J Nutr Health. 2024 Jun;57(3):282-291
https://doi.org/10.4163/jnh.2024.57.3.282
eISSN 2288-3959

JNH
Journal of Nutrition and Health

Research Article

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Impact of dietary fiber intake on non-alcoholic fatty liver disease risk in Korean patients with obesity and type 2 diabetes mellitus

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OPEN ACCESS

Received: Mar 27, 2024
Revised: Jun 12, 2024
Accepted: Jun 18, 2024
Published online: Jun 25, 2024

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Funding
This work was supported by the National Research Foundation (NRF) by the Korea government (MSIT) (No. RS2023-00242278).

ABSTRACT

Purpose: Korean patients with type 2 diabetes mellitus (T2DM) and obesity are at a high risk of developing severe non-alcoholic fatty liver disease (NAFLD). This study examined the dietary intakes and compared the risks of NAFLD-related complications in Korean patients with T2DM and obesity.

Methods: Data from the Korean National Diabetes Program cohort were used to study patients with T2DM. Two hundred and sixty-five obese patients with T2DM (body mass index ≥ 25 kg/m^2) were classified into NAFLD and non-NAFLD groups. The nutrient intake was analyzed using a 24-hour dietary recall questionnaire. Anthropometric and biochemical data were also obtained. Statistical analyses were performed to determine the significant differences between the 2 groups.

Results: The serum gamma-glutamyl transpeptidase levels in obese patients with T2DM and NAFLD were significantly higher than in obese T2DM patients without NAFLD ($p < 0.05$). The serum glucose and lipid profiles showed no significant differences between the NAFLD and non-NAFLD groups. The carbohydrate, protein, and fat levels also did not differ significantly. The results showed that the fiber intake of the NAFLD and non-NAFLD groups was 14.11 ± 3.86 g/100 kcal and 15.70 ± 4.56 g/1,000 kcal, respectively, showing that the dietary fiber intake of the non-NAFLD group was significantly higher ($p < 0.05$). A correlation was observed between total fiber intake and γ-glutamyl transpeptidase in either patient group. In addition, the odds ratio of developing NAFLD was 0.29× lower when the fiber was consumed at 125% of adequate intake.

Conclusions: A higher dietary fiber intake may reduce the risk of NAFLD in obese patients with T2DM. The dietary intake of Korean obese patients with T2DM should include and be enriched in dietary fiber to aid in preventing and treating NAFLD.

Keywords: non-alcoholic fatty liver disease; type 2 diabetes mellitus; obesity; dietary fiber

INTRODUCTION

Diabetes mellitus, which has a rapidly increasing incidence and prevalence, is a serious public health concern that causes significant morbidity, disability, and mortality worldwide

Conflict of Interest
There are no financial or other issues that might lead to conflict of interest.

Author Contributions
Conceptualization: Kim YS, Yim JE; Data curation: Park JS, Akbar H.; Investigation: Park JS, Akbar H; Methodology: Yim JE; Writing - original draft: Park JS; Writing - review & editing, Yim JE.

[1]. According to the International Diabetes Federation, 536.6 million adults worldwide had diabetes in 2021, and it is predicted that it will increase to 783.2 million by 2045 [2].

Non-alcoholic fatty liver disease (NAFLD) is an accumulate of fat in the liver cell of individuals without excessive alcohol intake. According to statistics, the prevalence of NAFLD is estimated to be 25% worldwide [3] and has been rapidly rising over the past 10 years. Asia has a higher prevalence of NAFLD (27%) than either North America or Europe (24%) [4]. Increased industrialization in many Asian countries has altered many lifestyles to become more sedentary and has resulted in higher levels of overnutrition—both of which are significantly associated with metabolic disorders [3].

Several studies have indicated that NAFLD is not limited to liver damage—as it is also linked to metabolic syndrome, type 2 diabetes mellitus (T2DM), cardiovascular disease [5], and chronic kidney disease [6]. The prevalence of NAFLD is higher in individuals with an elevated body mass index (BMI) and among patients with T2DM [7]. The risk factors for NAFLD and T2D are comparable, and their association has been further highlighted by their epidemiologies and pathophysiologies [5].

T2DM can increase the risk of NAFLD and related mortality [8], such as liver cirrhosis and hepatocellular carcinoma [9]. In addition, NAFDL also induces the risk of T2DM, leads to disorders of lipid and glucose metabolism, and increases the prevalence of diabetic microvascular disease [10]. T2DM and NAFLD present with similarly poor metabolic profiles (including genetic factors, insulin resistance, dyslipidemia, obesity, lifestyle factors, and others) [11]. Animal experiments and cell-based studies have demonstrated that insulin resistance plays an essential role in the mechanism behind NAFLD pathogenesis [12].

The impact of NAFLD on public health may be reduced by identifying controllable risk factors for its early prevention [13]. Dietary factors may be among the most important factors [14]; however, optimal diets for preventing NAFLD have not yet been established. Most previous studies have examined the effects of particular foods or nutrients on NAFLD—such as choline [15], nuts [16], and raw garlic [17]. A recent study found that a higher insoluble fiber intake (> 7.5 g/day) resulted in improvements in 3 different scales of liver fibrosis (hepatic steatosis index, fatty liver index, and NAFLD liver fat score) [18].

According to a cross-sectional study conducted in the Netherlands, participants with high fatty liver indexes had poor dietary fiber intake [19]. Another large cross-sectional study in China reported an interconnection between total dietary fiber intake and a low prevalence of newly diagnosed NAFLD [20]. Several studies have reported that dietary patterns can be used as a prophylactic prevention strategy in Korean adults at high risk of developing NAFLD [21], whereas another study concluded that dietary factors are significantly related to NAFLD in Korean adults [22]. However, no studies have yet established the association between dietary fiber intake and NAFLD prevention in Korean patients with T2DM.

Therefore, considering the rapid increase in the prevalence of diabetes and NAFLD in Korea, it is crucial to examine the relationship between NAFLD, diabetes, and obesity in a large cohort of Korean adults to provide evidence for their prevention and treatment. This study aimed to evaluate dietary intake according to the presence or absence of NAFLD in Korean patients with T2DM and compare their risks of developing NAFLD according to their dietary intake patterns.

https://doi.org/10.4163/jnh.2024.57.3.282

METHODS

Study design and participants

For this investigation, we used information from the Korean National Diabetes Program (KNDP) cohort database. The KNDP is a large-scale, prospective, multicenter cohort study that collects data from Korean individuals who have type 2 diabetes and those who are at high risk for developing the disease. Patients between the ages of 40 and 63 who had T2DM and BMIs of ≥ 25 kg/m^2 were recruited. The data were collected from various university hospitals in South Korea. Baseline clinical characteristics such as sex, age, BMI, blood pressure, smoking and drinking habits, glucose levels, glycated hemoglobin (HbA1c) levels, lipid profiles, and liver function indexes (blood urea nitrogen, aspartate aminotransferase [AST], alanine aminotransferase [ALT], and gamma-glutamyltranspeptidase [^{r}GTP]) were provided by the KNDP cohort data. In total, 265 patients with T2DM were included. The KNDP cohort comprised 2 groups: patients with T2DM, both with and without NAFLD. The experimental protocol was approved by the Ethics Committee of the Kyung Hee University Hospital (KMC IRB No. 0526-04) and conformed to the ethical principles of the Declaration of Helsinki.

Anthropometric measurements

Anthropometric measurements were performed with the participants wearing light clothing without shoes. Blood pressure was measured using oscilometric devices after the subjects rested for at least 5 minutes in a sitting position (Inbody BPBIO320; Biospace, Seoul, Korea). Both systolic and diastolic blood pressures were recorded. Waist circumference (WC) and hip circumference (HC) were measured in cm using soft measuring tapes. WC was measured halfway between the lower borders of the thoracic cage and iliac crest. Height and weight were measured in cm and kg, respectively. Body composition of participants was analyzed using bioelectrical impedance analysis (Inbody 720; Biospace). BMI was calculated as weight (kg) divided by height squared (m^2). The percentage of body fat (PBF) was also calculated for all 265 patients of both groups.

Biochemical measurements

Blood samples were collected after an overnight fast of at least 10 hours and stored at −70°C for subsequent assays. Biochemical data—including total cholesterol, triglycerides, high-density lipoprotein-cholesterol, low-density lipoprotein-cholesterol, AST, and ALT levels—were measured using a Toshiba 200FR Neo analyzer (Toshiba Medical System Co., Ltd., Tokyo, Japan) via the enzymatic colorimetric method. Following the manufacturer's instructions, a Toshiba 200 FR autoanalyzer (Toshiba Medical System Co., Ltd.) and an ion-exchange high-performance liquid chromatograph (Bio-Rad Laboratories, Inc., Hercules, CA, USA) were used to measure fasting plasma glucose and HbA1c levels, respectively.

Dietary assessment

For dietary intake, an in-person question-and-answer session was held with patients by trained certified dieticians using a 24-hour dietary recall questionnaire. Photographs and food models were used to evaluate portion sizes. A 24-hour dietary recall questionnaire was used during an in-person question-and-answer session with patients by professional dieticians with training. Portion sizes were assessed using food models and photographs. Dietary intake was analyzed using the Computer-Aided Nutrient Analysis Program version 5.0 (CAN-Pro 5.0; The Korean Nutrition Society, Seoul, Korea), which converts food consumption records to nutrient intake. Fiber intake ratio (%) was calculated by dividing the fiber intake by the adequate intake (AI) and multiplying it by 100.

https://doi.org/10.4163/jnh.2024.57.3.282

Statistical analysis

Relative frequencies (%) and absolute frequencies (n) were used to represent categorical variables. Standard deviations ± mean values were used to represent continuous variables. Mann-Whitney U and χ^2 tests were used to conduct comparisons between the 2 groups. Spearman's correlation test was used to estimate the correlation between fiber intake and NAFLD-associated variables. Logistic regression analysis was used to assess odds ratios (ORs) and their corresponding 95% confidence intervals (95% CIs). Statistical evaluation was performed using statistical packages in SPSS version 27.0 (IBM Corp., Armonk, NY, USA), which was used to carry out all statistical analyses and data management. Statistical significance was set at $p < 0.05$.

RESULTS

Anthropometric measurements

The 265 patients with T2DM were categorized into 2 groups: NAFLD and non-NAFLD. A total of 55 had NAFLD, and the remaining 210 fell into the non-NAFLD group. **Table 1** summarizes the anthropometric characteristics (height, weight, BMI, PBF, WC, and HC) of all of the participants. Age, sex, height, and weight differed significantly between the groups ($p < 0.01$), with the non-NAFLD groups being older than the NAFLD one and the NAFLD group having higher height and weight measurements. However, there was no significant difference in BMI between the 2 groups.

Biochemical measurements

Table 2 presents the serum glycemic indexes and lipid profiles of all of the patients. There were no significant differences found between them in terms of HbA1c levels, as well as glycemic and lipid profiles. By contrast, representative liver function indexes showed that serum γGTP was significantly higher in the patients with NAFLD. The NAFLD group also tended to have higher ALT and AST levels than the non-NAFLD one.

Table 1. General characteristics and anthropometric measurements in patients with T2DM with and without NAFLD

Characteristics	Patients with T2DM and NAFLD (n = 55)	Patients with T2DM without NAFLD (n = 210)	p-value
Age (yrs)	48.36 ± 11.36	53.00 ± 10.55	0.005
Male	38 (69.1)	85 (40.5)	0.001
Height (cm)	165.55 ± 9.16	160.97 ± 8.45	0.000
Weight (kg)	76.51 ± 10.03	71.37 ± 8.09	0.001
BMI (kg/m^2)	27.89 ± 2.63	27.50 ± 2.17	0.439
WC (cm)	91.20 ± 9.55	91.40 ± 6.61	0.552
HC (cm)	99.40 ± 9.53	100.23 ± 5.37	0.979
SBP (mmHg)	124.07 ± 14.51	126.81 ± 17.03	0.163
DBP (mmHg)	82.78 ± 11.07	80.88 ± 11.54	0.224
PBF (%)	34.83 ± 3.97	36.38 ± 5.68	0.454
BFM (kg)	23.25 ± 2.76	27.72 ± 3.85	0.485
SMM (kg)	23.98 ± 4.19	24.11 ± 5.34	0.472

Values are presented as numbers (%) or means ± standard deviations. Analyses were performed using the Mann-Whitney U and χ^2 tests.
T2DM, type 2 diabetes mellitus; NAFLD, non-alcoholic fatty liver disease; BMI, body mass index; WC, waist circumference; HC, hip circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; PBF, percentage of body fat; BMF, body fat mass; SMM, skeletal muscle mass.

https://doi.org/10.4163/jnh.2024.57.3.282

Table 2. Biochemical profiles of patients with T2DM with and without NAFLD

Characteristics	Patients with T2DM and NAFLD (n = 55)	Patients with T2DM without NAFLD (n = 210)	p-value
Glucose (mg/dL)	114.05 ± 58.43	106.58 ± 13.02	0.910
HbA1c (%)	6.66 ± 6.47	5.84 ± 0.48	0.061
Insulin (μIU/mL)	14.88 ± 35.37	10.06 ± 6.26	0.815
HOMA-IR	2.52 ± 1.69	2.67 ± 1.76	0.720
AIR	0.72 ± 0.60	0.67 ± 0.51	0.798
LDL-C (mg/dL)	123.82 ± 30.48	118.65 ± 30.77	0.910
HDL-C (mg/dL)	49.94 ± 18.59	48.38 ± 11.17	0.058
TG (mg/dL)	167.35 ± 112.23	144.62 ± 80.11	0.815
TC (mg/dL)	192.19 ± 33.56	189.35 ± 36.84	0.720
BUN (mg/dL)	13.01 ± 3.33	13.74 ± 3.73	0.458
Albumin (g/dL)	4.43 ± 0.18	4.37 ± 0.38	0.718
AST (U/L)	34.92 ± 41.59	25.24 ± 9.85	0.075
ALT (U/L)	36.79 ± 35.05	28.25 ± 20.1	0.084
γGTP (U/L)	55.18 ± 49.25	36.91 ± 34.74	0.003

Values are presented as means ± standard deviations. Data were analyzed using the Mann-Whitney U test.
T2DM, type 2 diabetes mellitus; NAFLD, non-alcoholic fatty liver disease; HbA1c, glycated hemoglobin; HOMA-IR, homeostatic model assessment of insulin resistance; AIR, acute insulin response; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; TG, triglyceride; TC, total cholesterol; BUN, blood urea nitrogen; AST, aspartate transaminase; ALT, alanine transferase; γGTP, γ-glutamyl transpeptidase.

Dietary assessment

Table 3 shows the carbohydrate, protein, fat, and fiber intakes of the participants. There were no significant differences in terms of macronutrient intakes; however, the dietary fiber intakes of the patients with T2DM who did not have NAFLD (15.70 ± 4.56 g/1,000 kcal) were significantly higher than those of the patients with NAFLD (14.1 ± 3.86 g/1,000 kcal, $p < 0.05$). The fiber intake ratios of the patients without NAFLD were significantly higher than that of those with NAFLD ($p = 0.001$).

Dietary fiber and NAFLD

Fig. 1 shows the associations between fiber intake ratio and γGTP in our patients with T2DM, with and without NAFLD. The correlation between total fiber intake and γGTP was negative in both the patients with NAFLD ($r = -0.345$, $p = 0.025$) and those without ($r = -0.145$, $p = 0.045$). With an increase in the fiber intake ratio achieving AI, the risk of developing NAFLD decreased. The association between fiber intake and NAFLD is presented in **Table 4**. When intakes of fiber were stratified by ratio to the AI target, those with a 125% fiber intake ratio had a 0.29× lower risk of having NAFLD (OR, 0.289; 95% CI, 0.121–0.679; $p < 0.01$). Patients

Table 3. Daily nutrient intake in patients with T2DM with and without NAFLD

Dietary intake	Patients with T2DM and NAFLD (n = 55)	Patients with T2DM without NAFLD (n = 210)	p-value
Energy (kcal)	1,768.17 ± 408.29	1,735.51 ± 448.86	0.442
Carbohydrate (g)	256.83 ± 58.13	259.10 ± 63.10	0.275
Protein (g)	75.94 ± 22.06	74.30 ± 23.38	0.869
Fat (g)	45.42 ± 19.77	44.64 ± 23.21	0.697
Energy (%)[1)]	80.15 ± 14.90	88.30 ± 23.65	0.014
Carbohydrate (%)[2)]	197.56 ± 44.72	199.31 ± 48.77	0.716
Protein (%)[2)]	126.93 ± 32.92	136.35 ± 41.82	0.185
C:P:F	59.1:17.2:22.8	60.7:17.1:22.4	0.838
Fiber (g)	24.46 ± 7.12	26.84 ± 9.53	0.069
Fiber (%)[3)]	92.67 ± 27.17	117.61 ± 46.54	0.001
Fiber (g)/1,000 kcal	14.11 ± 3.86	15.70 ± 4.56	0.047
Cholesterol (mg)	270.56 ± 181.55	259.10 ± 63.40	0.580

Values are presented as means ± standard deviations. Data were analyzed using the Mann-Whitney U test.
T2DM, type 2 diabetes mellitus; NAFLD, non-alcoholic fatty liver disease; C, carbohydrate; P, protein; F, fat.
[1)]Ratio of estimated energy requirements; [2)]Ratio of recommended nutrient intake; [3)]Ratio of adequate intake.

https://doi.org/10.4163/jnh.2024.57.3.282

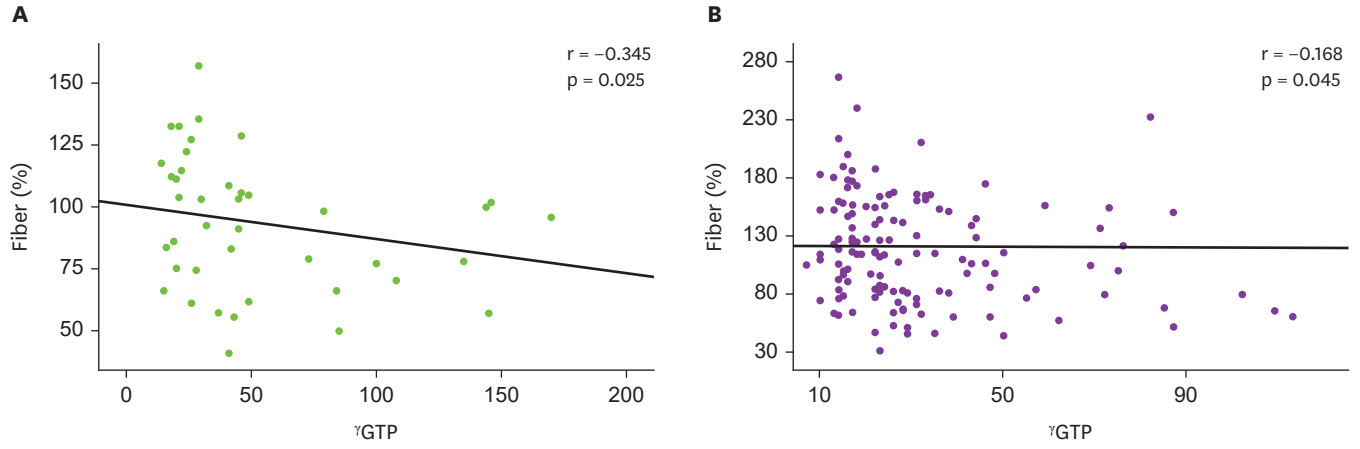

Fig. 1. The correlation between fiber intake ratio and γGTP in patients with type 2 diabetes mellitus and NAFLD (A) or without NAFLD (B).
γGTP, gamma-glutamyltranspeptidase; NAFLD, non-alcoholic fatty liver disease.

Table 4. Logistic regression analyses to evaluate the association between fiber intake and non-alcoholic fatty liver disease

Fiber intake	B	ORs	95% CI	p-value
50% of adequate intake	0.113	1.120	0.432–2.903	0.054
75% of adequate intake	−0.694	0.499	0.233–1.070	0.074
100% of adequate intake	0.664	0.515	0.265–1.002	0.051
125% of adequate intake	−1.251	0.286	0.121–0.679	0.005
150% of adequate intake	−2.581	0.076	0.010–0.565	0.012

Values are ORs at 95% CIs as continuous variables, per standard deviation increment, for evaluating NAFLD using logistic regression.
OR, odds ratio; CI, confidence interval.

with a fiber intake ratio of 150% of the AI had 0.08× lower OR for NAFLD (OR, 0.076; 95% CI, 0.010–0.565; $p < 0.05$). As the ratio of fiber intake to AI increased, the OR for NAFLD tended to decrease; however, the difference was not statistically significant.

DISCUSSION

Over the past 10 years, the prevalence of diabetes and NAFLD has increased in several regions, including Korea, owing to decreases in health-conscious behaviors and more Westernized lifestyles [23]. This has increased the incidence of health-related problems in several Asian countries [24]. According to a recent meta-analysis, 28.5% of Asians suffer from NAFLD [25]. In one Korean cohort study, the prevalence of NAFLD was 27%, and 47% of patients with prediabetes had NAFLD [26].

This study aimed to compare the dietary intake patterns of patients with T2DM with and without NAFLD, as well as the relationship between the anthropometric and biochemical variables associated with NAFLD. The results indicated that dietary fiber intake may be associated with NAFLD. The group with NAFLD in our patient cohort was found to have a lower overall fiber intake. Notably, we also found that a higher fiber intake was associated with a lower risk of NAFLD in patients with T2DM.

Previous nutritional and NAFLD-related studies have mainly focused on the negative effects of fat intake. One study revealed that a high-fat diet may lead to the rapid development of

https://doi.org/10.4163/jnh.2024.57.3.282

NAFLD, while others have suggested an association between NAFLD and different types of fat. However, we found that the patient group with NAFLD in our cohort had a lower fiber consumption. In a cross-sectional study of healthy Dutch adults, the participants with high fatty liver indexes were shown to have lower levels of dietary fiber consumption [19]. A similar Chinese study found a negative correlation between total dietary fiber intake and NAFLD [20]. Several other studies have also investigated the relationship between dietary fiber intake and NAFLD, with findings that are consistent with ours from this study.

Furthermore, a recent randomized controlled trial found a correlation between fiber intake and degree of liver fibrosis. That study showed that, while consuming higher fruit fiber (≥ 8.8 g/day) significantly decreased hepatic enzymes, consuming higher insoluble fiber (≥ 7.5 g/day) improved liver fibrosis [18]. Another study found that an increased intake of soluble and insoluble fibers, from 19 to 29 g/day, improved hepatic steatosis and reduced liver enzymatic activity in patients with NAFLD, potentially by altering intestinal permeability [27].

The average dietary fiber intake of 24.5 and 26.8 g in this study was adequate, as the recommended intake for Koreans is 20 g for women and 30 g for men [28]. However, the risk of developing NAFLD was reduced when 125% of the AI for fiber (up to 37.5 g for men and up to 25 g for women) was consumed. Notably, increasing this intake ratio to 150% further reduced the risk of developing NAFLD. These results are consistent with those of another recent cross-sectional study in China [29]. As the total daily fiber intakes of the Chinese participants in that study increased, the OR 0.20 (0.16–0.25) for the risk of developing NAFLD decreased significantly [29]. Another study from Iran demonstrated that patients with NAFLD (31.2 g) consumed less dietary fiber than healthy controls (35.3 g) and reported that reduced fiber intake may play an important role in the progression of NAFLD [30]. Studies on the association between dietary fiber intake and NAFLD have reported on the intake of soluble or insoluble dietary fibers from various sources. No associations have been observed between soluble dietary fiber and insoluble fiber intake; however, a significant association was reported with higher insoluble fiber intake [20]. Regardless of the source of dietary fiber, an increased intake appears to reduce the risk of developing NAFLD [30]. There is limited research on the recommended amount of fiber intake to reduce the risk of NAFLD; however, most studies agree that increasing fiber intake is important. Notably, the American Diabetes Association recommends that men and women with diabetes maintain a dietary fiber intake of up to 38 g and up to 25 g per day, respectively [31]. Our study recommends that patients with obesity and T2DM increase their fiber intake by 1.25–1.5 times the AI to prevent and treat complications such as NAFLD.

Although the mechanisms underlying the relationship between dietary fiber intake and NAFLD are poorly understood, several potential mechanisms have been proposed. Specifically, the pathophysiological mechanism of NAFLD has been found to include insulin resistance, hepatic lipid metabolism, and intestinal floral changes [31-34]. Dietary fiber consumption can reduce postprandial blood glucose levels and stomach emptying [31]. Furthermore, research has indicated that dietary fiber intake may promote fat excretion [32]. In addition, intestinal microbes ferment dietary fiber to create short-chain fatty acids (such as propionic acid and butyric acid) [33], which control hepatic lipid metabolism and improve insulin sensitivity [34,35]. In other words, dietary fiber helps patients with NAFLD by promoting a lower caloric intake and stimulating healthy gut microbiota, which in turn reduces inflammation and liver injury.

https://doi.org/10.4163/jnh.2024.57.3.282

This study had several notable strengths. First, a standardized approach was established and strictly maintained by researchers with specialized training. Second, we confirmed a statistically significant negative correlation between dietary fiber intake and NAFLD using various analyses. Nevertheless, the study was also subject to certain key limitations worth noting. First, because the study cohort included individuals who visited particular health screening centers in Korea for their checks, it's possible that it wasn't completely representative of the general population and that selection bias played some role in it. Second, we could not evaluate the participant's physical activity habits, which is a significant factor in NAFLD. Third, owing to the cross-sectional design of our study, we could not establish a relationship between dietary fiber intake and the risk of NAFLD.

SUMMARY

The purpose of this study was to investigate the dietary fiber intake in patients with T2DM, both with and without NAFLD. Dietary intake levels of total fiber—including cereals, fruits, and vegetables—were found to be negatively associated with the risk of developing NAFLD in middle-aged Korean patients with T2DM. Middle-aged patients with T2DM and obesity should therefore be advised to increase their levels of dietary fiber intake to prevent NAFLD. To further clarify this correlation, we strongly recommend conducting larger prospective surveys.

REFERENCES

1. Heald AH, Stedman M, Davies M, Livingston M, Alshames R, Lunt M, et al. Estimating life years lost to diabetes: outcomes from analysis of National Diabetes Audit and Office of National Statistics data. Cardiovasc Endocrinol Metab 2020; 9(4): 183-185. PUBMED | CROSSREF
2. Sun H, Saeedi P, Karuranga S, Pinkepank M, Ogurtsova K, Duncan BB, et al. IDF Diabetes atlas: global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. Diabetes Res Clin Pract 2022; 183: 109119. PUBMED | CROSSREF
3. Younossi ZM, Koenig AB, Abdelatif D, Fazel Y, Henry L, Wymer M. Global epidemiology of nonalcoholic fatty liver disease-Meta-analytic assessment of prevalence, incidence, and outcomes. Hepatology 2016; 64(1): 73-84. PUBMED | CROSSREF
4. Farrell GC, Wong VW, Chitturi S. NAFLD in Asia--as common and important as in the West. Nat Rev Gastroenterol Hepatol 2013; 10(5): 307-318. PUBMED | CROSSREF
5. Chew NW, Ng CH, Muthiah MD, Sanyal AJ. Comprehensive review and updates on holistic approach towards non-alcoholic fatty liver disease management with cardiovascular disease. Curr Atheroscler Rep 2022; 24(7): 515-532. PUBMED | CROSSREF
6. Seo DH, Suh YJ, Cho Y, Ahn SH, Seo S, Hong S, et al. Advanced liver fibrosis is associated with chronic kidney disease in patients with type 2 diabetes mellitus and nonalcoholic fatty liver disease. Diabetes Metab J 2022; 46(4): 630-639. PUBMED | CROSSREF
7. Ye Q, Zou B, Yeo YH, Li J, Huang DQ, Wu Y, et al. Global prevalence, incidence, and outcomes of non-obese or lean non-alcoholic fatty liver disease: a systematic review and meta-analysis. Lancet Gastroenterol Hepatol 2020; 5(8): 739-752. PUBMED | CROSSREF
8. Mantovani A, Byrne CD, Bonora E, Targher G. Nonalcoholic fatty liver disease and risk of incident type 2 diabetes: a meta-analysis. Diabetes Care 2018; 41(2): 372-382. PUBMED | CROSSREF
9. Rhee EJ. Nonalcoholic fatty liver disease and diabetes: an epidemiological perspective. Endocrinol Metab 2019; 34(3): 226-233. PUBMED | CROSSREF
10. Bril F, Cusi K. Management of nonalcoholic fatty liver disease in patients with type 2 diabetes: a call to action. Diabetes Care 2017; 40(3): 419-430. PUBMED | CROSSREF
11. Dharmalingam M, Yamasandhi PG. Nonalcoholic fatty liver disease and type 2 diabetes mellitus. Indian J Endocrinol Metab 2018; 22(3): 421-428. PUBMED | CROSSREF

12. Palma R, Pronio A, Romeo M, Scognamiglio F, Ventriglia L, Ormando VM, et al. The role of insulin resistance in fueling NAFLD pathogenesis: from molecular mechanisms to clinical implications. J Clin Med 2022; 11(13): 3649. PUBMED | CROSSREF

13. Radaelli MG, Martucci F, Perra S, Accornero S, Castoldi G, Lattuada G, et al. NAFLD/NASH in patients with type 2 diabetes and related treatment options. J Endocrinol Invest 2018; 41(5): 509-521. PUBMED | CROSSREF

14. Chalasani N, Younossi Z, Lavine JE, Charlton M, Cusi K, Rinella M, et al. The diagnosis and management of nonalcoholic fatty liver disease: practice guidance from the American Association for the Study of Liver Diseases. Hepatology 2018; 67(1): 328-357. PUBMED | CROSSREF

15. Guerrerio AL, Colvin RM, Schwartz AK, Molleston JP, Murray KF, Diehl A, et al. Choline intake in a large cohort of patients with nonalcoholic fatty liver disease. Am J Clin Nutr 2012; 95(4): 892-900. PUBMED | CROSSREF

16. Zhang S, Fu J, Zhang Q, Liu L, Meng G, Yao Z, et al. Association between nut consumption and non-alcoholic fatty liver disease in adults. Liver Int 2019; 39(9): 1732-1741. PUBMED | CROSSREF

17. Zhang S, Gu Y, Wang L, Zhang Q, Liu L, Lu M, et al. Association between dietary raw garlic intake and newly diagnosed nonalcoholic fatty liver disease: a population-based study. Eur J Endocrinol 2019; 181(6): 591-602. PUBMED | CROSSREF

18. Cantero I, Abete I, Monreal JI, Martinez JA, Zulet MA. Fruit fiber consumption specifically improves liver health status in obese subjects under energy restriction. Nutrients 2017; 9(7): 667. PUBMED | CROSSREF

19. Rietman A, Sluik D, Feskens EJ, Kok FJ, Mensink M. Associations between dietary factors and markers of NAFLD in a general Dutch adult population. Eur J Clin Nutr 2018; 72(1): 117-123. PUBMED | CROSSREF

20. Xia Y, Zhang S, Zhang Q, Liu L, Meng G, Wu H, et al. Insoluble dietary fibre intake is associated with lower prevalence of newly-diagnosed non-alcoholic fatty liver disease in Chinese men: a large population-based cross-sectional study. Nutr Metab (Lond) 2020; 17(1): 4. PUBMED | CROSSREF

21. Chung GE, Youn J, Kim YS, Lee JE, Yang SY, Lim JH, et al. Dietary patterns are associated with the prevalence of nonalcoholic fatty liver disease in Korean adults. Nutrition 2019; 62: 32-38. PUBMED | CROSSREF

22. Han JM, Jo AN, Lee SM, Bae HS, Jun DW, Cho YK, et al. Associations between intakes of individual nutrients or whole food groups and non-alcoholic fatty liver disease among Korean adults. J Gastroenterol Hepatol 2014; 29(6): 1265-1272. PUBMED | CROSSREF

23. Li J, Zou B, Yeo YH, Feng Y, Xie X, Lee DH, et al. Prevalence, incidence, and outcome of non-alcoholic fatty liver disease in Asia, 1999-2019: a systematic review and meta-analysis. Lancet Gastroenterol Hepatol 2019; 4(5): 389-398. PUBMED | CROSSREF

24. Chang Y, Jung HS, Yun KE, Cho J, Cho YK, Ryu S. Cohort study of non-alcoholic fatty liver disease, NAFLD fibrosis score, and the risk of incident diabetes in a Korean population. Am J Gastroenterol 2013; 108(12): 1861-1868. PUBMED | CROSSREF

25. Chon YE, Kim KJ, Jung KS, Kim SU, Park JY, Kim Y, et al. The relationship between type 2 diabetes mellitus and non-alcoholic fatty liver disease measured by controlled attenuation parameter. Yonsei Med J 2016; 57(4): 885-892. PUBMED | CROSSREF

26. Jimba S, Nakagami T, Takahashi M, Wakamatsu T, Hirota Y, Iwamoto Y, et al. Prevalence of non-alcoholic fatty liver disease and its association with impaired glucose metabolism in Japanese adults. Diabet Med 2005; 22(9): 1141-1145. PUBMED | CROSSREF

27. Krawczyk M, Maciejewska D, Ryterska K, Czerwińka-Rogowska M, Jamioł-Milc D, Skonieczna-Żydecka K, et al. Gut permeability might be improved by dietary fiber in individuals with nonalcoholic fatty liver disease (NAFLD) undergoing weight reduction. Nutrients 2018; 10(11): 1793. PUBMED | CROSSREF

28. The Korean Nutrition Society. Dietary Reference Intakes for Koreans 2015. Seoul: The Korean Nutrition Society; 2020.

29. Zolfaghari H, Askari G, Siassi F, Feizi A, Sotoudeh G. Intake of nutrients, fiber, and sugar in patients with nonalcoholic fatty liver disease in comparison to healthy individuals. Int J Prev Med 2016; 7: 98. PUBMED | CROSSREF

30. Zhao H, Yang A, Mao L, Quan Y, Cui J, Sun Y. Association between dietary fiber intake and non-alcoholic fatty liver disease in adults. Front Nutr 2020; 7: 593735. PUBMED | CROSSREF

31. American Diabetes Association. American Diabetes Association (ADA) guidelines. Arlington (VA): American Diabetes Association; 2010.

32. Kristensen M, Jensen MG, Aarestrup J, Petersen KE, Søndergaard L, Mikkelsen MS, et al. Flaxseed dietary fibers lower cholesterol and increase fecal fat excretion, but magnitude of effect depend on food type. Nutr Metab (Lond) 2012; 9(1): 8. PUBMED | CROSSREF

33. de Carvalho CM, de Paula TP, Viana LV, Machado VM, de Almeida JC, Azevedo MJ. Plasma glucose and insulin responses after consumption of breakfasts with different sources of soluble fiber in type 2 diabetes patients: a randomized crossover clinical trial. Am J Clin Nutr 2017; 106(5): 1238-1245. PUBMED | CROSSREF

34. Lundin EA, Zhang JX, Lairon D, Tidehag P, Aman P, Adlercreutz H, et al. Effects of meal frequency and high-fibre rye-bread diet on glucose and lipid metabolism and ileal excretion of energy and sterols in ileostomy subjects. Eur J Clin Nutr 2004; 58(10): 1410-1419. PUBMED | CROSSREF

35. Sandberg JC, Björck IM, Nilsson AC. Rye-based evening meals favorably affected glucose regulation and appetite variables at the following breakfast; a randomized controlled study in healthy subjects. PLoS One 2016; 11(3): e0151985. PUBMED | CROSSREF