

Association of the Cardiovascular Health Diet Index and Concise Healthy Diet Score with Non-Alcoholic Fatty Liver Disease: A Secondary Analysis of a Case-Control Study

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Abstract

Purpose

Diet quality plays a pivotal role in the prevention of non-alcoholic fatty liver disease (NAFLD). However, evidence on the associations between the Cardiovascular Health Diet Index (CHDI) and the Concise Healthy Diet Score (CHDS) and NAFLD remains limited, particularly in Middle Eastern populations. In this study, we investigated this association.

Methods

This case-control study included 675 Iranian adults (225 patients with NAFLD and 450 controls). Dietary intake was evaluated utilizing a validated 168-item food frequency questionnaire. Multivariable logistic regression models were used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) for NAFLD after adjustment for potential confounders.

Results

Among the NAFLD cases, the mean CHDI score was 55.9 ± 10.3 , and the median CHDS score was 2.00 (IQR: 1.00–3.00). Among the controls, the mean CHDI score was 62.2 ± 10.9 , and median CHDS score was 2.00 (IQR: 2.00–3.00). In multivariable adjusted model, participants in the highest tertile of the CHDI had an 84% lower odds of NAFLD compared with those in the lowest tertile (OR = 0.16; 95% CI: 0.08–0.32; P for trend < 0.001). Similarly, for the CHDS, participants in the highest tertile had 69% lower odds of NAFLD compared with the lowest tertile (OR = 0.31; 95% CI: 0.17–0.60; P for trend = 0.001). These inverse associations were also observed per one-unit increase in each score, with an 8% reduction for CHDI (OR = 0.92; 95% CI: 0.90–0.95, P < 0.001) and a 36% reduction for CHDS (OR = 0.64; 95% CI: 0.49–0.85, P = 0.002).

Conclusion

Higher adherence to the CHDI and CHDS was independently associated with lower odds of NAFLD, respectively. These findings highlight that improving overall dietary quality may be an effective strategy for NAFLD prevention.

Introduction

Non-alcoholic fatty liver disease (NAFLD) represents one of the most commonly encountered chronic hepatic disorders, influencing an estimated 30% of the adult population globally, and has become a major public health problem (1). Latin America has the highest prevalence of NAFLD among all regions, with more than 40% prevalence. It is followed by the Middle East and South Asia with 36 and 33%,

respectively (2). In Iran, evidence indicates that approximately 33–37% of adults suffer from NAFLD. This substantial disease burden is primarily linked to the rising prevalence of obesity, type 2 diabetes, and sedentary behaviors (3, 4). The development of NAFLD is strongly associated with obesity, type 2 diabetes, and sedentary lifestyle behaviors (5). Beyond liver-related complications, NAFLD has negative impacts on cancer, chronic renal disease, and cardiovascular health (6). The high prevalence of NAFLD and its related problems emphasizes the urgent need for safe, effective, and broadly applicable therapeutic strategies (7).

Lifestyle modification, particularly dietary improvement and weight reduction, is reported to be an effective approach. Specifically, the Mediterranean diet contains 35–45% fat, of which at least half is from monounsaturated fatty acids (MUFAs). This diet is reported to include high amounts of legumes, vegetables, fish, and whole grains (8). Based on the American Heart Association's (AHA) dietary recommendations for a healthy diet to prevent CVD and promote cardiovascular health, which is called the Cardiovascular Healthy Diet Index (CHDI), it includes food groups that reflect adherence to dietary recommendations for cardiovascular health, emphasizing greater intake of plant-based foods and lower consumption of processed foods and sugar-sweetened beverages (9). The Concise Healthy Diet Score (CHDS) is a simplified dietary index developed to assess adherence to a healthy dietary pattern and evaluate its association with chronic disease risk. The score includes five key dietary components: higher consumption of vegetables, fruits, fresh fish, and beans, along with lower salt intake. These components were selected based on dietary guideline recommendations and epidemiological evidence demonstrating their protective effects against chronic diseases. CHDS ranges from 0 to 5, with higher scores indicating greater adherence to a healthy dietary pattern. Owing to its emphasis on nutrient-rich foods and sodium restriction, the CHDS may also be relevant to metabolic disorders such as NAFLD, although evidence regarding this association remains limited (10).

Although both CHDI and CHDS emphasize healthy dietary behaviors, evidence regarding their association with NAFLD, particularly in Middle Eastern populations, remains limited. Therefore, the present study aimed to investigate the association between the Cardiovascular CHDI and the CHDS and the odds of NAFLD among adults using a case-control design.

Materials and Methods

Study Design and Participants

This case–control study was conducted among 675 adults aged 20–60 years in Tehran, Iran, comprising 225 cases with NAFLD and 450 healthy controls. Participants were recruited from the Metabolic Liver Disease Research Center, a referral center affiliated with Isfahan University of Medical Sciences.

All subjects underwent abdominal ultrasonography using a GE Logiq S8 ultrasound system (GE Healthcare, USA) equipped with a convex transducer. An experienced radiologist, blinded to participants' dietary intake data and other exposure variables related to this study's hypothesis, conducted

hepatobiliary imaging examinations. Hepatic steatosis was identified using ultrasonographic findings, including increased hepatic echogenicity relative to the renal cortex, decreased ultrasound signal, and reduced visualization of the intrahepatic diaphragm and vessels. Cases were classified as NAFLD if they presented ultrasonographic evidence of hepatic steatosis. At the same time, other participants with other causes of liver disease and with a history of alcohol consumption had been excluded. Controls were selected from the same source population and had no ultrasonographic signs or clinical symptoms suggestive of NAFLD.

Participants were excluded if they: 1) were following a special diet; 2) had a background of chronic metabolic disease or organ-specific disease such as kidney disease, gastrointestinal disease, hepatic disease, including autoimmune hepatitis, Wilson's disease, etc., and Alcoholic fatty liver disease; 3) had a cancer diagnosis; 4) were taking medications known to cause hepatic steatosis or hepatotoxicity; 5) had incomplete dietary data (< 35 items reported in the food frequency questionnaire(FFQ)); 6) reported implausible energy intake (< 800 or > 4200 kcal/day); To ensure the inclusion of incident NAFLD cases, individuals with other chronic metabolic disease such as diabetes were excluded from both the case and control groups, thus reducing the likelihood of enrolling participants with pre-existing or long-standing NAFLD.

Measurements

Dietary Assessment

A 168-item semi-quantitative (FFQ), which was validated in the Iranian adult population and has demonstrated acceptable relative validity compared with repeated 24-hour dietary recalls, was used to assess dietary intake during the last year (11, 12). Participants articulated the regularity of consumption for each food category utilizing standardized classifications (never, monthly, weekly, or daily). Portion sizes were quantified in grams by employing Iranian domestic measurement standards. The United States Department of Agriculture (USDA) Food Composition Table (FCT) (13) was the primary source used to calculate energy and nutrient intakes; data from the Iranian FCT were used for traditional Iranian foods not included in the USDA database. Afterward, reported frequencies were converted to daily consumption levels (g/day).

Calculation of Dietary Indices

The AHA guidelines were used to calculate the CHDI index, which advised a lower intake of red meat, sugar-sweetened beverages, and ultra-processed foods, and a regular intake of vegetables, fruits, nuts, whole-grain cereals, dairy products, beans, and fish and seafood (14).

CHDI was calculated based on the consumption of 11 components, resulting in a score ranging from 0 to 10, and each participant received a score between 0 and 110. A maximum score of 10 is assigned to

participants who have intake above the amount of each nutrient, including fruits(340 g/d), vegetables(180 g/d), nuts(12.9 g/d), whole-grain cereals (90 g/d), beans(80 g/d), dairy products (250 g/d), and fish and seafood (28.6 g/d). However, they received 0 points if they had higher intake than 12.9 g/d of processed meat,28.6 g/d of red meat, 142.9 ml/d of sugar-sweetened beverages, and 23 points of ultra-processed foods. Higher scores indicated greater adherence to cardiovascular-healthy dietary recommendations (15).

The CHDS was calculated using selected dietary components, including fruits, vegetables, beans, fish, and sodium intake. Higher scores represented better overall dietary quality (16). Dietary intake was assessed using the validated FFQ, and daily intakes of each component were calculated for each participant. Participants received one point for meeting the predefined criterion for each healthy dietary component and zero otherwise. Because sodium is considered an unfavorable component, participants with lower sodium intake received one point. Therefore, the total CHDS ranged from 0 to 5, with higher scores indicating better diet quality.

Physical activity assessment

Each participant's level of physical activity was evaluated at the study baseline using the Modifiable Activity Questionnaire (MAQ). It has been verified in the past to evaluate Iranians' level of physical activity. Participants were asked about the frequency and duration of their activities throughout the past year through a skilled interviewer. The time spent on a particular activity each week was multiplied by its corresponding metabolic equivalent (MET) to obtain the level of physical activity, which was then expressed as MET-hours per week (MET-h/week) (17).

Demographic, anthropometric, and clinical assessment

Information regarding socio-demographic factors (age, sex, smoking status, marital status, socioeconomic status (SES), academic status, employment, and anthropometric measurements) was collected using standardized questionnaires administered by skilled interviewers (18). A digital scale with a 100g accuracy was used to determine individuals' weight while they were wearing light clothing and no shoes. A stadiometer with a precision of 0.5 centimeters was used to measure the height of participants in a standing position, without shoes. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Three factors were used to calculate SES: possessions ownership, academic education, and home size (≤ 4). Each principle was worth one point, and participants were classified as low (0–1), middle (2), or high SES (3).

Statistical Analysis

All statistical analyses were performed using SPSS software (version 21.0; IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Kolmogorov–Smirnov test and by visual inspection of histograms. Data are presented as mean $\pm$ standard deviation (SD) or median (interquartile range, IQR) for continuous variables and as percentages for categorical variables. Between-groups

comparisons (NAFLD and non-NAFLD) were conducted using chi-square tests for categorical variables and independent t-tests for continuous variables. Participants were also classified into tertiles based on CHDI and CHDS scores. Trends of variables across these tertiles were evaluated employing linear regression for continuous variables and chi-square tests for categorical variables.

Multivariable logistic regression models were used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) for the presence of NAFLD across tertiles. Three distinct models were constructed for the analytical framework. The crude model remained unadjusted. Model 1 incorporated adjustments for age and sex, while Model 2 included additional adjustments for BMI, smoking status, physical activity, SES, and total dietary energy intake. Also, the ORs and 95% CIs for NAFLD per one-unit increase in the CHDI and CHDS scores were estimated using multivariable-adjusted logistic regression models. The threshold for statistical significance was established at $P < 0.05$ for all conducted analyses.

Results

A total of 675 participants (225 cases with NAFLD and 450 controls) were included in this case-control study. Among the 225 NAFLD cases, the mean age was 38.6 ± 8.7 years, mean BMI was 30.5 ± 4.02 kg/m², mean CHDI score was 55.9 ± 10.3 , and median CHDS score was 2.00 (IQR: 1.00–3.00). Among the 450 controls, the mean age was 37.8 ± 8.9 years, mean BMI was 24.9 ± 3.0 kg/m², mean CHDI score was 62.2 ± 10.9 , and median CHDS score was 2.00 (IQR: 2.00–3.00).

Table 1 compares the baseline characteristics between cases and controls. Compared with controls, NAFLD cases had significantly higher BMI ($P < 0.001$), lower physical activity ($P < 0.001$), and higher percentage of smokers ($P = 0.006$), higher prevalence of being married ($P = 0.012$), higher prevalence of large family size ($P < 0.001$), higher percentage of foreign travel ($P < 0.001$), high income ($P < 0.001$), and higher SES ($P < 0.001$). Conversely, house ownership was lower in cases ($P = 0.008$). Regarding dietary intakes, cases had significantly higher energy intake ($P = 0.004$). For CHDI components, cases consumed fewer vegetables ($P < 0.001$) but more dairy products ($P = 0.005$), processed meat ($P < 0.001$), sugar-sweetened beverages ($P < 0.001$), and ultra-processed foods ($P < 0.001$). The CHDI score was significantly lower in cases ($P < 0.001$). For CHDS components, cases had lower vegetable intake ($P = 0.001$), while no significant differences were observed for fruits, beans, fish, sodium, or the CHDS score.

Table 1
Population characteristics based on the cases and controls.

Variables	NAFLD status		P-value
	Cases (n = 225)	Controls (n = 450)	
Demographic data			
Age (year)	38.6 ± 8.7	37.8 ± 8.9	0.293
Sex (male)	51.6	51.8	0.354
Body mass index (Kg/m ²)	30.5 ± 4.02	24.9 ± 3.0	< 0.001
Physical activity (MET/h/week)	1119 ± 616	1590 ± 949	< 0.001
Smoking (yes)	7.1	2.7	0.006
Marital status (married, %)	88.9	81.3	0.012
Education level (Bachelor and higher, %)	44.9	47.8	0.478
Family size (> 4 member, %)	85.8	57.3	< 0.001
House acquisition (yes, %)	61.8	71.8	0.008
Foreign travel (yes, %)	23.6	12.0	< 0.001
Income (high, %)	24.9	4.7	< 0.001
Socio-economic status			< 0.001
Low	21.3	31.6	
Middle	33.8	40.4	
High	44.9	28.0	
Dietary intake			
Energy intake (Kcal/d)	2315 ± 606	2170 ± 625	0.004
Carbohydrate (% Kcal)	55.9 ± 7.4	55.9 ± 6.56	0.913
Protein (% Kcal)	13.2 ± 2.46	13.2 ± 2.2	0.924
Fat (% Kcal)	30.7 ± 7.4	30.8 ± 6.5	0.941
CHDI components			
CHDI; Cardiovascular Health Diet Index, CHDS; Concise Healthy Diet Score.			
Data were expressed as mean (SD) or median (interquartile range) and percent (%) for continuous and categorical variables, respectively.			

Variables	NAFLD status		P-value
	Cases (n = 225)	Controls (n = 450)	
Demographic data			
Fruits (g/d)	358 ± 260	353 ± 270	0.823
Vegetables (g/d)	258 ± 137	300 ± 151	< 0.001
Nuts (g/d)	3.53 (1.62–7.58)	3.79 (1.92–6.95)	0.652
Whole-grain cereal (g/d)	67.10 (32.09–116)	56.94 (27.52–120.32)	0.329
Beans (g/d)	8.61 (4.67–17.23)	9.61 (5.25–18.84)	0.542
Fish (g/d)	6.66 (3.47–13.23)	6.80 (3.65–12.74)	0.637
Dairy products (g/d)	472 ± 250	417 ± 239	0.005
Red meat (g/d)	17.26 (9.02–27.70)	15.23 (8.48–26.02)	0.394
Processed meat (g/d)	10.68 (4.31–16.78)	2.00 (0.32–4.83)	< 0.001
Sugar-sweetened beverages (g/d)	35.33 (9.67–80.00)	9.33 (2.92–23.58)	< 0.001
Ultra-processed foods (g/d)	202 ± 152	120 ± 82.8	< 0.001
CHDI score	55.9 ± 10.3	62.2 ± 10.9	< 0.001
CHDS components			
Fruits (serving/d)	3.0 ± 2.2	2.9 ± 2.3	0.876
Vegetables (serving/d)	2.6 ± 1.3	3.0 ± 1.5	0.001
Beans (serving/d)	0.64 (0.32–1.18)	0.68 (0.36–1.33)	0.504
Fish (serving/d)	1.55 (0.80–3.08)	1.58 (0.85–2.97)	0.637
Sodium (mg/d)	3547 (2681–5213)	3425 (2450–5448)	0.502
CHDS score	2.00 (1.00–3.00)	2.00 (2.00–3.00)	0.064
CHDI; Cardiovascular Health Diet Index, CHDS; Concise Healthy Diet Score.			
Data were expressed as mean (SD) or median (interquartile range) and percent (%) for continuous and categorical variables, respectively.			

Table 2 presents the characteristics of participants across tertiles of the CHDI. Across increasing tertiles of CHDI (indicating better diet quality), participants were older (P for trend = 0.002), had lower BMI (P for trend < 0.001), and consumed more energy (P for trend < 0.001). The percentages of energy from protein (P for trend = 0.004) and carbohydrate (P for trend < 0.001) increased across tertiles, whereas the fat percentage decreased (P for trend < 0.001). The intakes of fruits, vegetables, nuts, whole grains, beans,

fish, and dairy products increased across tertiles of the CHDI (P for trend < 0.001). In contrast, intakes of processed meat, sugar-sweetened beverages, and ultra-processed foods were lower in higher tertiles (P for trend < 0.001). No significant trend was observed for red meat.

Table 2
Population characteristics based on the tertiles of cardiovascular health diet index

Variables	Tertiles of CHDI			P-trend
	T ₁ (n = 285)	T ₂ (n = 211)	T ₃ (n = 179)	
Demographic data				
Age (year)	37.2 ± 8.7	37.8 ± 8.6	40.0 ± 9.0	0.002
Sex (male)	53.3	55.9	49.2	0.408
Body mass index (Kg/m ²)	27.3 ± 4.2	26.8 ± 4.3	26.0 ± 4.3	< 0.001
Physical activity (MET/h/week)	1409 ± 877	1439 ± 915	1463 ± 848	0.512
Smoking (yes)	5.6	4.3	1.7	0.085
Marital status (married, %)	81.8	85.8	84.9	0.439
Socio-economic status				0.256
Low	27.4	24.6	33.5	
Middle	37.5	38.9	38.5	
High	35.1	36.5	27.9	
Dietary intake				
Energy intake (Kcal/d)	2090 ± 635	2259 ± 601	2376 ± 586	< 0.001
Carbohydrate (% Kcal)	54.7 ± 7.5	56.7 ± 5.6	56.8 ± 6.7	< 0.001
Protein (% Kcal)	12.9 ± 2.2	13.3 ± 2.5	13.6 ± 2.0	0.004
Fat (% Kcal)	32.3 ± 7.5	29.8 ± 5.5	29.5 ± 6.7	< 0.001
CHDI components				
Fruits (g/d)	249 ± 219	374 ± 224	499 ± 308	< 0.001
Vegetables (g/d)	239 ± 139	291 ± 126	355 ± 159	< 0.001
Nuts (g/d)	2.42 (1.00–4.41)	4.16 (2.24–7.50)	6.13 (3.56–12.7)	< 0.001
Whole-grain cereal (g/d)	35.7 (17.2–74.3)	65.5 (35.9–121.2)	110.8 (67.1–161.6)	< 0.001
CHDI; Cardiovascular Health Diet Index.				
Data were expressed as mean (SD) or median (interquartile range) and percent (%) for continuous and categorical variables, respectively.				

Variables	Tertiles of CHDI			P-trend
	T ₁ (n = 285)	T ₂ (n = 211)	T ₃ (n = 179)	
Demographic data				
Beans (g/d)	8.1 (4.0–14.7)	9.0 (5.5–16.4)	13.3 (5.9–28.6)	< 0.001
Fish (g/d)	5.9 (3.1–11.0)	7.0 (4.0–12.8)	8.7 (4.6–15.7)	< 0.001
Dairy products (g/d)	398 ± 258	457 ± 233	469 ± 224	0.001
Red meat (g/d)	19.5 (9.3–30.9)	15.3 (8.9–25.1)	13.0 (7.3–25.0)	0.098
Processed meat (g/d)	6.2 (2.8–13.0)	3.1 (0.71–7.4)	1.33 (0.16–2.83)	< 0.001
Sugar sweetened beverages (g/d)	24.3 (9.3–65.7)	12.1 (8.2–35.3)	8.3 (0.7–16.0)	< 0.001
Ultra-processed foods (g/d)	182.0 ± 145	139 ± 91	102 ± 67	< 0.001
CHDI score	49.6 ± 6.2	62.6 ± 2.6	73.9 ± 5.2	< 0.001
CHDI; Cardiovascular Health Diet Index.				
Data were expressed as mean (SD) or median (interquartile range) and percent (%) for continuous and categorical variables, respectively.				

The characteristics of participants across tertiles of the CHDS are shown in Table 3. Across tertiles of CHDS, participants were older, consumed more energy, and had higher protein intake (P for trend < 0.001). The intakes of fruits, vegetables, beans, and fish increased across tertiles of the CHDS (P for trend < 0.001). Sodium intake was significantly lower in the highest tertile (P for trend = 0.010). No significant trends were observed for BMI, physical activity, smoking, marital status, or SES.

Table 3
Population characteristics based on the tertiles of Concise Healthy Diet Score

Variables	Tertiles of CHDS			P-trend
	T ₁ (n = 172)	T ₂ (n = 306)	T ₃ (n = 197)	
Demographic data				
Age (year)	36.5 ± 8.5	37.7 ± 8.6	40.1 ± 9.0	< 0.001
Sex (male)	57.0	54.6	47.2	0.132
Body mass index (Kg/m ²)	26.7 ± 4.0	26.5 ± 4.2	27.4 ± 4.7	0.085
Physical activity (MET/h/week)	1477.5 ± 888.7	1464 ± 883	1346 ± 868.7	0.143
Smoking (yes)	2.3	5.6	3.6	0.195
Marital status (married, %)	82.6	81.7	88.3	0.112
Socio-economic status				0.585
Low	25.0	30.7	26.9	
Middle	41.9	35.3	39.6	
High	33.1	34.0	33.5	
Dietary intake				
Energy intake (Kcal/d)	2069.8 ± 592.9	2234 ± 594	2324.2 ± 667.5	< 0.001
Carbohydrate (% Kcal)	55.6 ± 7.1	56.0 ± 6.7	56.1 ± 6.7	0.510
Protein (% Kcal)	12.7 ± 2.3	13.2 ± 2.0	13.6 ± 2.4	< 0.001
Fat (% Kcal)	31.5 ± 7.0	30.8 ± 7.0	30.2 ± 6.4	0.053
CHDS components				
Fruits (serving/d)	1.9 ± 1.8	3.1 ± 2.2	3.6 ± 2.5	< 0.001
Vegetables (serving/d)	1.7 ± 1.0	3.1 ± 1.3	3.5 ± 1.4	< 0.001
Beans (serving/d)	0.52 (0.23–0.86)	0.68 (0.36–1.28)	0.83 (0.44–2.70)	< 0.001
Fish (serving/d)	1.08 (0.60–1.64)	1.48 (0.83–2.23)	3.47 (1.73–4.61)	< 0.001
Sodium (mg/d)	3494 (2792–5570)	3597 (2593–5577)	3039 (2136–4542)	0.010
CHDS; Concise Healthy Diet Score.				
Data were expressed as mean (SD) or median (interquartile range) and percent (%) for continuous and categorical variables, respectively.				

Variables	Tertiles of CHDS			P-trend
	T ₁ (n = 172)	T ₂ (n = 306)	T ₃ (n = 197)	
Demographic data				
CHDS score	1.00 (1.00–1.00)	2.00 (2.00–2.00)	3.00 (3.00–3.00)	< 0.001
CHDS; Concise Healthy Diet Score.				
Data were expressed as mean (SD) or median (interquartile range) and percent (%) for continuous and categorical variables, respectively.				

Table 4 presents the ORs and 95% CIs for NAFLD across tertiles of CHDI and CHDS, as well as per one-unit increase in each score. For CHDI, in Model 1, after adjustment for age and sex, there was a significant inverse association between a higher CHDI score and odds of NAFLD (OR: 0.20; 95%CI: 0.12–0.32; P for trend < 0.001). Further adjustment for BMI, smoking, physical activity, marital status, SES, and energy intake strengthened this inverse relationship (OR: 0.16; 95%CI: 0.08–0.32; P for trend < 0.001). Furthermore, in the fully adjusted model (Model 2), each one-unit increase in CHDI score was associated with an 8% reduction in the odds of NAFLD (OR = 0.92; 95% CI: 0.90–0.95, P < 0.001), confirming a protective direction. For CHDS, in Model 1, after adjustment for age and sex, a significant inverse trend was observed (OR: 0.61; 95%CI: 0.40–0.95; P for trend = 0.032). In the multivariable adjusted model (Model 2), the inverse association between CHDS and odds of NAFLD became stronger (OR: 0.31; 95%CI: 0.17–0.60; P for trend = 0.001). Furthermore, based on the multivariable model, each one-unit increase in CHDS score was associated with a 36% lower odds of NAFLD (OR = 0.64; 95% CI: 0.49–0.85, P = 0.002).

Table 4
Odds ratio (95% CI) of NAFLD across tertiles of Cardiovascular Health Diet Index

Dietary indices	OR (95% CI) of NAFLD					
	Tertile 1	Tertile 2	Tertile 3	P trend*	Per one unit	P value
CHDI						
Median score	51.4	62.6	72.9			
Case/Controls	135 / 150	61 / 150	29 / 150			
Crude model	1.00 (Ref)	0.45 (0.31–0.66)	0.21 (0.13–0.34)	< 0.001	0.94 (0.93–0.96)	< 0.001
Model 1*	1.00 (Ref)	0.44 (0.30–0.66)	0.20 (0.12–0.32)	< 0.001	0.94 (0.93–0.96)	< 0.001
Model 2 [†]	1.00 (Ref)	0.25 (0.14–0.44)	0.16 (0.08–0.32)	< 0.001	0.92 (0.90–0.95)	< 0.001
CHDS						
Median score	1.0	2.0	3.0			
Case/Controls	74 / 98	87 / 219	64 / 133			
Crude model	1.00 (Ref)	0.52 (0.35–0.78)	0.64 (0.41–0.97)	0.043	0.86 (0.71–1.03)	0.102
Model 1*	1.00 (Ref)	0.52 (0.35–0.77)	0.61 (0.40–0.95)	0.032	0.84 (0.70–1.02)	0.077
Model 2 [†]	1.00 (Ref)	0.33 (0.19–0.60)	0.31 (0.17–0.60)	0.001	0.64 (0.49–0.85)	0.002
CHDI; Cardiovascular Health Diet Index, CHDS; Concise Healthy Diet Score.						
*Model 1: adjusted for age and sex						
[†] Model 2: additionally adjusted for Model 1 and body mass index, smoking, physical activity, marital status, socio-economic status, and dietary intake of energy						

Discussion

In this case-control study of 675 Iranian adults, higher adherence to both the CHDI and the CHDS was associated with significantly lower odds of NAFLD. The inverse association was particularly strong for CHDI, as participants in the highest category had 84% lower odds of NAFLD compared with those in the lowest category in the fully adjusted model. Likewise, greater adherence to CHDS was associated with a lower likelihood of NAFLD. In addition, each one-unit increase in CHDI and CHDS was associated with 8% and 36% lower odds of NAFLD, respectively.

These findings are biologically plausible and consistent with current understanding of NAFLD pathogenesis. NAFLD is strongly linked to insulin resistance, excess hepatic de novo lipogenesis, adipose tissue dysfunction, oxidative stress, chronic low-grade inflammation, and alterations in the gut–liver axis (19, 20). Dietary patterns characterized by higher intake of vegetables, fruits, legumes, whole grains, fish, and nuts, alongside lower consumption of processed meats, sugar-sweetened beverages, sodium, and ultra-processed foods, may improve insulin sensitivity, reduce hepatic triglyceride accumulation, and attenuate inflammatory and oxidative pathways involved in hepatic steatosis and progression to steatohepatitis (21). Therefore, the inverse associations observed for both CHDI and CHDS may reflect the cumulative influence of healthier overall dietary behavior on key metabolic mechanisms underlying NAFLD.

Our baseline findings support this interpretation. Compared with controls, patients with NAFLD had higher BMI, lower physical activity, greater smoking prevalence, and higher energy intake, all of which are established correlates of hepatic steatosis and metabolic dysfunction (22–24). Cases also consumed fewer vegetables and more processed meats, sugar-sweetened beverages, dairy products, and ultra-processed foods, with a lower mean CHDI score. This pattern is consistent with prior evidence suggesting that lower-quality diets, particularly those rich in refined or industrially processed foods, may increase the risk of NAFLD through mechanisms involving excess energy intake, poor satiety regulation, insulin resistance, and increased liver fat deposition (25, 26).

An important strength of the present study is the simultaneous evaluation of two separate diet-quality indices. Although both CHDI and CHDS were inversely associated with NAFLD, the association appeared stronger for CHDI. This may indicate that CHDI captures dietary components more closely linked to hepatic fat accumulation and metabolic dysfunction (15). If CHDI places greater emphasis on food groups such as vegetables, whole grains, and foods to limit (e.g., processed meats and sugar-sweetened beverages), it may be more sensitive to dietary patterns directly relevant to NAFLD pathogenesis (21, 25). By contrast, CHDS may reflect a broader healthy-eating construct but with less specificity regarding liver-related metabolic risk (16). Nevertheless, the consistency in direction across both indices strengthens the overall inference that higher diet quality is associated with lower odds of NAFLD.

Our findings are in line with a growing body of evidence linking healthy dietary patterns to lower NAFLD risk. Systematic reviews and clinical guidance have shown that adherence to Mediterranean-style diets, DASH-like patterns, and other high-quality dietary patterns is associated with lower liver fat, improved liver enzymes, and reduced odds of NAFLD or metabolic dysfunction-associated steatotic liver disease (27, 28). These dietary patterns generally share key features with CHDI and CHDS, including greater intake of plant-based foods and lower consumption of highly processed and high-sugar products. Similarly, studies examining healthy diet-quality indices such as the Healthy Eating Index and Alternative Healthy Eating Index have reported inverse associations with fatty liver and related metabolic abnormalities (29). The present study extends this literature by demonstrating similar associations using CHDI and CHDS in an Iranian case-control setting.

The association between cardiovascular-oriented diet scores and NAFLD is especially noteworthy because cardiovascular disease and NAFLD share multiple pathophysiological pathways (30). NAFLD is now widely regarded as a multisystem metabolic disorder with important extrahepatic consequences, particularly increased risk of cardiovascular morbidity and mortality (31). Dietary indices originally designed to predict or improve cardiovascular health may therefore also identify individuals at lower risk of NAFLD. In this context, our findings support the broader concept that dietary patterns beneficial for cardiometabolic health may also protect against liver fat accumulation and liver-related metabolic dysfunction (32).

The persistence of significant associations after adjustment for BMI, physical activity, smoking, socioeconomic status, marital status, and total energy intake is noteworthy. This suggests that the relationship between diet quality and NAFLD is not explained solely by differences in adiposity or general lifestyle factors. However, BMI may also lie on the causal pathway between diet and NAFLD, meaning that adjustment for BMI could have partially attenuated the true effect of dietary quality (33). Thus, the persistence of significant associations after multivariable adjustment may indicate a relatively robust relationship.

The present study has several strengths. First, the sample size was relatively large and included a 1:2 ratio of cases to controls, which improved statistical efficiency. Second, NAFLD diagnosis was based on ultrasound combined with specialist physician confirmation, which likely increased the accuracy of case ascertainment in comparison with studies relying only on liver enzymes or self-report (34). Third, the study examined two different but related indices of diet quality, allowing a more nuanced assessment of whether healthy dietary patterns are consistently associated with NAFLD. Finally, adjustment for several demographic, behavioral, and socioeconomic covariates strengthens confidence in the observed associations. Several limitations should also be acknowledged. First, because of the case-control design, causal inference is limited and reverse causation cannot be fully excluded, although the inclusion of only newly diagnosed cases likely minimized this concern, as dietary changes after diagnosis were unlikely (35). Second, although ultrasound is widely used in epidemiologic studies, it has reduced sensitivity for detecting mild steatosis compared with MRI-based techniques, potentially leading to misclassification of disease. Third, despite adjustment for several confounders, residual confounding by unmeasured factors such as medication use, psychological stress, or more detailed metabolic characteristics cannot be ruled out. Finally, because the study population was Iranian, generalizability to other ethnic or geographic populations should be considered with caution. Despite these limitations, the findings have meaningful clinical and public health implications. Since both CHDI and CHDS were inversely associated with NAFLD, these dietary indices may have value not only in cardiovascular prevention but also in identifying individuals at elevated liver-related metabolic risk (33). In populations undergoing rapid nutrition transition, including increased consumption of processed and ultra-processed foods, promoting high-quality dietary patterns may be an important strategy for reducing the burden of NAFLD and related cardiometabolic disorders (28). From a practical standpoint, dietary guidance encouraging greater intake of vegetables, legumes, whole grains, and fish, while reducing sugar-

sweetened beverages, processed meats, and ultra-processed foods, may be beneficial for liver and cardiovascular health (21).

Conclusions

This case-control study in an Iranian population revealed that greater adherence to both the CHDI and the CHDS was associated with lower odds of NAFLD. These results reinforce the importance of overall dietary quality in preventing fatty liver disease and support the idea that dietary patterns favorable for cardiovascular health may also benefit liver health. Prospective cohort studies and well-designed intervention trials are needed to clarify temporality, examine causality, and determine whether improving diet quality can reduce the incidence and progression of NAFLD.

Declarations

Conflicts of Interest: The authors declare no competing interests.

Ethics approval and consent to participate

Informed written consent was obtained from participants. All procedures performed in studies involving human participants adhered to the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Ethics Committee of Shahid Beheshti University Medical Sciences, Tehran, Iran.

Conflict of interest

The authors declare there is no conflict of interest.

Data Availability

The datasets analyzed in the current study are available from the corresponding author on reasonable request.

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Authors Contributions

R.S., F.T., and P.M. contributed to the conception, design, methodology, data curation, and statistical analysis. **E.M, Z.D., R.S., N.H, H.F., S.J., S.H.** and **A.S.** contributed to data collection, investigation, manuscript drafting, and critical revision of the manuscript. **F.T** and **H.F.** supervised the study. All authors made significant contributions to this study. All authors read and approved the final version of the manuscript.

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