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ZJU指数在NAFLD与ASCVD关联中的统计学中介作用

——基于NHANES数据的横断面研究

吴岳峰，罗　涛*

重庆医科大学附属第一医院老年医学科，重庆

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摘　要

背景：非酒精性脂肪性肝病(Non-Alcoholic Fatty Liver Disease, NAFLD)是一种与代谢综合征密切相关的疾病，其全球患病率超过25%，而在我国，这一比例更是高达29.2%，成为目前西方国家和我国肝脏疾病的最主要类型。NAFLD的危害不仅仅局限于肝脏本身，它与代谢性疾病如肥胖、2型糖尿病和心血管疾病等有着复杂的关联。流行病学证据表明，NAFLD患者心血管疾病(Cardiovascular Disease, CVD)风险显著升高，其中动脉粥样硬化性心血管疾病(Atherosclerotic Cardiovascular Disease, ASCVD)作为CVD的主要临床表型，构成全球CVD相关死亡与致残的核心负担，并已成为NAFLD患者的首要死因之一。有鉴于此，特别需要对NAFLD患者进行早期心血管风险评估，制定优化的管理策略。ZJU指数由浙江大学Wang等提出，该指数整合了体重指数(Body Mass Index, BMI)、空腹血糖(Fasting Blood Glucose, FPG)、甘油三酯(Triglyceride, TG)及丙氨酸转氨酶(Alanine Aminotransferase, ALT)与天门冬氨酸转氨酶比值(Aspartate Aminotransferase, AST)，为评估个体代谢健康状况提供了一个综合性的量化工具。现有研究表明，ZJU指数在NAFLD的诊断和风险评估中显示出了较高的预测效能，并被广泛运用于相关的研究领域。本研究旨在基于大样本人群数据，明确NAFLD与ASCVD之间的独立关联，评估ZJU指数在这一关联中的解释路径，为NAFLD患者心血管风险分层及临床管理提供实证依据。方法：本研究基于美国国家健康与营养调查(National Health And Nutrition Examination Survey, NHANES)数据库从1999到2020年间的数据，总共纳入21,463名研究对象。采用逻辑回归与线性回归模型分析NAFLD与ASCVD及ZJU指数的关联，并分析探讨代谢异常在NAFLD-ASCVD关联中的潜在统计学中介作用。结果：研究结果显示，NAFLD与ASCVD风险存在显著关联，在充分校正混杂因素后，NAFLD仍是ASCVD的独立危险因素(OR = 1.39, 95% CI: 1.16~1.67, P < 0.001)。同时，ZJU指数与NAFLD呈显著正相关(校正后β = 1.32，95% CI：1.16~1.48)。统计学中介作用分析表明，ZJU指数可解释NAFLD-ASCVD关联中15.28%的效应量。结论：基于NHANES数据库的分析结果显示，ZJU指数在一定程度上介导了NAFLD与ASCVD的关联，提示其有望成为NAFLD相关心血管风险评估的辅助工具，在临床心血管风险筛查中具有潜在应用价值。

关键词

非酒精性脂肪性肝病，动脉粥样硬化性心血管疾病，ZJU指数

*通讯作者。

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Statistical Mediating Effect of the ZJU Index on the Association between NAFLD and ASCVD

—A Cross-Sectional Study Based on NHANES Data

Yuefeng Wu, Tao Luo*

Department of Geriatrics, The First Affiliated Hospital of Chongqing Medical University, Chongqing

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Abstract

Background: Non-alcoholic fatty liver disease (NAFLD) is a disease closely related to metabolic syndrome, with a global prevalence of more than 25%. In China, the proportion is as high as 29.2%, which has become the most important type of liver disease in Western countries and China. The harm of NAFLD is not limited to the liver itself. It has a complex association with metabolic diseases such as obesity, type 2 diabetes and cardiovascular diseases. Epidemiological evidence shows that the risk of cardiovascular disease (CVD) in patients with NAFLD is significantly increased. Atherosclerotic cardiovascular disease (ASCVD), as the main clinical phenotype of CVD, constitutes the core burden of global CVD-related death and disability, and has become one of the leading causes of death in patients with NAFLD. In view of this, it is particularly necessary to carry out early cardiovascular risk assessment for NAFLD patients and formulate optimized management strategies. ZJU index was proposed by Wang *et al.* from Zhejiang University. This index integrates body mass index (BMI), fasting blood glucose (FPG), triglyceride (TG) and the ratio of alanine aminotransferase (ALT) to aspartate aminotransferase (AST), which provides a comprehensive quantitative tool for assessing individual metabolic health status. Existing studies have shown that the ZJU index shows high predictive efficacy in the diagnosis and risk assessment of NAFLD and is widely used in related research fields. The purpose of this study is to clarify the independent association between NAFLD and ASCVD based on large sample population data, and to evaluate the interpretation path of ZJU index in this association, so as to provide empirical evidence for cardiovascular risk stratification and clinical management of NAFLD patients. Methods: This study was based on data from the National Health and Nutrition Examination Survey (NHANES) database from 1999 to 2020, and a total of 21,463 subjects were included. Logistic regression and linear regression models were used to analyze the association between NAFLD and ASCVD and ZJU index, and to explore the potential statistical mediating role of metabolic abnormalities in the association between NAFLD and ASCVD. Results: The results showed that NAFLD was significantly associated with the risk of ASCVD. After fully adjusting for confounding factors, NAFLD was still an independent risk factor for ASCVD (OR = 1.39, 95% CI: 1.16~1.67, P < 0.001). At the same time, ZJU index was significantly positively correlated with NAFLD (corrected β = 1.32, 95% CI: 1.16~1.48). Mediation analysis showed that ZJU index could explain 15.28% of the effect size in NAFLD-ASCVD association. Conclusions: The ZJU index mediates the association between NAFLD and ASCVD to a certain extent, suggesting that it is expected to become an auxiliary tool for NAFLD-related cardiovascular risk assessment and has potential application value in clinical cardiovascular risk screening.

Keywords

Nonalcoholic Fatty Liver Disease, Atherosclerotic Cardiovascular Disease, ZJU Index

1. 背景

非酒精性脂肪性肝病(Non-Alcoholic Fatty Liver Disease, NAFLD)是全球最常见的慢性肝病，患病率在普通人群中高达 25% [1]。NAFLD 与多种代谢紊乱密切相关，如肥胖、2 型糖尿病及血脂异常等[2] [3]，流行病学研究表明，NAFLD 患心血管疾病(Cardiovascular Disease, CVD)的风险显著升高[3]，其中，动脉粥样硬化性心血管疾病(Atherosclerotic Cardiovascular Disease, ASCVD)是心血管疾病(CVD)中最主要的临床表型之一，构成全球范围内 CVD 相关死亡和致残负担的主要部分[3] [4]，而 NAFLD 所伴随的不良心血管结局进一步凸显了其作为 ASCVD 风险因素的重要性。因此，NAFLD 已被视为心血管疾病的新兴危险因素，其临床管理不仅需关注肝脏健康，更应重视心血管风险的评估与干预。尽管现有证据提示 NAFLD 与 ASCVD 相关，但二者关联的因果性及作用机制仍存在争议。一方面，NAFLD 可能通过促进炎症反应、增加氧化应激及加速动脉粥样硬化形成，对心血管风险产生直接的影响；另一方面，这一种关联也可能主要由肥胖、糖尿病、高血压和血脂异常等代谢危险因素介导[5]-[9]。因此，定量评估代谢因素在 NAFLD-ASCVD 关联中的中介效应，对于阐明二者关系机制、制定有效的防治策略都具有十分重要意义。

浙江大学指数(Zhejiang University index, ZJU)最早由 Wang 等在 2015 年提出[5]，用于中国人群 NAFLD 的预测。这是由一种基于常规体检指标的非侵入性评分系统，整合了身体质量指数(Body Mass Index, BMI)、空腹血糖(Fasting Plasma Glucose, FPG)、甘油三酯(Triglyceride, TG)、丙氨酸氨基转移酶(Alanine aminotransferase, ALT)及天门冬氨酸氨基转移酶(Aspartate aminotransferase, AST)等参数。已有研究证实，在 NAFLD 筛查中，ZJU 指数具有良好的预测能力[10]，此外，ZJU 指数在如儿童、糖尿病患者等特定人群中的诊断价值也得到证实[11]-[13]。虽然有研究提示 ZJU 指数可能与心血管疾病相关[14]-[17]，但它在 NAFLD 相关心血管风险评估中的作用，以及作为代谢途径标志物的应用潜力，目前还缺乏直接证据支持。

基于此，本研究利用美国国家健康与营养调查(NHANES)数据库 1999~2020 年间的数据，通过大样本回归分析及中介效应分析，系统评估 ZJU 指数在 NAFLD 与 ASCVD 关联中的作用路径，旨在为阐明 NAFLD-ASCVD 关联的代谢机制及优化临床心血管风险评估提供新的证据支持。

2. 资料与方法

2.1. 研究对象

本研究基于 NHANES 1999~2020 年周期数据。NHANES 由美国国家卫生统计中心(NCHS)负责实施，通过复杂的多阶段分层抽样设计评估美国人群的健康状况，所有调查方案均经 NCHS 伦理审查委员会批准，参与者均签署书面知情同意书。初始样本涵盖 1999~2020 年所有周期中的参与者，依据以下标准筛选：1) 排除腹部超声、AST、ALT、FPG 或 TG 等关键变量缺失者；2) 排除年龄 < 20 岁的参与者；3) 排除 NAFLD 及 ASCVD 诊断数据缺失者；最终纳入 21,463 名符合条件的研究对象。

2.2. 研究方法

2.2.1. NAFLD 评估

参照 AASLD 临床实践指南[18]，NAFLD 定义为：1) 腹部超声由经培训的专业人员按标准规则操作，提示存在肝脏脂肪变性；2) 通过饮酒量及饮酒次数问卷计算，排除过量饮酒(男性 > 30 g/天，女性 > 20

g/天)；3) 排除病毒性肝炎(乙肝表面抗原或丙肝抗体血清学阳性)、恶性肿瘤(问卷“患有何种恶性肿瘤”)及其他肝病(实验室数据)的参与者。

2.2.2. ASCVD 评估

参照 2023 AHA/ACC 指南[19]，心脏病发作、心绞痛、冠心病、卒中的医疗问卷回答为“是”的参与者被认为患 ASCVD。

2.2.3. ZJU 指数计算

ZJU 指数的计算公式为：男性 ZJU 指数 = FPG + BMI + 3 × (ALT/AST) + TG；女性 ZJU 指数 = FPG + BMI + 3 × (ALT/AST) + TG + 2。

2.2.4. 协变量评估

协变量包括年龄、性别、种族、教育水平、贫困收入比、吸烟、饮酒、BMI、糖尿病、ALT、AST、TG、FPG。通过 NHANES 实验室检查数据及问卷调查收集。

2.3. 统计分析

连续变量表示为均数 ± 标准差或中位数(四分位数间距)，分类变量表示为频数和百分比。采用 logistic 回归分析 NAFLD 合并 ASCVD 的危险因素，linear 回归评估 ZJU 指数与 NAFLD 的关联强度，并运用统计学中介作用分析研究 ZJU 指数在 NAFLD 与 ASCVD 风险关联中的潜在解释路径。

所有统计分析均在 R 软件(version 4.2.0)与 Stata 软件(version 17.0)中完成，$P < 0.05$ 为差异具有统计学意义的判断标准。

3. 结果

3.1. 基线数据

如表 1 所示，研究对象共 21,463 人。基线数据显示，NAFLD 患病率为 21.7% (n = 4663)，ASCVD 患病率为 9.3% (n = 2005)，各组的人口学差异及临床特征均具有统计学意义。

Table 1. Baseline characteristics of study participants
表 1. 研究对象的基线特征

变量	总计 l (N = 21463)	NAFLD 合并 ASCVD (N = 731)	NAFLD 不合并 ASCVD (N = 3932)	ASCVD 不合并 NAFLD (N = 1274)	无 NAFLD 与 ASCVD (N = 15,526)	P 值
年龄，岁，mean (SD)	49.08 (17.99)	66.65 (11.44)	52.62 (16.81)	66.15 (13.37)	45.95 (17.42)	<0.001
性别，n (%)						
男性	10,288 (48.1)	450 (61.9)	2032 (54.1)	710 (51.9)	7096 (46.1)	<0.001
女性	11,175 (51.9)	281 (38.1)	1900 (45.9)	564 (48.1)	8430 (53.9)	
种族，n (%)						
墨西哥裔美国人	3573 (7.5)	125 (5.7)	1161 (12.4)	87 (2.6)	2200 (6.8)	<0.001
其他西班牙裔	1760 (5.6)	43 (3.1)	350 (6.5)	78 (3.6)	1289 (5.7)	
非西班牙裔白人	9682 (69.2)	444 (80.5)	1789 (70.5)	690 (73.7)	6759 (68.2)	
非西班牙裔黑人	4490 (10.9)	93 (6.8)	434 (6.1)	332 (12.9)	3631 (12.0)	
其他种族	1958 (6.8)	26 (3.9)	198 (4.6)	87 (7.3)	1647 (7.3)	

续表

教育水平，n (%)						
高中以下学历	5516 (17.4)	261 (28.5)	1373 (23.5)	399 (25.9)	3483 (15.1)	<0.001
高中毕业/普通同等学历证书或部分大学/副学士学位	10,823 (52.8)	366 (55.7)	1909 (55.8)	647 (51.9)	7901 (52.1)	
大学本科毕业或以上	5005 (29.4)	102 (15.7)	626 (20.3)	221 (21.8)	4056 (32.3)	
拒绝回答/不知道	119 (0.5)	2 (0.1)	24 (0.4)	7 (0.4)	86 (0.5)	
贫困收入比，n (%)						
贫困	4223 (13.4)	152 (15.1)	835 (14.4)	288 (16.6)	2948 (12.9)	<0.001
非贫困	17,240 (86.6)	579 (84.9)	3097 (85.6)	986 (83.4)	12,578 (87.1)	
吸烟，n (%)						
是	9882 (46.9)	455 (64.8)	1812 (46.5)	790 (63.1)	6825 (45.4)	<0.001
否	11,581 (53.1)	276 (35.2)	2120 (53.5)	484 (36.9)	8701 (54.6)	
饮酒，n (%)						
是	13,469 (65.7)	436 (61.2)	2360 (62.9)	762 (62.5)	9911 (66.7)	<0.001
否	7994 (34.3)	295 (38.8)	1572 (37.1)	512 (37.5)	5615 (33.3)	
BMI, kg/m^2, mean (SD)	28.30 (6.30)	32.97 (6.46)	33.57 (6.75)	27.14 (5.31)	26.83 (5.35)	<0.001
糖尿病，n (%)						
是	4011 (14.4)	413 (52.8)	1335 (28.9)	365 (24.0)	1898 (9.3)	<0.001
否	17,452 (85.6)	318 (47.2)	2597 (71.1)	909 (76.0)	13,628 (90.7)	
ALT, U/L, mean (SD)	24.60 (27.47)	26.03 (15.21)	31.63 (38.71)	21.55 (16.12)	23.01 (24.82)	<0.001
AST, U/L, mean (SD)	25.04 (22.24)	26.19 (11.77)	27.14 (16.82)	24.66 (13.90)	24.48 (24.26)	<0.001
TG, mmol/L, mean (SD)	1.47 (1.34)	2.12 (1.48)	2.11 (1.82)	1.44 (0.97)	1.31 (1.17)	<0.001
FPG, mmol/L, mean (SD)	5.72 (1.56)	7.28 (2.67)	6.49 (2.30)	5.98 (1.70)	5.49 (1.16)	<0.001
ZJU, mean (SD)	39.24 (7.45)	46.42 (7.53)	47.24 (7.69)	38.04 (6.27)	37.33 (6.02)	<0.001

NAFLD 合并 ASCVD 组的平均年龄最高(66.65 ± 11.44 岁)，男性比例(61.9%)和非西班牙裔白人比例(80.5%)均高于其他组。该组的受教育程度较低(高中及以下占 84.2%)，贫困率较高(15.1%)。吸烟率(64.8%)明显比其他组更高，而饮酒率(61.2%)略低于总体平均水平。在 NAFLD 合并 ASCVD 组的研究对象中，患有糖尿病的比例为四组最高(52.8%)，空腹血糖水平最高(7.28 ± 2.67 mmol/L)，显著高于单纯 NAFLD 组(28.9%)和单纯 ASCVD 组(24.0%)。其 BMI (32.97 ± 6.46 kg/m^2)和甘油三酯(2.12 ± 1.48 mmol/L)均高于未患有 NAFLD 及 ASCVD 组；但单纯 NAFLD 组的 BMI (33.57 ± 6.75 kg/m^2)和 ALT (31.63 U/L)略高于 NAFLD 合并 ASCVD 组。此外 NAFLD 合并 ASCVD 组的 ZJU 指数最高(46.42 ± 7.53)，提示合并 NAFLD 与 ASCVD 的患者代谢异常更加明显。

基线数据表明，NAFLD 合并 ASCVD 患者多表现为高龄、多重代谢异常(尤以高血糖突出)及不良生活方式聚集。

3.2. NAFLD 与 ASCVD 之间的 Logistic 回归分析

多因素 Logistic 回归分析结果显示，NAFLD 与 ASCVD 存在显著关联(表 2)。在未对混杂因素进行调整的模型 1 中，NAFLD 患者发生 ASCVD 的比值比(OR)为 2.47 (95% CI: 2.17~2.80, P < 0.001)。在进一步调整年龄、性别和种族的模型 2 中，两种疾病之间的关联仍具有统计学意义(OR = 1.95, 95% CI: 1.69~2.24, P < 0.001)。进一步校正教育水平、BMI、贫困收入比(PIR)、吸烟、饮酒、高血压、糖尿病及高脂血症等潜在混杂因素后(模型 3)，NAFLD 仍与 ASCVD 独立相关(OR = 1.39, 95% CI: 1.16~1.67, P < 0.001)。

Table 2. Logistic regression analysis of NAFLD and ASCVD
表 2. NAFLD 与 ASCVD 的 Logistic 回归分析

	OR	95% CI	P 值
模型 1	2.47	2.17~2.80	<0.001
模型 2	1.95	1.69~2.24	<0.001
模型 3	1.39	1.16~1.67	<0.001

模型 1：未调整任何变量；模型 2：调整年龄、性别和种族；模型 3：调整年龄、性别、种族、教育水平、BMI、PIR、吸烟、饮酒、高血压、糖尿病及高脂血症。

3.3. ZJU 指数与 NAFLD 之间的 linear 回归分析

对研究对象的线性回归分析结果表明，NAFLD 与 ZJU 指数存在显著相关性(表 3)。在未对混杂因素进行调整的模型中，NAFLD 与 ZJU 指数之间呈显著的正相关(β = 9.76, 95% CI: 9.42~10.09, P < 0.001)。在逐步调整年龄、性别、种族等因素后，NAFLD 与 ZJU 之间的相关性依然存在(β = 10.06, 95% CI: 9.73~10.39, P < 0.001)。进一步控制教育水平、BMI、PIR、吸烟、饮酒、高血压、糖尿病及高脂血症后，效应虽有所下降，但仍具有统计学意义(β = 1.32, 95% CI: 1.16~1.48, P < 0.001)。

Table 3. Linear regression analysis between NAFLD and ZJU
表 3. NAFLD 与 ZJU 之间的 Linear 回归分析

	β value	95% CI	P 值
模型 1	9.76	9.42, 10.09	<0.001
模型 2	10.06	9.73, 10.39	<0.001
模型 3	1.32	1.16, 1.48	<0.001

模型 1：未调整任何变量；模型 2：调整年龄、性别和种族；模型 3：调整年龄、性别、种族、教育水平、BMI、PIR、吸烟、饮酒、高血压、糖尿病及高脂血症。

3.4. 中介分析

中介效应分析结果表明，NAFLD 对 ASCVD 具有显著的总效应(系数 = 0.03056，95% CI: 0.02081~0.04000，P < 0.001) (表 4)。在将 ZJU 指数作为中介变量纳入模型后，NAFLD 对 ASCVD 的直接效应仍具有统计学意义(系数 = 0.02640，95% CI：0.01655~0.04000，P < 0.001)。间接效应分析表明，经由 ZJU 指数的中介路径亦显著(系数 = 0.00416，95% CI：0.00164~0.01000，P = 0.002)，占总效应的 13.61% (95% CI: 4.78%~24.00%)，提示 ZJU 指数在 NAFLD 与 ASCVD 的关联中发挥部分中介作用。

Table 4. Mediation analysis between NAFLD and ASCVD
表 4. NAFLD 与 ASCVD 的中介效应分析

总效应		间接效应		直接效应		中介比例，% (95% CI)
系数，95% CI	P 值	系数，95% CI	P 值	系数，95% CI	P 值	
0.03056 (0.02081, 0.04000)	<0.001	0.00416 (0.00164, 0.01000)	0.002	0.02640 (0.01655, 0.04000)	<0.001	13.61 (4.78, 24.00)

调整：年龄、性别、种族、教育水平、BMI、PIR、吸烟、饮酒、高血压、糖尿病及高脂血症。

4. 讨论

NAFLD 目前已跃居全球慢性肝病的首要病因[20]。流行病学数据显示，该病影响着全球约 25%的人群，且其患病率仍在不断攀升[21] [22]。本研究共纳入 21,463 例研究对象。值得注意的是，2023 年多学会共识已建议采用“代谢功能障碍相关脂肪性肝病”(Metabolic Dysfunction-Associated Steatotic Liver Disease, MASLD)这一术语，以替代 NAFLD [23]。当前的验证研究表明，在普通人群中 NAFLD 和 MASLD 定义之间具有极高的一致性(>95%) [24]，若采用 MASLD 标准重新界定人群，本研究所得到的 NAFLD 与 ASCVD 的关联以及 ZJU 指数在其中的统计学解释路径预计仍保持稳健。鉴于本研究的设计及数据采集与定义体系均基于既往 NAFLD 诊断标准，为确保与现有文献及历史数据的可比性，本文仍沿用 NAFLD 这一术语进行表述。需要特别说明的是，本研究采用横断面设计，所观察到的各类关联仅反映特定时间点的统计学联系，尚不足以推断因果关系。

基线分析显示，NAFLD 合并 ASCVD 组患者年龄较大(66.7 ± 11.4 岁)，且男性占比较高(61.9%)。该组在代谢特征方面表现出明显的代谢异常，糖尿病患病率(52.8%)与空腹血糖水平(7.28 ± 2.67 mmol/L)均高于其他组别。此外，吸烟比例高达 64.8%。尽管该组的 BMI (32.97 ± 6.46 kg/m^2)较单纯 NAFLD 组(33.57 ± 6.75 kg/m^2)更低，但是其 ZJU 指数仍处于较高水平(46.42 ± 7.53)，提示即使全身性肥胖程度较轻，代谢的异常依然较为显著。上述人口学与代谢特征与既往大型队列研究结果一致[25]-[27]，反映出高龄、高血糖、吸烟及内脏脂肪堆积等心血管危险因素在 NAFLD 合并 ASCVD 人群中高度聚集。

多因素 Logistic 回归分析显示，NAFLD 与 ASCVD 风险之间存在独立关联。在未调整模型中，NAFLD 与 ASCVD 显著相关(OR = 2.47)；随着逐步校正人口学特征、社会经济状况和生活方式等因素，关联强度有所减弱，但仍具统计学意义。即使在完全调整模型(模型 3)中进一步控制 BMI、高血压、糖尿病和血脂异常等传统心血管危险因素后，NAFLD 患者发生 ASCVD 的风险仍高出 39% (OR = 1.39, 95% CI: 1.16~1.67, P < 0.001)。这一结果表明，NAFLD 可能作为 ASCVD 的独立危险因素发挥作用。线性回归分析进一步支持 NAFLD 与 ZJU 指数之间存在独立的正向关联。尽管在逐步校正 BMI 及相关代谢共病后，回归系数有所降低(从未调整模型的 $\beta = 9.76$ 降至完全调整模型的 $\beta = 1.32$)，该关联仍保持高度统计学显著性(95% CI: 1.16~1.48, P < 0.001)。这一结果表明，即使在控制体重指数及其他传统代谢因素后，NAFLD 仍与较高的 ZJU 指数水平显著相关，NAFLD 患者存在显著的内脏脂肪蓄积，这一发现支持了既往研究中 NAFLD 与内脏肥胖密切相关的结果[28]-[30]。尽管 ZJU 指数最初是基于中国人群构建的内脏肥胖特异性指标，本研究在 NHANES 多族裔样本中的分析仍验证了其良好的外部效度。该指数在西方人群中亦能有效反映个体的代谢负荷与脂肪蓄积程度，其跨人种的一致性为将其作为本研究中关键中介变量提供了可靠的方法学支撑。

进一步的统计学中介作用研究揭示了 NAFLD 与 ASCVD 之间关联的解释路径。分析结果显示，ZJU 指数在该关联中发挥了部分中介作用：在 NAFLD 对 ASCVD 的效应中，13.6% (95% CI: 4.78%~24.00%) 通过 ZJU 指数介导(系数 = 0.00416，P = 0.002)。无论是否引入 ZJU 指数作为中介变量，NAFLD 对 ASCVD

的直接效应均具有统计学意义。这一结果表明，NAFLD 对 ASCVD 风险的影响可能具有双重机制，既包含独立于 ZJU 指数的直接作用，也涉及通过升高 ZJU 指数所介导的间接途径。

5. 结论

综上所述，NAFLD 与 ASCVD 风险存在显著的独立正相关关系，且该关联部分通过 ZJU 指数介导。需要指出的是，受限于横断面研究的设计特点，无法完全排除潜在混杂因素的影响，因此所有结论均应谨慎理解为关联性观察，而非因果推断。ZJU 指数作为 NAFLD 患者代谢状态的关键指标，同时在心血管风险评估中展现出潜在应用价值。因此，在临床管理中，除常规肝脏病变干预外，监测并控制 ZJU 指数水平，可能成为降低 NAFLD 患者 ASCVD 负担的有效策略。

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