data were recorded, encompassing height, weight, waist circumference (WC), hip circumference (HC), and abdominal circumference (AC). Weight was determined to the nearest 0.1 kg using a calibrated digital scale, with participants dressed in light clothing and without footwear. Height was recorded with a portable stadiometer, ensuring that the participant was standing straight with heels together and head aligned in the Frankfort horizontal plane. WC, HC, and AC were measured with a flexible, non-stretchable tape measure, adhering to standardized protocols from WHO: WC was taken at the midpoint between the lower rib margin and the iliac crest; HC at the widest section of the hips; and AC at the level of the belly button. Each measurement was conducted twice, and the average value was utilized for analysis. All measurements were carried out by trained personnel in the outpatient departments (OPD) of public hospitals to ensure consistency.

Biochemical Assessments: A series of biochemical tests, including complete blood count (CBC) reports, lipid profiles, blood sugar levels (both fasting and postprandial), HbA1C, liver function tests- Alanine Aminotransferase (ALT/SGPT), Aspartate Aminotransferase (AST/SGOT), and fibroscan assessments were conducted. Additionally, C-reactive protein (CRP) levels, serum fasting insulin levels, and ultrasound sonography (USG) reports were obtained from the patients.

Comorbidities and Clinical Symptoms: Information was collected on symptoms such as fatigue, bloating, abdominal pain, and stool type like Normal defecation: indicating regular and satisfactory defecation without discomfort (normal bowel movement), or Constipation: indicating a frequent sensation of incomplete emptying or unsatisfactory defecation/ hard stool and comorbidities like diabetes, hypertension, thyroid, and dyspepsia.

Dietary Assessments: Food frequency questionnaires (FFQs) were used to assess dietary consumption.
Lifestyle Factors: Physical activity levels, smoking status, and alcohol consumption were also recorded.

Data Collection: Before data collection, patients consulted a gastroenterologist at the OPD. Only those diagnosed with NAFLD and who met the inclusion criteria were included in the study. After obtaining informed consent, a trained interviewer collected data using the questionnaire. Anthropometric measurements were collected in the OPD with standardized procedures using calibrated instruments. Waist-hip ratio (WHR) and BMI were calculated. All measurements were taken twice for accuracy. Dietary intake was assessed using FFQs wherein participants were asked to recall their food intake over the past month. After that, as per Asian BMI cut-offs (WHO, 2004), NAFLD cases were categorized among three BMI-based categories: lean NAFLD (BMI 18.5-22.9 kg/m^2), overweight NAFLD (BMI 23-24.9 kg/m^2), and obese NAFLD (BMI ≥25 kg/m^2).

Data Analysis: Data was analyzed using the Statistical Package for Social Sciences (SPSS Version 23.0) software. For Categorical variables (gender, age, education, dietary habit, socioeconomic status, clinical

parameters, etc.) Descriptive statistics were calculated and summarized in frequency (%), whereas, for continuous variables (Blood parameters, Income, age, etc.), mean ±Standard Deviation was used. Pearson's Chi-square test and Kruskal-Wallis H test were used to compare data among three distinct body types of NAFLD patients. An alpha level of $p< 0.005$ was selected to determine statistical significance.

Ethical Approval and Trial registration: The study protocol was approved by the Ethics Committee of the Institute of Science, Banaras Hindu University (I.SC./ECM-XVI/2023-24) with trial registration number CTRI/2024/04/065699.

Results

Data were analyzed thoroughly from different perspectives of the patients (N=154) and interpreted:
Table 1 below presents the demographic characteristics of NAFLD patients categorized by body type (lean, overweight, and obese) across two states, Odisha and Uttar Pradesh. Variables compared include marital status, gender distribution, education level, type of physical activity, family structure, residential area, and dietary preferences. This comparison provides insight into the socio-demographic patterns associated with different NAFLD phenotypes and highlights regional variations. Key factors such as physical inactivity and dietary habits are also explored to assess potential lifestyle influences on disease prevalence.

Table 1: Socio-Demographic Characteristics of Lean, Overweight, and Obese NAFLD Patients in Odisha and Uttar Pradesh (N=154)

Demographic Characteristics		Lean NAFLD (N)%		*p*-value	Overweight NAFLD (N)%		*p*-Value	Obese NAFLD(ON) (N)%		*p*-value
		Odisha	UP*		Odisha	UP*		Odisha	UP*	
Marital status	Married	(10)90.9	(05)83.3	0.643	(10)100	(14)87.5	0.245	(51)89.5	(40)74.1	**0.035**
	Unmarried	(01)9.1	(01)16.7%		0	(02)12.5		(06)10.5	(14)25.9	
Gender	Male	(09)81.8	(04)66.7%	0.482	(08)80	(10)62.5	0.347	(34)59.6	(45)83.3	**0.006**
	Female	(02)18.2	(02)33.3%		(02)20	(06)37.5		(23)40.4	(09)16.7	
Education	Primary	0	0	**0.027**	0	(01)6.3	0.087	(05)8.8	0	0.059
	Secondary	(08)72.7	(01)16.7		(04)40	(01)6.3		(18)31.6%	(23)42.6	
	Tertiary	(03)27.3	(05)83.3		(06)60	(14)87.5		(34)59.6	(31)57.4	
Types of activity	Sedentary	(09)81.8	(06)100	0.266	(09)90	(15)93.8	0.727	(52)91.2	(41)75.9	0.029
	Moderate	(02)18	0		(01)10	(01)6.3		(05)8.8	(13)24.1	
Types of Family	Nuclear	(10)91	(04)66.7	0.210	(09)90	(10)62.5	0.124	(56)98.2	(36)66.7	**0.000**
	Joint	(01)9.1	(02)33.3		(01)10	(06)37.5		(01)1.8	(18)33.3	
Area	Rural	(06)54.5	(03)50	0.370	(02)20	(06)37.5	0.585	(13)22.8	(21)38.9	0.096

	Semi- urban	(05)45.5	(02)33.3		(04)40	(04)25		(25)43.9	(23)42.6	
	Urban	0	(01)16.7		(04)40	(06)37.5		(19)33.3	(10)18.5	
Dietary Preference	Vegetarian	0	(03)50	**0.010**	0	(08)50	**0.007**	(06)10.5	(08)14.8	0.496
	Non- vegetarian	(11)100	(03)50		(10)100	(08)50		(57)100	(46)85.2	

*UP- Uttar Pradesh

Table 1 shows that married individuals in all NAFLD groups were in higher proportion across both states, with a significant difference in the obese NAFLD group (p = 0.0035). Gender distribution showed a statistically significant difference in male predominance in all groups. The obese NAFLD group (p = 0.006), where males were more prevalent in Uttar Pradesh (83.3%) compared to Odisha (59.6%), was observed in the current study. In terms of educational levels, tertiary education was more common in obese NAFLD patients in both states; however, primary education was negligible ($p < 0.001$ in all groups). A predominantly sedentary lifestyle was observed in all groups, with significant differences in the obese NAFLD group (p = 0.029). The nuclear families were predominant in Odisha, especially in obese NAFLD patients (98.2%), while joint families were more common in Uttar Pradesh ($p < 0.001$), in stark contrast. Rural and semi-urban areas were the major contributors to lean NAFLD cases, whereas obese NAFLD patients were more frequently from semi-urban and urban areas (p = 0.096). The dietary pattern showed statistical significance in lean and overweight NAFLD groups, with vegetarianism being more prevalent in Uttar Pradesh compared to Odisha ($p < 0.01$). Non-vegetarian diets were predominant among obese NAFLD patients across both regions (p = 0.496) (Table 1).

Table 2 below describes the anthropometric characteristics of NAFLD patients who fall into the lean, overweight, and obese groups. The waist-hip ratio (WHR), waist circumference (WC), hip circumference (HC), abdominal circumference (AC), height, weight, age, and BMI are important factors that are compared. Weight, BMI, and circumferential measurements demonstrate notable patterns across rising body size categories, highlighting the physical and body composition variations across the groups.

Table 2: Comparison of Anthropometric Measures among NAFLD Patients by Body Type (N=154)

Characteristics			**Lean NAFLD**	**Overweight NAFLD**	**Obese NAFLD**	***p*-value**
			(Mean ± S.D.)			
Age			38.64 ± 12.70	38.57 ± 9.78	40.52 ± 10.69	0.642
Height (In c.m.)			165.75 ± 7.66	167.11 ± 8.99	161.98 ± 8.40	**0.026**
Weight (In k.g)			59.11 ± 6.83	67.24 ± 7.17	76.51 ± 10.10	**0.000**
BMI*			21.46 ± 0.97	24.04 ± 0.68	29.28 ± 3.59	**0.000**
WC†	**(In c.m.)**		35.81± 2.45	36.70 ± 1.74	40.17 ± 3.22	**0.000**
HC‡			36.85 ± 1.53	37.75 ± 2.22	40.88 ± 3.02	**0.000**
AC§			35.43 ± 3.29	37.24 ± 1.91	40.44 ± 3.28	**0.000**
WHR‖			0.96 ± 0.05	0.97 ± 0.04	0.97 ± 0.05	0.935

*BMI-Body Mass Index, WC-waist circumference, ‡HC- hip circumference, §AC- Abdominal circumference, ||WHR- Waist Hip ratio.

Table 2 shows weight, BMI, WC, HC, and AC all gradually increased from lean to obese people ($p < 0.05$), highlighting variations in features between the Lean, overweight, and Obese NAFLD groups. However, there were no notable differences in age or waist-to-hip ratio (WHR) between the groups. Given that greater BMI and central obesity (as measured by WC and AC) are significantly linked to the advancement of NAFLD because of increased fat deposition in the liver and systemic metabolic dysfunction, the observed differences may be explained by the degree of adiposity. While the overweight group most likely represents moderate adiposity and lifestyle factors leading to liver fat accumulation without overt obesity, lean NAFLD may be caused by genetic susceptibility, ectopic fat deposition, or poor metabolic control. The greatest adiposity is seen in the obese group, which may contribute to more severe inflammation and metabolic abnormalities.

The prevalence of metabolic and gastrointestinal symptoms among NAFLD patients differed across BMI categories, as shown in Table 3.

Table 3: Comparison of Comorbidities and Gastrointestinal Symptoms in NAFLD Patients across Body Types and Regions (N=154)

Characteristics		**Lean NAFLD** (N)%		***p*-Value**	**Overweight NAFLD** (N)%		***p*-*Value***	**Obese NAFLD** (N)%		***p*-value**
		Odisha	**UP**		**Odisha**	**UP**		**Odisha**	**UP**	
Diabetes Mellitus	Yes	(03)27.3	0	0.515	(04)40	(02)12.5	0.163	(14)24.6	(04)7.4	**0.020**
	No	(08)72.7	(06)100		(06)60	(14)87.5		(43)75.4	(50)92.6	
Hypertension	Yes	(01)9.1	0	1.0	(02)20	0	0.138	(14)24.6	(10)18.5	0.495
	No	(10)90.9	(06)100		(08)80	(16)100		(43)75.4	(44)81.5	
Dyslipidemia	Yes	(03)27.3	(01)16.7	1.0	(05)50	(06)37.5	0.689	(21)36.8	(18)33.3	0.843
	No	(08)72.7	(05)83.3		(05)50	(10)62.5		(36)63.2	(36)66.7	
Stools	Normal	(04)36.4	(02)33.3	0.493	(01)10	(09)56.3	**0.001**	(30)52.6	(30)55.6	**0.027**
	Constipated	(07)63.6	(04)66.7		(09)90	(07)43.8		(27)47.4	(24)44.5	
Fatigue	Yes	(08)72.7	(04)66.7	0.793	(07)70	(09)56.3	0.483	(33)57.9	(38)70.4	0.171
	No	(03)27.3	(02)33.3		(03)30	(07)43.8		(24)42.1	(16)29.6	
Abdominal pain	Yes	(07)63.6	(03)50	0.585	(04)40	(07)43.8	0.435	(29)51	(23)42.6	0.382
	No	(04)36.4	(03)50		(05)50	(09)56.3		(28)49.1	(31)57.4	
Bloating/ Gas	Yes	(09)81.8	(04)66.7	0.624	(07)70	(06)50	**0.064**	(44)77.2	(38)70.4	0.686
	No	(02)18.2	(02)33.3		(03)30	(10)62.5		(13)22.8	(16)29.6	
Dyspepsia	Yes	(05)45.5	(01)16.7	0.235	(03)30	(07)43.8	0.483	(13)22.8	(18)33.3	0.217

	No	(06)54.5	(05)83.3		(07)70	(09)56.3		(44)77.2	(36)66.7	
Loss of Appetite	Yes	(03)27.3	(05)83.3	**0.027**	(4)40	(03)18.8	0.235	(14)24.6	(20)37	0.154
	No	(08)72.7	(01)16.7		(06)60	(13)81.3		(43)75.4	(34)63	

Table 3 illustrates the prevalence of comorbidities and symptoms among the Lean, Non-Obese, and Obese NAFLD categories in Odisha and Uttar Pradesh is shown in this table. Diabetes incidence increased from lean to obese NAFLD patients over time, with a substantially greater prevalence among obese Odisha residents (24.6%) than in Uttar Pradesh (7.4%, p = 0.020). Although there were no notable geographical differences, the obese group had a higher prevalence of hypertension. There were no appreciable differences in the frequency of dyslipidemia between groups or geographical areas. Among symptoms, obese people from Odisha (52.6%) had substantially greater stool clarity than those from UP (44.5%, p = 0.027). There were no appreciable variations in the prevalence of fatigue and stomach discomfort reported across all categories and geographical areas. Although this difference was not statistically significant, bloating and gas were also common but somewhat less common in UP overweight people. Lean people in UP experienced a much greater rate of appetite loss (83.3%) than those in Odisha (27.3%, p = 0.027). These results imply that certain symptoms, such as appetite loss and stool clarity, and comorbidities like diabetes differ by area and obesity status, possibly due to lifestyle and environmental variables.

Table 4 presents the biochemical and liver function parameters among lean, overweight, and obese NAFLD patients from Odisha and Uttar Pradesh. The table compares key metabolic markers, including SGOT, SGPT, HDL, LDL, triglycerides (TG), total cholesterol (TC), and liver size, across different BMI categories.

Table 4: Comparison of Liver Enzymes, Lipid Profile, and Liver Size in Lean, Overweight, and Obese NAFLD Patients (N=154)

Characteristics	Lean (Mean ± S.D.)		*p* Value	Overweight (Mean ± S.D.)		*p* Value	Obese (Mean ± S.D.)		*p* Value
	OD	UP		OD	UP		OD	UP	
SGOT*	42.18±49.31	35.05±7.50	0.784	43.16± 36.95	54.18±22.21	0.461	36.53±35.19	50.78±25.26	0.063
SGPT†	36.90± 34.82	50.40±16.39	0.486	47.42 ±23.11	65.68± 34.09	0.213	56.40±85.36	68.16 ±47.74	0.492
HDL§	41.26±3.73	41.95±0.91	0.816	41.14±5.89	45.36±11.82	0.372	42.24±11.76	41.29±12.41	0.803
LDL‖	93.98±11.96	159.45±6.29	**0.001**	13.66±31.75	109.99±48.61	0.866	102±44.76	120.64±43.10	0.212
TC**	172.12±25.76	197 ±0.98	0.253	184.15±41.54	189.68±46.51	0.813	191.87±46.13	178.18±43.70	0.345
TG‡	188.60±102.88	206.95±60.59	0.828	232.85±168.70	214.48±96.94	0.814	239.48±215.93	196.32±93.12	0.383
VLDL¶	36.88±19.11	41.40±12.16	0.775	33.52±12.11	42.89±19.38	0.311	52.30±46.14	37.54±19.77	0.245
Liver Size	13.99±1.1	15.64 ±1.73	0.062	14.90 ±2.25	14.61 ±1.23	0.788	14.01±1.75	16.06 ±3.73	**0.008**

*SGOT- Serum Glutamic Oxaloacetic Transaminase, † SGPT- Serum glutamic pyruvic transaminase, §HDL- high density lipoprotein, ‖LDL- Low density lipoprotein,**TC-Total Cholesterol, ‡TG-Triglyceride, ¶VLDL- Very low-density lipoprotein, , S.D.-Standard Deviation.

The analysis shows (Table- 4), the biochemical and clinical characteristics of lean, overweight, and obese NAFLD patients in Odisha (OD) and Uttar Pradesh (UP) are contrasted in this table. Even though SGPT levels were marginally higher in overweight and obese people from Uttar Pradesh than in Odisha, liver enzymes (SGOT and SGPT) did not significantly differ across groups. Regarding the lipid profile, thin NAFLD patients from UP had substantially higher LDL levels than those from Odisha ($p = 0.001$), however, HDL values were constant across groups and geographical areas. Although there was modest variance in the levels of total cholesterol (TC), triglycerides (TG), and VLDL especially greater TG levels in obese groups—these variations were not statistically significant.

Figure 1 illustrates the dietary consumption habits of NAFLD patients from Uttar Pradesh, highlighting how often they consume various food groups, including meat, nuts/seeds, dairy products, beverages, vegetables, vegetables, legumes, and green leafy vegetables (GLVs). The chart classifies their intake frequencies as daily, weekly, monthly, rarely when accessible, or never, offering an in-depth perspective on their eating behaviors.

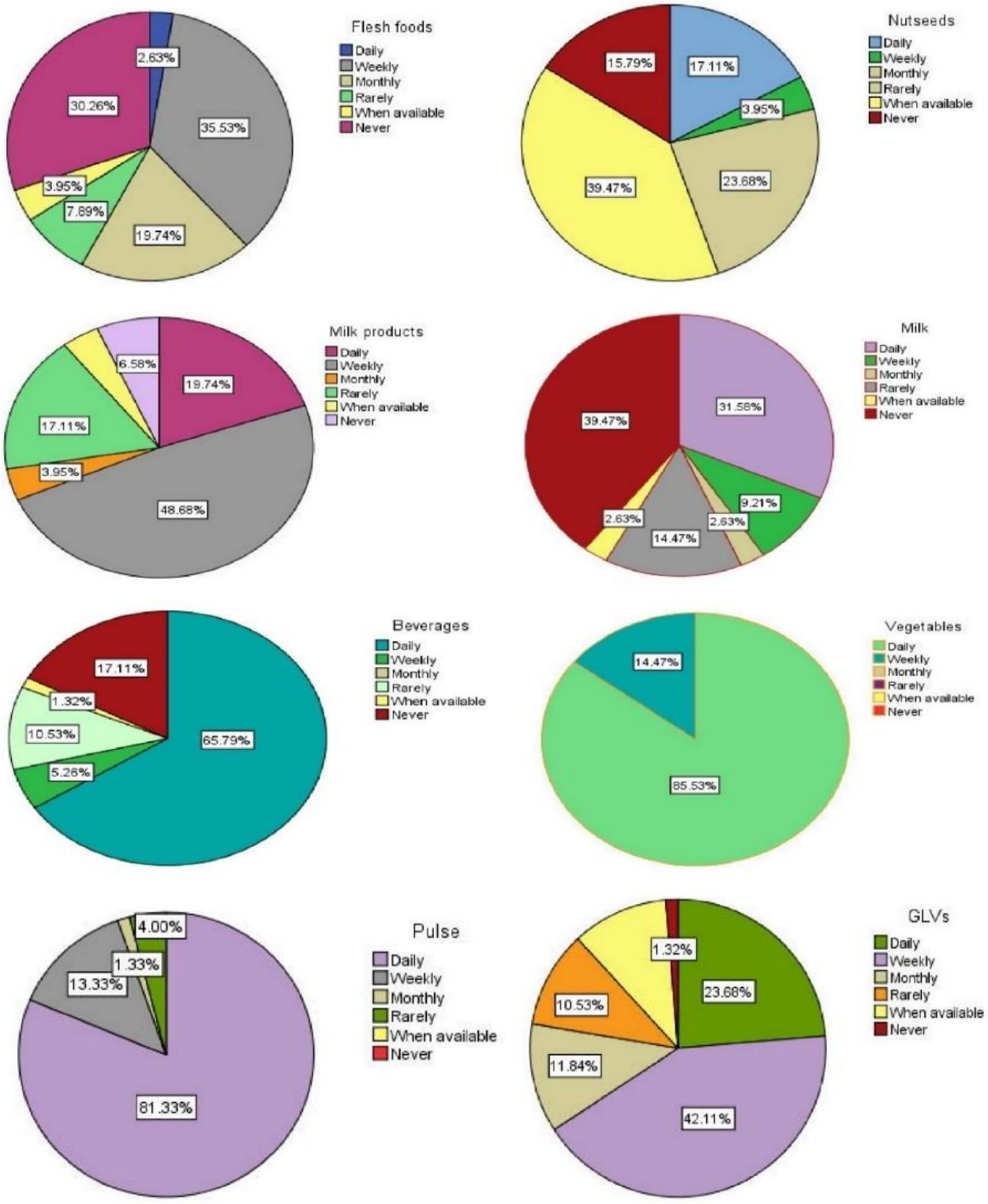
Figure 1 analyses the FFQ (Food Frequency Questionnaire) among NAFLD patients from UP, revealing their dietary habits. Besides staple foods like cereals, sugar, and fats, other food groups were examined. Flesh foods, milk products, and green vegetables were primarily consumed on a weekly basis, with percentages ranging from 35.53% to 48.68%. Nut and seed consumption patterns varied among patients: 39.47% consumed them only when available, 23.68% on a monthly basis, and approximately 17% reported daily consumption. Daily consumption was prominent for pulses, beverages, and vegetables, with percentages ranging from 65.79% to 85.53%. While green vegetables were mainly consumed daily (42.11%), a significant portion also consumed them weekly (23.66%). About 39.47% of patients never consumed milk, while 31.58% consumed it daily.

Figure 2 depicts the eating habits of NAFLD patients from Odisha, emphasizing how often they consume different food categories such as meat, nuts and seeds, dairy, beverages, vegetables, legumes, and green leafy vegetables (GLVs). The diagram classifies these consumption patterns as daily, weekly, monthly, seldom, based on availability, or not at all, offering a glimpse into the nutritional practices of the participants in the study.

A study from Odisha shows that the dietary habits of the participants were varied. A significant portion, 40.26%, consumed flesh foods on a weekly basis, while 23.38% reported never consuming them (Figure 2). Nut seeds were consumed daily by 37.16% of participants, with 25.64% rarely consuming them and 24.36% never. Regarding milk, 37.66% reported never consuming it, while 25.97% rarely did, and 15.58% consumed it daily. Milk products were consumed weekly or rarely by 35.06% of participants, while 16.88% consumed them daily. Beverages were a daily habit for 56.41% of participants and weekly for 16.67%. Vegetables were a daily staple for 56.41% and weekly for 20.51%. Pulse consumption was primarily daily, with 62.82% reporting daily consumption and 14.10% weekly. Green leafy vegetables were consumed daily by 42.31% of participants and weekly by 37.18%.

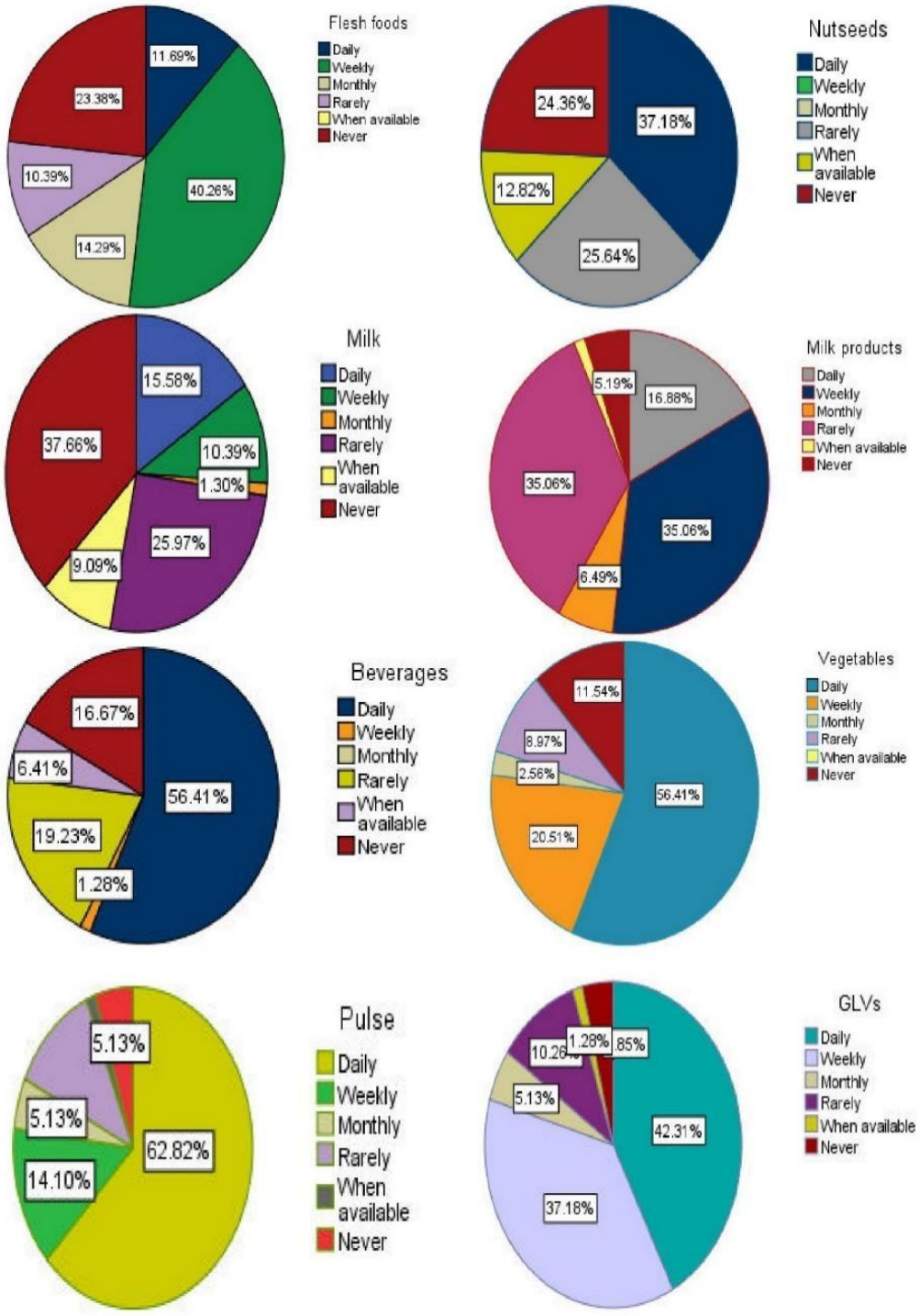
Figure 3 illustrates the distribution of NAFLD patients in Odisha and Uttar Pradesh by Asian BMI groups across three body types: lean (18.5-22.9kg/m²), overweight (23-25 kg/m^2), and obese. It emphasizes the prevalence of obesity (>25 kg/m²) among individuals in both states, with a lesser percentage identified as lean or overweight. This visual comparison highlights the differences in body type distribution across the study population by region.

Figure 1: Food Frequency Pattern among NAFLD Patients from UP (N=76)



*GLVs- Green leafy Vegetables: The above variables are mentioned in Percentage (%)

Figure 2 Food Frequency Pattern among NAFLD Patients from Odisha (N=78)



GLVs- Green leafy Vegetables: The above variables are mentioned in Percentage (%)

Figure 3: Divisions of NAFLD Patients among Two Different Geographical Areas (N=154).

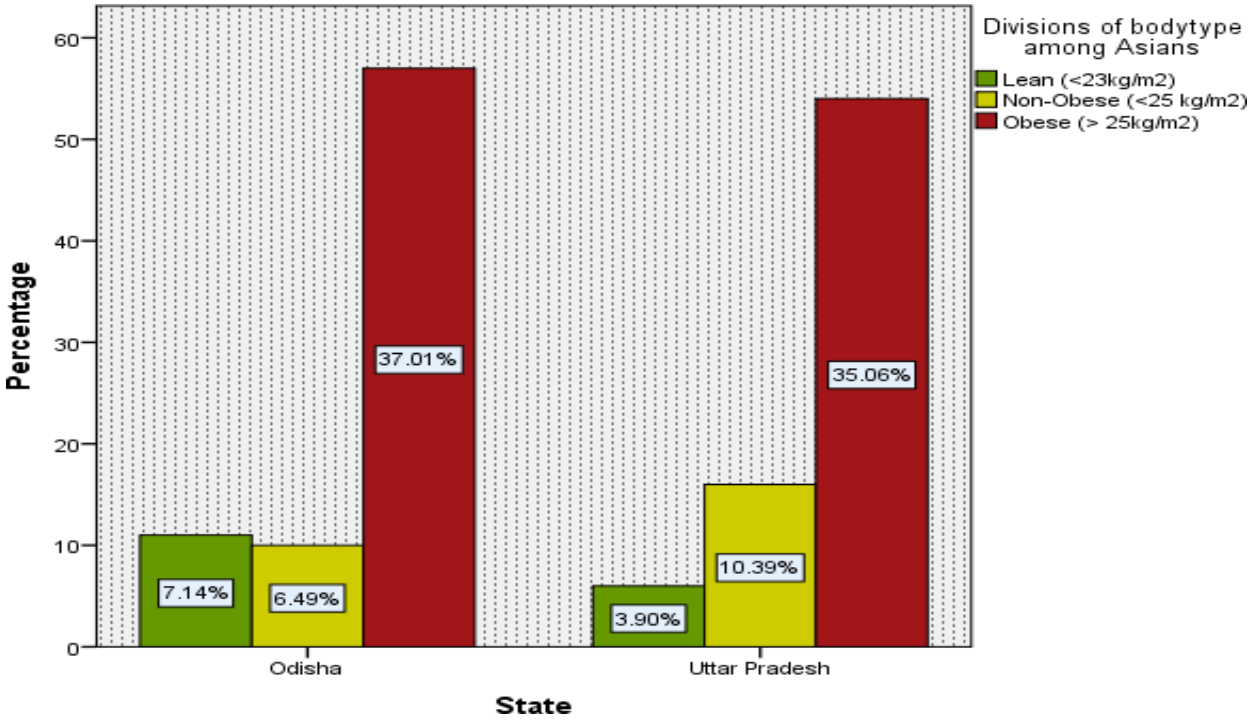


Figure 3 depicts that in both Odisha and Uttar Pradesh, obesity was the most common phenotype among NAFLD patients, making up 37.01% and 35.06% of cases, respectively. The percentage of lean NAFLD patients was significantly higher in Odisha (7.14%) than in Uttar Pradesh (3.90%), whereas the percentage of overweight patients was marginally higher in Uttar Pradesh (10.39%) than in Odisha (6.49%). These results highlight a prevalent pattern of obesity-related non-alcoholic fatty liver disease (NAFLD) in both areas, with minor changes in the distribution of lean and overweight phenotypes that may be due to regional differences in body composition as well as environmental or lifestyle variables.

Discussion

The increasing prevalence of NAFLD has been a global concern, especially in India and the entire South Asia. The factors, such as elevated BMI, the presence of diabetes mellitus (DM), metabolic syndrome (MeS), and abdominal obesity, showed the risk-associated factors for the high prevalence rate of NAFLD, particularly in states like Odisha and Uttar Pradesh (UP). The current finding was corroborated by the previous study, which revealed similar risk-associated factors for NAFLD in India among 1305 participants[9].

In the current study, Odisha and UP exhibited a higher rate of NAFLD, which resonates with other regional findings; the broader regional context of NAFLD prevalence is further supported by research such as the study "Nonalcoholic Fatty Liver Disease in South Asia", which explored the rising rates of NAFLD in South Asian countries, driven largely by factors like sedentary lifestyles, urbanization, and changing dietary patterns[10].

Moreover, the global prevalence of NAFLD in overweight individuals is 10.6%, and a slightly higher rate of 11.1% when diagnosed via ultrasound [11]. This global trend parallels the significant contribution of overweight individuals to the overall NAFLD burden in these regions. Prevalence rates of this study are approximately similar to the neighboring states of Haryana and Punjab (49.2–53.5%), whereas overall,

the prevalence of NAFLD in Indian populations varies between 9% and 53% [3]. Altogether, the corroboration of the current findings with the past studies, indicates that the eastern coastal and north-central regions of India exhibit the highest prevalence of NAFLD. This contrasts with the findings, which reported a higher prevalence in northern India[12].

Differential lipid profiles between lean and obese NAFLD patients are frequently explored and reported higher cholesterol and triglyceride (TG) levels in obese patients compared to lean individuals. [13] However, a study found lean individuals had elevated total cholesterol levels and lower TG levels[14]. Both groups, regardless of obesity status, show dyslipidemia as a key contributor to the pathogenesis of NAFLD[15]. It was found similar levels of total cholesterol and TGs in both lean and obese individuals, though statistical significance was absent [16, 17].

Regional findings echo global research as well reported an overweight NAFLD prevalence of 14.2% in the obese population, which mirrors higher rates in UP. Whereas a meta-analysis, which includes 14 observational studies involving a total of 94,181 patients with NAFLD, indicates a significant link between lean NAFLD and a higher risk of all-cause mortality. Specifically, individuals with lean NAFLD showed a 1.6 times greater risk of dying compared to those without lean NAFLD. This increased risk of mortality was consistently observed across different subgroups and remained unaffected by factors such as age, sex, and cardiometabolic risk factors [18]. Data from the National Institute of Diabetes and Digestive and Kidney Diseases also suggest a lower prevalence of lean NAFLD in the Indian context compared to the global average [19]. While Odisha shows higher rates, UP is on the lower end of the spectrum. These regional variations highlight the diverse distribution of NAFLD subtypes.

A study investigated the impact of central obesity (CO) on liver disease severity in lean patients with NAFLD (BMI <23 kg/m²). Among 170 lean NAFLD patients, 56.5% had CO, which was associated with a higher prevalence of female gender, hypertriglyceridemia, and metabolic syndrome. CO patients exhibited more severe liver steatosis on ultrasound, higher controlled attenuation parameter (CAP) values, elevated FAST scores, and increased fibrosis markers (FIB-4 and liver stiffness measurement). Importantly, CO was independently linked to advanced fibrosis, even after adjusting BMI and other metabolic risk factors. Similar findings were observed in patients meeting MASLD criteria, underscoring that lean patients with NAFLD or MASLD who also have central obesity are at a higher risk for more severe liver disease[20].

A systematic review and meta-analysis reviewed 62 datasets and revealed a pooled NAFLD prevalence of 38.6% among Indian adults[21]. Notably, prevalence rates were higher in high-risk groups, such as those with obesity, diabetes, and coronary artery disease, at 52.8%. Community-based studies reported lower prevalence (28.2%), indicating a gap in capturing certain populations, including rural groups and children. Additionally, the interplay between lifestyle, dietary habits, and NAFLD development needs further exploration to improve preventative and management strategies.

Dietary survey of this study in Odisha and UP reveals contrasting food landscapes for NAFLD patients. UP diets center around daily pulses and vegetables, with less emphasis on milk and meat. Odisha features more varied diets, with regular vegetables and weekly meat consumption. Critically, both regions under-consume milk and nuts, representing a key opportunity for dietary change. Given these distinct regional dietary profiles and varying NAFLD rates, targeted, culturally relevant interventions are essential to tackle India's rising NAFLD burden, a condition strongly associated with diabetes, dyslipidemia, and obesity, and increasingly prevalent beyond its traditional Western context.

A related observational study was conducted in India that explored the socio-demographic and clinical characteristics of NAFLD patients in Uttar Pradesh (UP) and Odisha [22]. The study found that patients from UP had higher SGOT/SGPT levels than those from Odisha, whereas triglyceride levels were slightly

higher in Odisha. But among NAFLD diversity (lean, Overweight, and Obese) there were no such significant biochemical differences observed. Some other factors like Socioeconomic factors showed that Odisha had more nuclear families, higher average monthly income, and a stronger preference for non-vegetarian diets (90.6%) compared to UP (75.06%), suggesting that lifestyle and socioeconomic factors may influence the clinical presentation of NAFLD. These findings underscore the need for region-specific strategies in managing and researching NAFLD. Likewise, another study was carried by Arke De et al., 2023 it compared the lean & non-lean NAFLD patients over 10 years among 1040 patients and found out that although lean NAFLD patients have fewer metabolic comorbidities, the severity of liver disease is similar to that of non-lean patients [12].

Conclusions: Overall, the current findings contribute to the understanding of the significant burden of NAFLD among overweight individuals, particularly within South Asian populations. However, it is crucial to know the limitations of using only the FFQ method for dietary intake analysis, suggesting potential for improvement through additional methods like the 24-hour recall. Further investigation is essential to uncover the factors behind the demographic differences observed among other regions. Variances in stool issues, dyslipidemia patterns, and fatigue trends underscore the necessity for deeper exploration into the underlying mechanisms. Aggressive dyslipidemia treatment, focusing on statins and omega-3 fatty acids, is crucial for NAFLD patients in both states. The management strategies are warranted due to differences in dyslipidemia patterns as variations in diabetes prevalence, bloating, and stool clarity among lean, overweight, and obese NAFLD patients emphasize the need for region-specific approaches. The highest frequency of NAFLD has been continuously found in Eastern India and northern-central coastal regions. This emphasizes having more public awareness campaigns involving governmental and non-governmental organizations.

Limitation: The cross-sectional methodology, absence of genetic analysis, and sample size (154 patients) of this multicentric, hospital-based study restricts its applicability. The self-reported nature of dietary evaluations may have introduced recollection bias.

Futuristic goals: Beyond conventional metabolic considerations, these studies highlight genetic, environmental, and societal aspects, providing fresh insights into NAFLD. To provide successful, customised preventative and treatment methods for NAFLD, future research should be built on these findings.

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