



Association between Mustard Oil Intake, BMI, Lipid Profile and Vitamin D Levels of Adults: A Cross-sectional Study

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ABSTRACT

Background: Mustard oil is a predominant oil used in North India, Northeast India and Asia. Mustard oil contains bioactives that possess pharmacological potential. While several studies support the consumption of mustard oil, evidence of causal association remains inconclusive. Mustard oil has been studied for its vitamin D content. This study attempts to expound the association between mustard oil, BMI, serum concentration of vitamin D and serum lipids.

Methods: Five hundred fifty-six adults aged 18 to 45 years, native to Shillong, participated in this cross-sectional study. A web-based questionnaire was designed to collect demographic details. The tool also included information on anthropometric parameters, dietary habits, types of fats and oils and the quantity and frequency of fat consumption. Food intake was measured with the 24-hour dietary recall tool to quantify the amount of oil used per day. Blood samples were drawn to study the vitamin D and lipid profile. Multiple regression models were used to analyse and associate the BMI, serum concentrations of lipids and vitamin D with mustard oil intake.

Result: Increase in age was significantly correlated with higher BMI ($p=0.003$). The frequency ($p=0.21$) and the amount ($p=0.015$) of mustard oil consumption were found to increase serum vitamin D levels. WHR was linked to higher TG ($p=.005$) and VLDL-C levels ($p=.005$). The findings of the study positively highlighted that mustard oil consumption is favourable for maintaining BMI, serum concentrations of lipids and vitamin D.

Key words: BMI, Lipid profile, Mustard oil, Serum Vitamin D, WHR.

INTRODUCTION

Mustard oil has been used for centuries, dating back to the Indus Valley civilisation. It is a predominant oil used in North, North East India and across Asia (Choudhary *et al.*, 2014; Acharya, 1995). It is widely used in these regions for its pungency and natural flavours, imparting a unique aroma and taste to foods. Mustard oil has been extensively studied for its composition (Chakraborty *et al.*, 2018). A favourable ratio of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), n-6 (omega-6) polyunsaturated fatty acids (PUFA) and n-3 (omega-3) PUFA was found in mustard oil (Chhajed *et al.*, 2021; Sharma *et al.*, 2022). The n-3 to n-6 fatty acids ratio in mustard oil is in the recommended range (Manchanda and Passi, 2016). While several studies support the consumption of mustard oil (Singh, 2018), evidence of causal association remains inconclusive (Poddar *et al.*, 2022). Studies also suggested the potential of Indian mustard seeds for both external and internal application. Mustard oil contains bioactives that possess pharmacological potential (Rahman *et al.*, 2018), namely antiviral, antibacterial, anti-inflammatory and antioxidant. Several secondary metabolites like phenolic compounds, glucosinolates and omega-3 PUFA's have been characteristic features in mustard seeds (Engels *et al.*, 2012) and several of these biologically active compounds have been isolated from mustard seeds (Das *et al.*, 2022; Grygier, 2023), confirming the potential benefits of mustard oil on certain cancers, diabetes, obesity and cataracts (Kaur *et al.*, 2019; Tian and Deng, 2020; Shristy *et al.*, 2023).

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Certain nutrients and derivatives from mustard oil, namely allyl isothiocyanate, catechin and vitamins A, C, E and D have proven to offer immunomodulatory benefits (Akhtar and Khan, 2024). The presence of bioactives like glucosinolates, phenols and sterols also makes the oil therapeutic in diseases like hyperlipidemia, diabetes, tumours *etc* and increased amounts of it may disrupt thyroid function (Shahzadi *et al.*, 2025; Morya *et al.*, 2022).

The lipid association of India (LAI) advocated mustard oil as a heart-friendly oil in its guidelines (Puri *et al.*, 2020). Mustard oil consumption has a positive correlation with weight loss, low body mass index (BMI) (Al-Fartosi *et al.*, 2017) and the hypolipidemic effect of the oil has also been

proven in several studies (Szollosi, 2020; Prakash *et al.*, 2019). However, there was a recent study with contradictory results (Manna *et al.*, 2016; Islam *et al.*, 2023).

Mustard oil has been investigated for its vitamin D content and it was quantified to 0.73 mg/ml compared to other oils. The presence of ergosterol and 7-dehydrocholesterol revealed that these naturally occurring compounds in plant oils are underestimating their ability to synthesise vitamin D (Huang *et al.*, 2015). Vitamin D was enhanced and increased in mustard oil exposed to sunlight from 0.73 mg/ml to 1.89 mg/ml (Amithabh *et al.*, 2025). Another finding by Silva and Furlanetto, (2018) observed that different carrier oils exhibited different levels of bioaccessibility in oils rich in monounsaturated fatty acids and declared better for encapsulating and delivering vitamin D. Several studies suggested better absorption of vitamin D when simultaneously taken with fat. Vitamin D was shown to play a role in hyperlipidemia (Lu *et al.*, 2022). Wang *et al.* (2016) found an association between vitamin D levels, hyperlipidemia and ideal levels of high-density lipoprotein-cholesterol (HDL-C). An increase in Waist to Hip Ratio (WHR) was associated with low vitamin D levels (Biswas *et al.*, 2021). Vitamin D could be considered one of the major biomedical markers for risk identification in metabolic disorders, diabetes and dyslipidemia, as reported by Dibaba (2019). Meta-analyses of cohorts revealed convincing results confirming the hypolipidemic outcome of increased vitamin D levels (Li *et al.*, 2021; Yang *et al.*, 2023; Liu *et al.*, 2025).

Mustard oil studies are limited, conclusive evidence is scarce and this demands more research on mustard oil and its effects (Rahman *et al.*, 2024). There are rare studies reporting the use of mustard oil (Nayak *et al.*, 2016), serum lipid levels and vitamin D levels (Gholamzad *et al.*, 2023). There is a huge gap in the literature as to which oils aid in better delivery of vitamin D, whether mustard oil is a favourable medium that can be associated with serum concentration of vitamin D and if there are multiple factors related to the type and frequency of oils and hypolipidemia.

This novel study attempts to address the gap by examining the association between mustard oil, BMI, serum concentration of vitamin D and serum lipid profile for a better understanding of the potential nutritional contributions of mustard oil.

MATERIALS AND METHODS

This cross-sectional study was conducted in Shillong, North-East India. The study was conducted with a total of 556 participants. The inclusion criteria applied were adults aged 18 to 45 years, native to Shillong. The exclusion criteria applied were non-natives belonging to other states of India and those with diet-related diseases. The Indian Council of Medical Research (ICMR) guidelines 2017 (ICMR 2017) were followed for the conduct of the study procedures. All study participants gave their informed consent. Ethical clearance was obtained from the study area and the university. The Institutional Ethics Committee Pasteur

Institute (Ref no: DHSR/IECP101/24/07), Shillong and the Institutional Human Ethics Committee (Ref no: AUX/IHEC/FSMD-22-23/XPD-3) of the Avinashilingam Institute for Home Science and Higher Education for Women, where work was carried out, approved the study. A web-based questionnaire was designed to collect data on sociodemographic details, like age, gender, tribe and educational qualification. The study was carried out from May 2023 to February 2024. The data collection tool also comprised information on the dietary habits of the participants, with special emphasis on the type of oil and fat, quantity and amount of fat in standard teaspoon measures used per day. To quantify the amount of oil used per day, a 24-hour dietary recall was utilised to record daily food intake for 3 days. The height, weight, waist and hip circumference were collected. The World Health Organisation criteria (WHO, 2004) were used to classify BMI and WHR. Ten per cent of the study participants were selected using the purposive sampling technique for a detailed investigation of blood parameters, due to a lack of funding. Of the 50 participants, five samples dropped out of this phase of the study. For quantitative studies, specifically biochemical analysis, a sample size of 40 is considered sufficient (Sadiq *et al.*, 2025). Overnight fasting blood samples of six millilitres were drawn from each sample. The serum samples were estimated for both vitamin D and lipids. The serum vitamin D was assessed using the Chemiluminescent Immuno Assay (CLIA) method (Frenzel *et al.*, 2006) and the lipid parameters, which were estimated, include total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C) and very low-density lipoprotein cholesterol (VLDL-C). The enzymatic calorimetric test using the Cholesterol Oxidase [CHOD] - Phenol - Aminoantipyrene [PAP] method was used to estimate cholesterol (Trinder, 1969), the Glycerol Phosphate Oxidase [GPO]- Phenol - Aminophenazone [PAP] method was used to estimate Triglycerides (Fossati and Lorenzo, 1982), the direct method or the Enzyme Selective Protection method was used for estimating HDL-C (Rifai *et al.*, 1999) and LDL-C was estimated by the Homogenous Enzymatic Calorimetric Assay (Nauck *et al.*, 2002). VLDL-C was estimated by calculating using the Friedewald formula (Friedewald, 1972).

Statistical analysis

The data were cleaned and transferred to the statistical software for further analysis, using the Statistical Package for Social Sciences version 22. Quantitative data were given in numbers and percentages. Independent and dependent variables were identified to conduct the correlation analysis. The one-sample t-test was employed to test the sample mean against the median value of the reference range. This was followed by a one-sample t-test (clinically chosen boundary) to determine the excess or deficiency of the value, with values closest to the mean indicating a normal level. The 95 per cent confidence interval (CI) ascertained statistical significance ($p < 0.05$). To handle the

missing data, multiple regression models were used. Multiple linear regression analysis was used to investigate the effects of anthropometric measures (BMI and WHR) and dietary oil consumption patterns (mustard oil and soybean oil frequency and amount) on triglyceride levels, HDL cholesterol levels and serum 25-hydroxy vitamin D levels among participants. The regression analysis examined both the size and statistical significance of the unstandardised regression coefficients, followed by standardised Beta coefficients to assess the relative strength of each predictor. The model's overall fit was finally evaluated using R, R² and the F-test.

RESULTS AND DISCUSSION

Table 1 depicts the sociodemographic profile, BMI and WHR of the study participants. About 33.3 per cent were males and 66.7 per cent were female participants. Sixty-nine per cent were between 21 and 30 years and a meagre 1.4 per cent were 41 to 45 years. The Khasi tribals comprised 78.2 per cent and 21.8 per cent were from the Jaintia tribe. Unmarried study participants comprised 92.6 per cent and 1.6 per cent were divorced/separated.

Students comprised 83.8 per cent, 10.3 per cent were employed and 2.3 per cent were involved in small start-up businesses. The anthropometric measurements revealed 65.6 per cent fall under the normal BMI classification and only 3.1 per cent were obese. About 71.6 per cent of the study participants had an unfavourable WHR >0.85.

This result is supported by previous findings (Chhajed *et al.*, 2021), which suggest mustard oil consumption has an inverse relationship with BMI and that a decrease in the occurrence of overweight and obesity is observed in comparison to the use of other oils as the predominant oil. Although 65.6 per cent of the study participants may have a normal BMI, WHR predicts visceral fat better compared to WC and BMI according to Gadekar *et al.* (2020).

The type, frequency and quantity of oil consumed are presented in Fig 1 and 2, respectively. A total of 72.7 per cent of the study participants used mustard oil daily and 15.3 per cent

used soybean oil for cooking daily. Nearly forty per cent of the study participants used 6 teaspoons (30 ml) of mustard oil per day and about 30.8 per cent of them used 2 teaspoons (10 ml) of soy oil per day. 33.8 per cent of them do not use soybean oil and 3.8 per cent of them do not use mustard oil.

Predominant oil comprises oil that was consumed in more than 50 per cent of the total oils used in a household (NSSO, 2014). Previous findings by Chhajed *et al.* (2021) also supported that mustard oil was consumed by 90 per cent of the population in North and Northeast India. According to Rahman *et al.* (2024), low levels of saturated fatty acids and higher MUFA, erucic acid, along with other bioactives like glucosinolates, omega-3 fatty acids, flavonoids, tannins, terpenols, phenylpropanoids and trace elements in mustard oil, contributes to its medicinal properties

Table 1: Demographics of the selected participants.

Variable (N=556)		Frequency	Per cent
Gender	Male	185	33.3
	Female	371	66.7
Age (in years)	< 20	141	25.4
	21-30	384	69.1
	31-40	23	4.1
	41-50	8	1.4
Occupation	Student	466	83.8
	Employed	59	10.6
	Business	13	2.3
BMI	Unemployed	18	3.2
	Underweight (<18.5)	101	18.2
	Normal (18.5-24.9)	365	65.6
	Overweight (25.0-29.9)	73	13.1
WHR	Obese (>29.9)	17	3.1
	<0.85	158	28.4
	>0.85	398	71.6

BMI- Body mass index.

WHR - Waist to hip ratio.

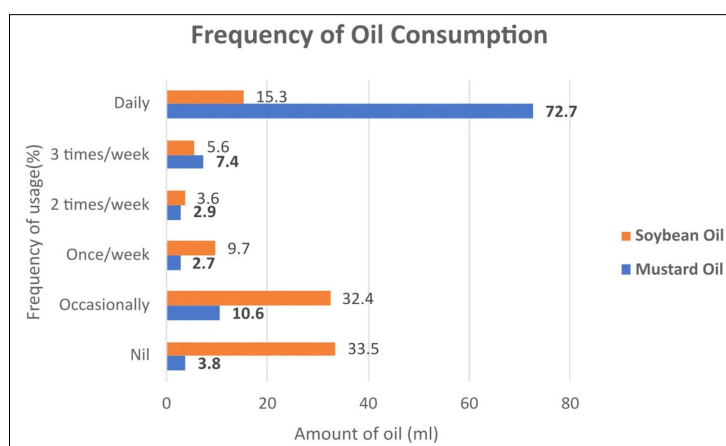


Fig 1: Frequency of oil consumption.

Table 2 records the blood lipid profile and serum concentration of 25-hydroxy vitamin D. serum total cholesterol, triglycerides and VLDL-C levels were all within the normal range, demonstrating statistically significant ($p < 0.05$). HDL-C mean was also higher ($p < 0.05$). The LDL-C level did not show any statistical significance. Prakash *et al.* (2019) reported that mustard oil with erucic acid and glucosinolate reduced serum triglycerides and increased HDL-C compared to mustard oils without erucic acid. The lipid profile of the study participants revealed a promising picture. Total cholesterol, triglycerides, VLDL-C and HDL-C values reflected a robust protective lipid profile

supported by previous studies. Mustard oil's hypolipidemic activities may have contributed to the normal levels in the study. Scientific evidence supported the hypolipidemic nature of mustard oil, which decreased total cholesterol and triglyceride levels, as suggested by Mishra and Manchanda (2012) and Akhtar and Khan (2024).

Serum 25-hydroxy vitamin D concentration in the selected study participants was much lower than normal values at 95 per cent CI ($p < 0.05$), indicating a deficient vitamin D level. Exposure to sunlight is a significant criterion in the synthesis of vitamin D. According to Oliver *et al.* (2023), climate and urban lifestyle could affect the synthesis of vitamin D.

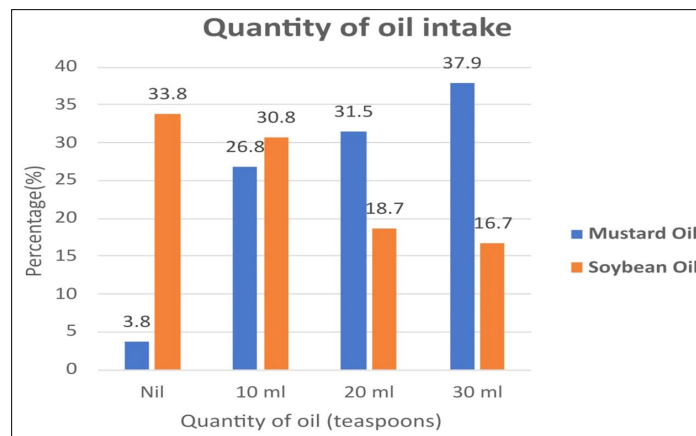


Fig 2: Quantity of oil consumption.

Table 2: Biochemical profile of the selected study participants.

Serum parameter	Mean	95% CI	Chosen boundary	p-value	Clinical Interpretation
Total Cholesterol (mg/dL)	168.156	[158.31, 178.00]	200	<0.05*	Significantly below the desirable threshold (200 mg/dL) - normal level
Triglycerides (mg/dL)	122.038	[103.97, 140.11]	150	<0.05*	Significantly below the normal-to-high threshold (150 mg/dL) - normal level
HDL-C (mg/dL)	45.860	[42.99, 48.73]	40	<0.05*	Significantly above the HDL Threshold (40 mg/dL) - normal level
LDL-C (mg/dL)	97.892	[90.58, 105.20]	100	NS	Not significantly different from normal cutoff (100 mg/dL) - borderline
VLDL-C (mg/dL)	24.403	[20.79, 28.02]	40	<0.05*	Significantly below upper normal limit (40 mg/dL) - normal range
Vitamin D-25-Hydroxy (ng/mL)	16.756	[15.24, 18.27]	20	<0.05*	Significantly below optimal lower level (20 ng/mL) - mild deficiency

*p is <0.05, indicating significant results.

CI - Confidence Interval.

HDL-C indicating High-Density Lipoprotein Cholesterol.

LDL-C indicating Low-Density Lipoprotein Cholesterol.

VLDL-C indicating Very Low-Density Lipoprotein Cholesterol.

Table 3 presents Model I of regression analysis, which assessed the influence of age, gender and oil intake on BMI. Age was identified as a dominant predictor of BMI, revealing statistical significance at a one per cent level ($p=0.003$). This confirms age is a predictor of BMI ($p<0.01$), as supported by a study by Gadekar *et al.*, (2020).

Another Model II (Table 4) examined BMI, WHR, Mustard oil, Soybean oil intake and the dependent variable triglyceride levels. The model showed that the selected variables together explained 42 per cent of the variance in triglyceride levels. The overall model was highly significant indicating a good fit. With a p -value of 0.001, thus proving a strong association between the anthropometric indices, type of oil and triglyceride levels. Furthermore, WHR emerged as a significant predictor of serum triglyceride levels. The relationship was significant at one per cent level with a $p=0.005$. Previous research had similar outcomes as reported by Bailey *et al.* (2013), Lam *et al.* (2015) and Miralles *et al.* (2015).

The third Model (Table 5) was fitted to test the association between VLDL-C levels, BMI, WHR, mustard oil and soybean oil intake, which resulted in an R value of 6.54 and R^2 value of 0.428, where all selected variables together explain 42 per cent of the variance in serum VLDL-C levels. A statistical significance was observed in this model ($p=0.005$). Among the independent variables, WHR emerged as the most significant contributor to VLDL-C levels; higher WHR was positively correlated with an increase in VLDL-C levels. Evidence by Sam *et al.* (2008) and Wei *et al.*, (2022) also supported that WHR significantly influences lipid parameters, VLDL-C concentration and triglyceride levels.

Model IV (Table 6) indicated that predictors like BMI, WHR, intake of mustard oil and the amount of mustard oil did bring about a statistical significance in serum vitamin D concentration in the study participants, however the amount and intake of mustard oil was the significant predictor of serum vitamin D levels indicating frequent

Table 3: Model I: Regression analysis associating BMI (dependent variable) and gender, age and oil intake (independent variables).

	Body mass index			
	b-coefficient	Std error	p-value	R ²
Gender	-0.378	-0.336	0.261	0.020
Age	0.838	0.281	0.003**	
Mustard oil intake (frequency)	-0.058	-0.108	0.592	
Mustard oil quantity (tsp)	0.035	0.100	0.722	
Soybean oil intake (frequency)	0.018	0.122	0.882	
Soybean oil quantity (tsp)	-0.039	0.105	0.712	

**p is <0.01 , indicating highly significant results.

Table 4: Model II: Regression analysis correlating triglycerides (dependent variable) and BMI, WHR and oil intake (independent variables).

	Body mass index			
	b-coefficient	Std error	p-value	R ²
BMI	3.123	3.009	0.306	0.428
WHR	391.421	130.164	0.005**	
Mustard oil Intake (frequency)	-8.936	6.417	0.172	
Mustard oil quantity (tsp)	4.186	5.022	0.410	
Soybean oil Intake (frequency)	-6.330	7.047	0.375	
Soybean oil quantity (tsp)	6.049	6.178	0.334	

**p is <0.01 , indicating highly significant results.

BMI: Body mass index; WHR: Waist to hip ratio.

Table 5: Model III: Regression analysis associating VLDL-C (dependent variable) with BMI, WHR and oil intake (independent variables).

	Body mass index			
	b-coefficient	Std error	p-value	R ²
BMI	0.625	0.602	0.306	0.428
WHR	78.292	26.050	0.005**	
Mustard oil intake (frequency)	-1.791	1.284	0.171	
Mustard oil quantity (tsp)	0.836	1.005	0.411	
Soybean oil intake (frequency)	-1.253	1.410	0.380	
Soybean oil quantity (tsp)	1.196	1.236	0.340	

**p is <0.01 , indicating highly significant results.

BMI: Body mass index; WHR: Waist to hip ratio.

Table 6: Model IV: Regression analysis associating 25-Hydroxy vitamin D (dependent variable) and BMI, WHR and oil intake (independent variables).

	Body mass index			
	b-coefficient	Std error	p-value	R ²
BMI	-0.010	0.287	0.972	0.255
WHR	17.380	12.425	0.170	
Mustard oil Intake (frequency)	1.481	0.613	0.021*	
Mustard oil quantity (tsp)	-1.217	0.479	0.015*	
Soybean oil Intake (frequency)	-0.357	0.673	0.599	
Soybean oil quantity (tsp)	0.143	0.590	0.810	

*p is <0.05, indicating significant results.

BMI - Body mass index; WHR - Waist to hip ratio.

intake of mustard oil (p=0.21) and the amount of mustard oil (p=0.015) intake increased the serum vitamin D levels.

The model resulted in 25 per cent of the deviation in serum vitamin D levels. However, the Model did not reveal any statistically significance (p=0.067).

Vitamin D bioavailability may be influenced by the type of fatty acids reported by Silva and Furlanetto, (2018) and Holmberg *et al.* (1990). Vitamin D absorption could be enhanced in mustard oil owing to the presence of MUFA in the oil. Similar research by Niramitmahapanya *et al.* (2011) has established a significant correlation between MUFA and vitamin D absorption. Furthermore, Amithabh *et al.* (2024) reported that vitamin D increased in mustard oil with exposure to ultraviolet (UV) radiation. Mustard oil, a structured triacylglycerol, may be a favourable medium for delivering vitamin D, suggests Guo *et al.* (2022). It contains vitamin D naturally in considerable amounts and its intake may be positively and significantly associated with a favourable BMI and lipid profile among our study participants.

CONCLUSION

Mustard oil intake may help to maintain the BMI and WHR in adults. Our findings suggest a positive association between mustard oil consumption and serum vitamin D levels, in addition to favourable blood lipid levels. However, longitudinal studies are needed to establish causality. Limitations of the study cannot be ignored. The cross-sectional design of the study realises the challenge to interpret the exact causality and associations between mustard oil, anthropometric parameters, lipid profile and vitamin D levels. The lack of funding has also restricted the study's sub-sample size for biochemical analysis. There may also be an issue of recall bias, as is common with all self-reported questionnaires. However, the findings of the study were similar to other international and national research findings.

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Disclaimers

The views and findings displayed in this study belong to the authors. The authors are responsible for the precision

and entirety of the content, but are unwilling to accept any liability resulting from the contextual usage.

Informed consent

All participants have given their consent prior to the conduct of the study.

Conflict of interest

The authors declare no conflicts of interest.

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