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Inverse association between uric acid levels and muscle quality index in adults: a cross-sectional analysis of NHANES 2011–2014

Haibin Wen[1†], Xianhua Li[2†] and Ning Tan[3*]

Abstract

Objective The objective of this study was to delineate the association between serum uric acid (UA) levels and Muscle Quality Index (MQI), assessing muscle strength relative to mass, in adults aged 20 to 59 years.

Methods Utilizing data from the National Health and Nutrition Examination Survey (NHANES) 2011–2014, this study examined the association between UA levels and MQI—a ratio of muscle strength to mass. Weighted linear models, adjusted for potential confounders, assessed the relationship, with a generalized additive model (GAM) probing for non-linear patterns. Subgroup analyses and interaction effects were conducted using weighted linear regression across diverse demographic and clinical groups to ensure the robustness and reliability of our findings.

Results Among 5,277 participants, a significant inverse association was observed between UA levels and MQI, with a 0.08 decrease in MQI per 1 mg/dL increase in UA (95% CI: -0.11 to -0.06, $p < 0.001$). The negative trend was dose-dependent across UA quartiles, which was most pronounced in the highest quartile (Q4: -0.28, 95% CI: -0.36 to -0.19, $p < 0.001$). Curve-fitting analysis revealed a consistent inverse relationship without evidence of non-linearity. Stratified analyses reinforced the core findings across all examined subgroups, highlighting the universal relevance of the observed association.

Conclusion Our findings demonstrate a significant inverse association between elevated serum UA levels and MQI, highlighting the potential importance of uric acid management in enhancing muscle quality among young and middle-aged adults. The consistency of this relationship across different subgroups underscores the need for targeted strategies and interventions to manage UA levels. Future research should explore longitudinal impacts and intervention outcomes to further elucidate the potential benefits of uric acid management on muscle health.

Keywords Uric acid, Muscle Quality Index (MQI), NHANES, Cross-sectional analysis, Muscle health

Introduction

Uric Acid (UA), a critical byproduct of purine metabolism, is integral to human metabolic processes, and influences various physiological and pathological states [1, 2]. Elevated UA levels are a risk factor for a range of conditions, such as hypertension, cardiovascular disease, and chronic kidney disease, which highlighs its broad impact on health [2–4]. Emerging evidence suggests a complex relationship between UA levels and muscle health, specifically within the context of sarcopenia, indicating the need for further exploration [5, 6].

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Handgrip Strength (HGS) and muscle mass (specifically appendicular skeletal muscle mass, ASM), are established surrogate markers for muscle health [7, 8], yet the relationship between UA and these indicators remains inconsistent. Studies have reported varying correlations—positive, negative, or nonexistent—between UA levels and HGS, as well as between UA and muscle mass, underscoring the diversity of findings and suggesting that such variations may arise from methodological differences, including study design and sample sizes [9–12]. This inconsistency highlights the potential limitation of evaluating muscle health solely through strength or mass, as doing so may overlook critical aspects of muscle functionality, leading to partial or biased interpretations [13].

The Muscle Quality Index (MQI), defined as the ratio of muscle strength (HGS) to mass, emerges as a vital metric for a comprehensive evaluation of skeletal muscle health [14]. MQI offers insights not only into muscle strength and mass but also delves into muscle architecture, tissue characteristics, and the capacity for force generation, providing a more nuanced understanding of muscle health [15, 16].

Acknowledging the intricacies of UA's potential impact on muscle health, our study aims to elucidate the association between UA levels and MQI, employing a large and nationally representative dataset. We adopt the MQI methodology articulated by Lopes et al. [15], leveraging data from the National Health and Nutrition Examination Survey (NHANES) 2011–2014, to provide a comprehensive analysis of this relationship.

Materials and methods

Study population

This cross-sectional analysis was conducted using data from the National Health and Nutrition Examination Survey (NHANES) for the 2011–2012 and 2013–2014 cycles. These specific periods were selected due to the inclusion of comprehensive assessments of muscle quality, including dual-energy X-ray absorptiometry (DXA) scans, a widely accepted practical standard for measuring muscle mass [15]. NHANES is a pivotal program aimed at evaluating the health and nutritional status of the US civilian noninstitutionalized population, utilizing structured personal interviews, detailed physical examinations, and laboratory tests to estimate the prevalence of major diseases and risk factors. The NHANES protocol adheres to ethical guidelines approved by the National Center for Health Statistics Research Ethics Review Board. Public access to the dataset is provided by the Centers for Disease Control and Prevention (CDC) [https://wwwn.cdc.gov/nchs/nhanes/Default.aspx].

Our initial pool consisted of 19,931 participants from the 2011 to 2014 NHANES cohorts. The age range of 20 to 59 years was specifically chosen because participants only in this demographic completed the DXA scans for muscle mass assessment, which is needed for analyzing muscle quality. The selection process was meticulously detailed in Fig. 1, applying strict inclusion and exclusion criteria: Individuals younger than 20 years ($n=8,602$) or older than or equal to 59 years ($n=3,632$) were excluded. This exclusion criterion was primarily based on the age range for which DXA scans were administered to eligible NHANES survey participants (8–59 years).The study further excluded participants with missing data for DXA scans ($n=1,250$), handgrip strength tests ($n=923$), or unavailable uric acid (UA) levels ($n=247$), ensuring a focused and comprehensive evaluation. Following these criteria, a total of 5,277 individuals were included in the analysis.

Study variables

Serum UA levels, the primary exposure variable of our study, were measured using the Beckman Coulter UniCel® DxC800 system over the 2011 to 2014 period. UA concentrations were categorized into quartiles, facilitating a comprehensive analysis across a spectrum of UA levels.

The MQI, expressed as the ratio of handgrip strength (kg) to appendicular skeletal muscle mass (kg), serves as a key indicator of muscle health. This index, quantified as kg/kg, derives from dividing the total handgrip strength (HGS)—aggregated from both hands—by the appendicular skeletal muscle mass (ASM). Handgrip strength was measured using a Takei dynamometer (TKK 5401, Takei Scientific Instruments, Tokyo, Japan). Participants performed this test standing, with arms extended and wrists positioned neutrally, exerting maximum force. For accuracy, each hand's grip was measured thrice, with intervals of 60 s. The highest value from the dominant hand was selected for analysis, aligning with established protocols (https://www.cdc.gov/nchs/data/nhanes/ms.pdf). Appendicular skeletal muscle mass (ASM) represents the lean soft tissue in the limbs, quantified via DXA scans as non-fat and non-bone tissue. The DXA scans were performed using a Hologic QDR-4500 A fan-beam densitometer (Hologic, Inc., Bedford, MA), which was calibrated daily. All scan results were acquired and analyzed using Hologic QDR-4500 software, version Apex 3.2 (Hologic, USA).

Covariates (Sociodemographic and lifestyle characteristics, comorbidities):

We comprehensively assessed covariates, including sociodemographic factors, lifestyle characteristics, and comorbid conditions, to contextualize the study's findings.Participants provided demographic information via a self-administered questionnaire, detailing age,

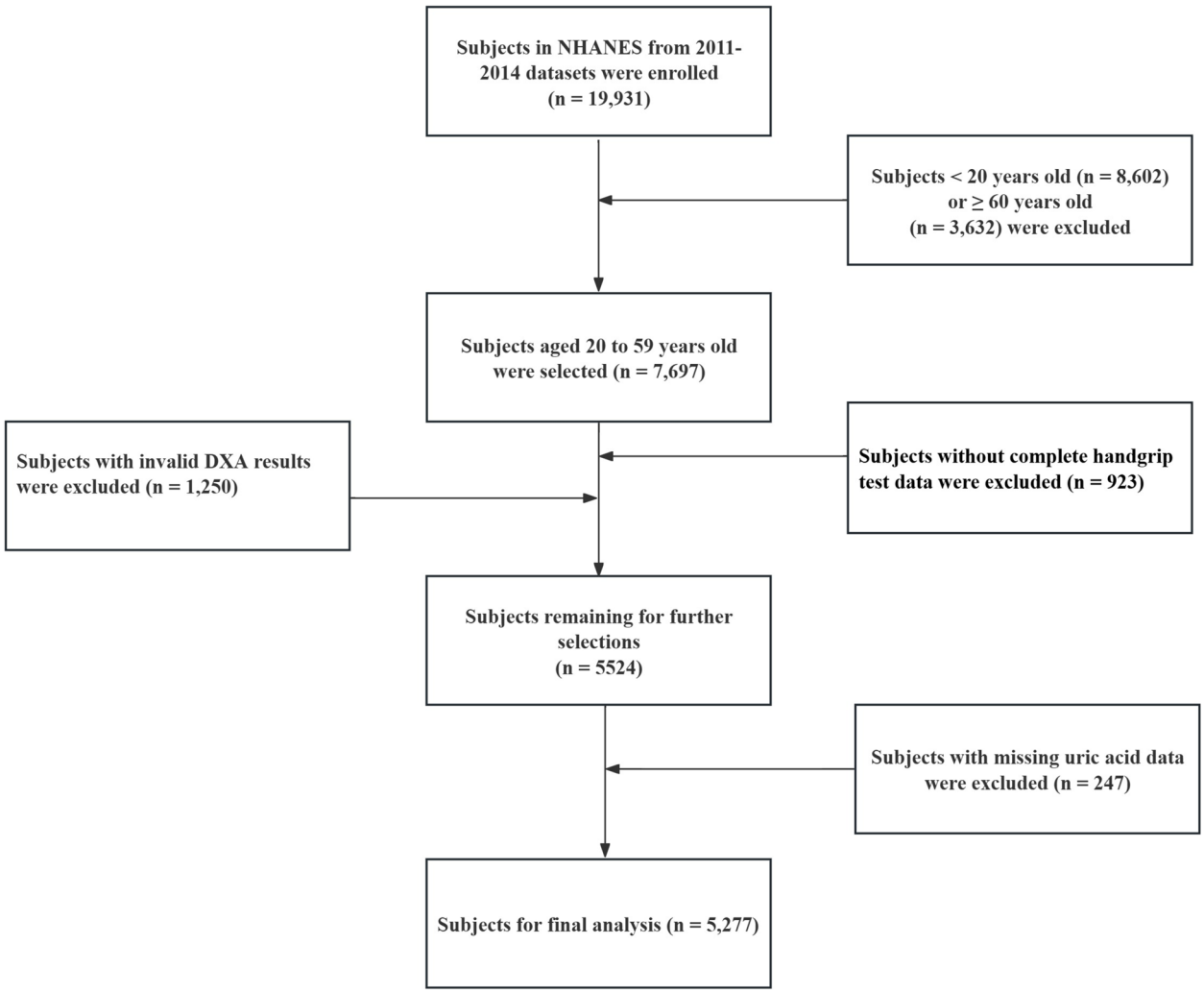


Fig. 1 Study selection process for NHANES 2011–2014

gender, marital status, household income, and education level. Race/ethnicity was categorized as Mexican American, Non-Hispanic White, Non-Hispanic Black, or Other. Body Mass Index (BMI) was calculated as body mass (kg)/height squared (m^2) and categorized into < 25, 25–30, and ≥ 30 kg/m^2 for underweight/normal, overweight, and obese, respectively [17]. Marital status was classified as either married/living with a partner or living alone. Education levels were divided into below high school, high school graduate/GED, or above high school. The poverty-to-income ratio was calculated by dividing household income by the poverty line specific to the survey year and state.

Smoking and alcohol drinking status were categorized into never, former, and current. Sedentary behavior was defined as ≥ 480 min/day or < 480 min/day, in line with the WHO Guidelines on Physical Activity and Sedentary Behavior [18]. Dietary intake was evaluated through two 24-h dietary recall interviews, with protein intake calculated as grams per kilogram per day [19].

Hypertension was identified by systolic BP ≥ 140 mmHg, diastolic BP ≥ 90 mmHg, or the use of antihypertensive medication [20]. Diabetes and prediabetes were classified based on ADA criteria, using thresholds for FBG and HbA1c levels. IFG was defined as fasting glucose levels between 6.1 mmol/L and 7.0 mmol/L, and IGT was defined as 2-hour glucose levels between 7.8 mmol/L and 11.1 mmol/L following a glucose tolerance test [21]. A history of stroke was self-reported. Hyperlipidemia was determined by specific lipid levels or medication use [22]. CKD was evaluated using the eGFR from the CKD Epidemiology Collaboration equation and albuminuria [23, 24].

Statistical analysis

Our analyses utilized sample weights to ensure accurate representation of the broader adult population. The study population was divided into four quartiles based on serum UA levels. All continuous variables are presented as means with standard errors (SE). Categorical variables were shown as frequency (%).

To assess differences among UA quartiles for continuous variables, Analysis of Variance (ANOVA) was employed. This was followed by post-hoc tests to delineate specific differences between groups. For categorical variables, differences across UA quartiles were examined using Chi-square tests or Fisher's exact test, chosen based on the expected frequencies in the contingency tables. UA levels were evaluated both as a continuous variable (per 1 mg/dL increase) and in categorized form (quartiles). The association between UA levels and the Muscle Quality Index (MQI) was examined using weighted linear regression models. Prior to constructing our weighted regression models, we conducted a Variance Inflation Factor (VIF) analysis to assess potential multicollinearity among covariates.These models were progressively adjusted in four stages: a crude model, followed by adjustments for sociodemographic factors, lifestyle characteristics, and comorbidity. To explore non-linear associations, generalized additive models (GAMs) with smooth curve fittings were employed, revealing the intricate dynamics of the UA-MQI relationship. Subgroup analyses and interaction effects were conducted using weighted linear regression across diverse demographic and clinical groups to ensure the robustness and reliability of our findings.

Empower software (http://www.empowerstats.com), FreeStatistics software version 1.8, and R version 4.2.0 (http://www.R-project.org) were employed for all analyses. A P value < 0.05 was considered statistically significant.

Results

When stratifying 5,277 participants into quartiles based on serum UA levels, our analysis identified significant disparities across demographic, lifestyle, and clinical profiles (Table 1). Notably, there was a pronounced gender disparity, with a predominance of males in the higher UA quartiles ($p < 0.0001$). Additionally, Body Mass Index (BMI) showed significant differences across the quartiles ($p < 0.0001$), indicating a correlation between increased UA levels and higher BMI categories. Lifestyle factors, such as smoking status, exhibited significant variance ($p = 0.01$), with increased physical activity and higher protein intake observed in the upper quartiles ($p < 0.0001$). Clinically, the analysis revealed that higher UA quartiles were significantly associated with increased prevalences of hypertension, diabetes mellitus, hyperlipidemia, and chronic kidney disease (CKD) (hypertension and hyperlipidemia: $p < 0.0001$; diabetes: $p < 0.001$; CKD: $p = 0.004$). Furthermore, a significant decline in the Muscle Quality Index (MQI) across UA quartiles was observed ($p < 0.0001$), suggesting an inverse relationship between UA levels and muscle quality.

Table 2 presents the findings from weighted regression analyses that explored the relationship between serum UA levels and the MQI. We conducted a Variance Inflation Factor (VIF) analysis for potential covariates to assess the degree of multicollinearity in our adjusted models. The results are presented in Supplementary Table 2. VIF values for all potential covariates were well below 2, with the highest being 1.6 for Gender. These results indicate very low multicollinearity among our selected variables, as VIF values below 5 are generally considered acceptable, and those below 2 suggest minimal collinearity. In the continuous (unadjusted) analysis of UA levels, each 1 mg/dL increase for UA was significantly associated with a decrease in the MQI. (β = -0.05; 95% CI: -0.06, -0.03, $p < 0.001$). This association remained significant in models adjusted for demographic factors (β = -0.10; 95% CI: -0.12, -0.09, $p < 0.001$), lifestyle and comorbidity factors (β = -0.08; 95% CI: -0.11, -0.06, $p < 0.001$).

The categorical analysis of UA, using quartiles and weighted liner regression, highlighted a dose-response relationship. In the fully adjusted model, the highest quartile (Q4) was associated witha significantly lower MQI when compared to the first quartile (Q1, reference group), with a decrease of β = -0.28 (95% CI: -0.36, -0.19, $p < 0.001$). This negative trend across the quartiles, indicative of an incremental impact on MQI as UA levels increase, was consistently significant (p for trend < 0.001). We conducted a sensitivity analysis using an alternative definition of muscle quality index (MQIarms), calculated as grip strength divided by arm lean mass only. This analysis was performed to assess the specificity of the relationship between uric acid and muscle quality when focusing solely on upper limb measurements. The results of this sensitivity analysis were consistent with our primary findings using the original MQI definition, supporting the robustness of our conclusions. The specific data can be found in Supplementary Table 1.

Figure Annotation: The relationship between the UA (x-axis) and the MQI (y-axis). This analysis was adjusted for a comprehensive array of confounders, including demographic factors (age, gender, race/ethnicity, poverty to income ratio - PIR), lifestyle factors (smoking status, alcohol consumption, sedentary behavior, physical activity levels, and protein intake), and comorbid conditions

Table 1 Weighted characteristics of study participants based on UA quartiles ($N = 5277$)

Characteristic	Total	Q1	Q2	Q3	Q4	*P*-value
Age (years), mean (SE)	39.36 (0.39)	38.96 (0.41)	39.08 (0.55)	40.18 (0.58)	39.17 (0.52)	0.12
Gender, n (%)						< 0.0001
Male	2685 (51.24)	258 (16.01)	480 (39.64)	884 (66.34)	1063 (85.23)	
Female	2592 (48.76)	1188 (83.99)	722 (60.36)	485 (33.66)	197 (14.77)	
Race, n (%)						0.14
Non-Hispanic White	2088 (64.19)	552 (62.75)	460 (61.96)	561 (65.71)	515 (66.24)	
Non-Hispanic Black	1128 (10.99)	287 (10.76)	279 (11.99)	273 (9.84)	289 (11.59)	
Mexican American	680 (9.90)	199 (10.30)	171 (10.87)	174 (9.63)	136 (8.85)	
Other Race	1381 (14.91)	408 (16.18)	292 (15.18)	361 (14.82)	320 (13.32)	
BMI (kg/m^2), n (%)						< 0.0001
Normal (< 25)	1725 (31.47)	692 (49.57)	418 (32.66)	392 (26.16)	223 (15.97)	
Overweight (25 to < 30)	1690 (33.94)	409 (29.21)	366 (34.03)	478 (36.98)	437 (36.00)	
Obese (30 or greater)	1853 (34.46)	341 (21.23)	415 (33.31)	498 (36.86)	599 (48.03)	
Marital status, n (%)						0.33
Living alone	2200 (38.51)	604 (39.00)	530 (40.52)	552 (36.74)	514 (38.06)	
Married or living with a partner	3077 (61.49)	842 (61.00)	672 (59.48)	817 (63.26)	746 (61.94)	
Education, n (%)						0.18
Below high school	258 (3.45)	68 (3.39)	71 (4.61)	61 (3.00)	58 (2.94)	
High school	1782 (31.04)	446 (28.65)	407 (30.44)	479 (32.65)	450 (32.52)	
Above high school	3237 (65.50)	932 (67.96)	724 (64.95)	829 (64.35)	752 (64.54)	
Poverty to income ratio (PIR)	2.92 (0.08)	2.88 (0.10)	2.86 (0.12)	2.98 (0.09)	2.98 (0.09)	0.25
Smoking status, n (%)						0.01
Never	3148 (58.16)	922 (59.59)	722 (59.57)	811 (59.26)	693 (54.02)	
Former	882 (19.08)	195 (15.45)	191 (18.21)	218 (19.20)	278 (23.89)	
Current	1245 (22.74)	329 (24.96)	288 (22.22)	340 (21.53)	288 (22.09)	
Drinking status, n (%)						0.08
Never	639 (9.32)	214 (11.12)	155 (10.10)	138 (7.50)	132 (8.59)	
Former	541 (9.87)	147 (9.90)	108 (8.09)	160 (11.14)	126 (10.10)	
Now	4097 (80.81)	1085 (78.98)	939 (81.81)	1071 (81.36)	1002 (81.32)	
ALT, U/L, mean (SE)	26.25 (0.33)	20.24 (0.44)	23.88 (0.51)	27.26 (0.48)	34.17 (1.04)	< 0.0001
AST, U/L, mean (SE)	25.58 (0.30)	22.41 (0.31)	25.08 (0.77)	25.82 (0.44)	29.39 (0.76)	< 0.0001
Sedentary behavior(min/daymean), mean (SE)	405.89 (5.61)	392.64 (6.79)	401.61 (9.98)	411.44 (9.34)	418.74 (9.10)	0.08
Physical activity (PA) (MET/h/week), mean (SE)	65.89 (2.67)	54.43 (3.31)	60.98 (3.24)	73.40 (4.18)	75.11 (4.85)	< 0.0001
Protein intake, g/d, n (SE)	87.01 (0.76)	78.27 (1.46)	85.91 (1.43)	89.45 (1.74)	95.07 (2.04)	< 0.0001
Hypertension, n (%)						< 0.0001
No	3800 (72.71)	1164 (82.29)	874 (74.77)	988 (72.14)	774 (60.52)	
Yes	1477 (27.29)	282 (17.71)	328 (25.23)	381 (27.86)	486 (39.48)	
Diabetes mellites, n (%)						<0.001
No	4382 (84.97)	1275 (90.00)	1001 (85.65)	1121 (83.33)	985 (80.45)	
IFG	161(3.21)	18 (1.18)	31 (2.77)	45 (3.77)	67 (5.29)	
IGT	184 (3.35)	34 (1.90)	45 (3.66)	54 (4.07)	51 (3.91)	
DM	550 (8.47)	119 (6.93)	125 (7.92)	149 (8.83)	157 (10.35)	
Stroke, n (%)						0.43
No	5209 (98.95)	1434 (99.07)	1186 (99.27)	1348 (98.43)	1241 (99.15)	
Yes	67 (1.04)	12 (0.93)	15 (0.73)	21 (1.57)	19 (0.85)	
Hyperlipidemia, n (%)						< 0.0001
No	1924 (35.61)	635 (43.99)	480 (38.09)	473 (33.59)	336 (26.04)	
Yes	3353 (64.39)	811 (56.01)	722 (61.91)	896 (66.41)	924 (73.96)	
Chronic kidney disease, n (%)						0.004
No	4784 (91.58)	1331 (93.09)	1107 (93.72)	1245 (91.69)	1101 (88.87)	
Yes	481 (8.12)	114 (6.91)	94 (6.28)	119 (8.31)	154 (11.13)	
Muscle quality index (kg/kg), mean (SE)	3.40 (0.02)	3.50 (0.02)	3.38 (0.03)	3.38 (0.03)	3.34 (0.02)	< 0.0001

Continuous Variables: Presented as means with standard errors (SE), Categorical Variables: Displayed as counts (n) and percentages (%)
IFG Impaired fasting glucose, *IGT* Impaired glucose tolerance, *DM* Diabetes mellitus

Table 2 Relationship between UA and MQI in different models

Exposure Variable	Model I B (95%CI) *p*-value	Model II β (95%CI) *p*-value	Model III B (95%CI) *p*-value	Model IV B (95%CI) *p*-value
UA (per 1 mg/dl change)	-0.05 (-0.06,-0.03), < 0.001	-0.1 (-0.12,-0.09), < 0.001	-0.1 (-0.12,-0.08), < 0.001	-0.08 (-0.11,-0.06), < 0.001
UA quartile				
Q1	ref	ref	ref	ref
Q2	-0.12 (-0.17,-0.06) < 0.001	-0.18 (-0.23,-0.13) < 0.001	-0.18 (-0.23,-0.13) < 0.001	-0.16 (-0.22,-0.10) < 0.001
Q3	-0.11 (-0.17,-0.05) < 0.001	-0.25 (-0.30,-0.19) < 0.001	-0.23 (-0.29,-0.18) < 0.001	-0.21 (-0.28,-0.13) < 0.001
Q4	-0.15 (-0.21,-0.10) < 0.001	-0.35 (-0.41,-0.30) < 0.001	-0.34 (-0.40,-0.27) < 0.001	-0.28 (-0.36,-0.19) < 0.001
P for trend	< 0.001	< 0.001	< 0.001	< 0.001

Model I: Not adjusted for any covariates

Model II: Adjusted for age, gender, race, and poverty-to-income ratio (PIR)

Model III: This model includes all adjustments from Model II, with additional adjustments for smoking, alcohol consumption, sedentary behavior, physical activity, and protein intake

Model IV: Extends the adjustments of Model III to include hypertension, diabetes, history of stroke, hyperlipidemia, and chronic kidney disease (CKD)

(hypertension, diabetes mellitus, history of stroke, hyperlipidemia, and chronic kidney disease).

As shown in Fig. 2,the resulting curve illustrates an inverse relationship between UA levels and MQI. Our GAM analysis revealed a stable linear relationship between UA levels and MQI, with no significant nonlinear patterns or inflection points. This finding supports the weighted linear regression models used in our primary analysis and suggests that UA's effect on MQI is consistent and predictable across the observed UA range.

In Fig. 3, subgroup analysis contrasts the MQI between participants in the highest (Q4) and lowest (Q1) quartiles of serum uric acid levels. Our findings reveal a consistent inverse association between UA levels and MQI across diverse demographic and clinical backgrounds. This pattern persists irrespective of age, gender, race/ethnicity, and BMI, although the magnitude of association varies. Notably, females, Mexican Americans, and individuals with a lower PIR exhibit a more significant decline in MQI at elevated UA levels. Despite the gender imbalance

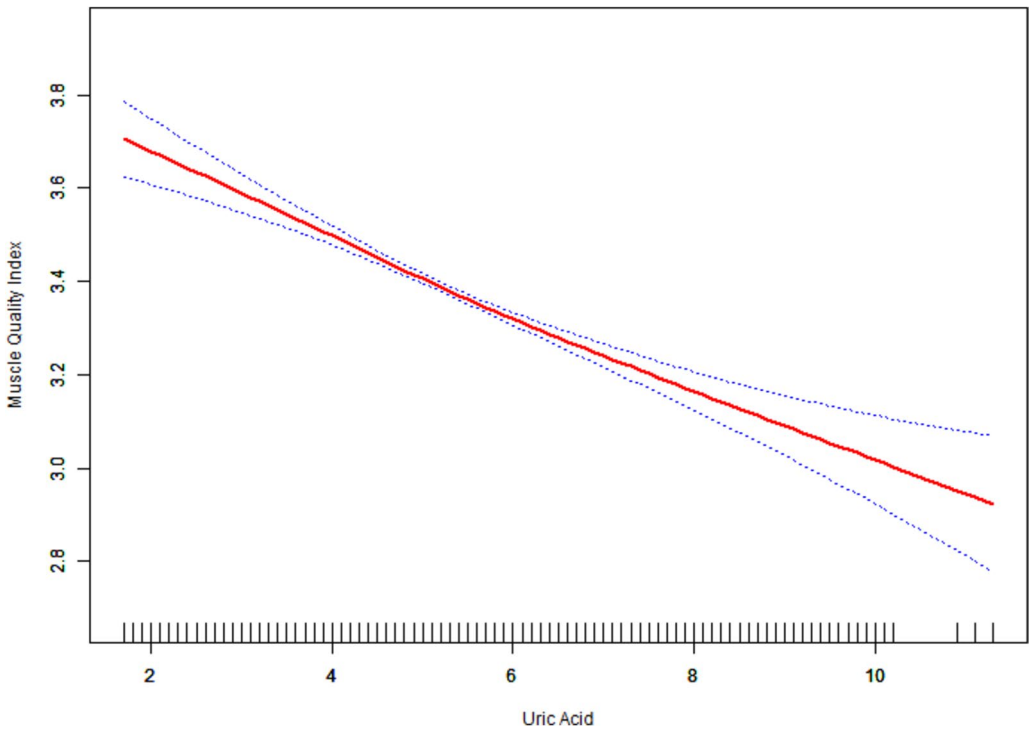
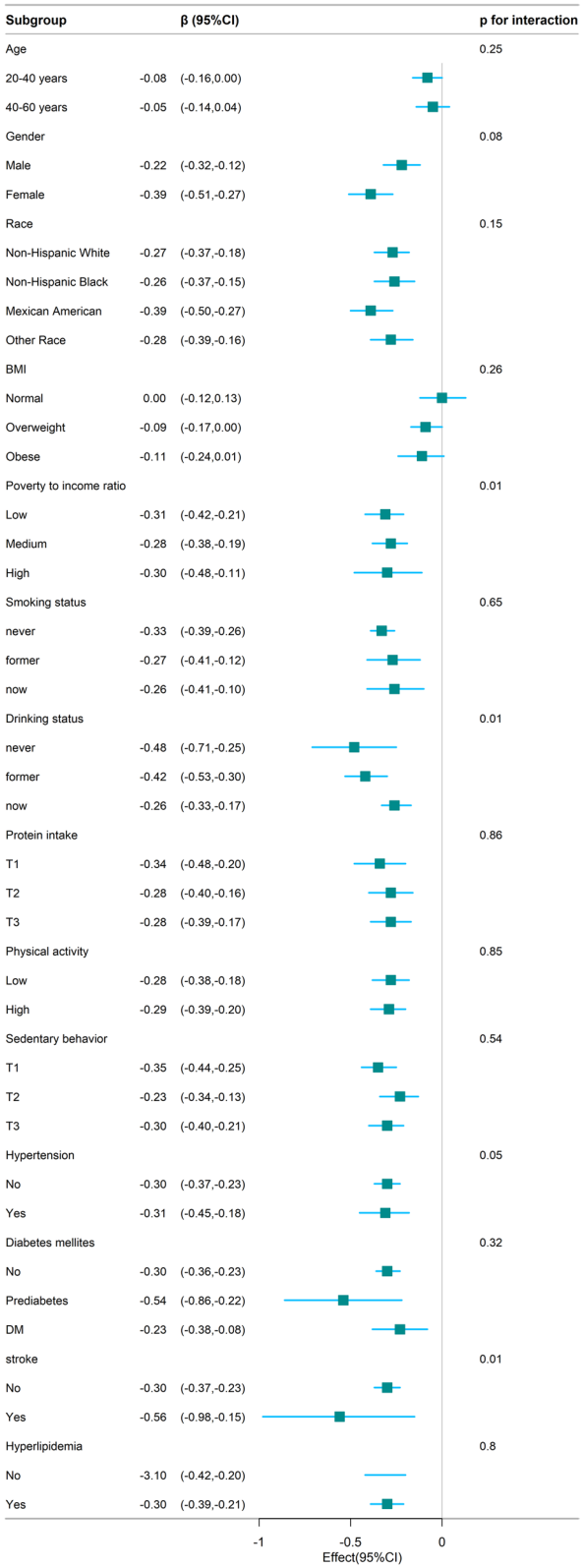


Fig. 2 Curve fitting analysis of UA and MQI



◀ **Fig. 3** Subgroup analyses and interaction effects of the association between UA and MQI. Note: *P*-values for interaction were calculated using weighted linear regression analysis, adjusting for age, gender, race, PIR, smoking, alcohol consumption, sedentary behavior, physical activity, protein intake, hypertension, diabetes, stroke, hyperlipidemia, and chronic kidney disease (CKD), excluding the specific subgroup variable being analyzed

in our study population, particularly in the highest UA quartile, our gender-stratified analysis revealed a consistent negative association between UA and MQI in both males (β = -0.22, 95% CI: -0.32, -0.12) and females (β = -0.39, 95% CI: -0.51, -0.27). The interaction term (0.08) suggests a slightly stronger association in females, but this difference was not statistically significant. Stratified analyses revealed that the relationship between UA and MQI remains consistent across different levels of physical activity and protein intake. For physical activity, we observed similar associations in both low (β = -0.28, 95% CI: -0.38 to -0.18) and high (β = -0.29, 95% CI: -0.39 to -0.20) activity groups, with no significant interaction ($p = 0.85$). Similarly, across protein intake tertiles, the association remained stable: T1: β = -0.34 (95% CI: -0.48 to -0.20), T2: β = -0.28 (95% CI: -0.40 to -0.16), and T3: β = -0.28 (95% CI: -0.39 to -0.17), with no significant interaction ($p = 0.86$). These results suggest that neither physical activity nor protein intake significantly modifies the negative relationship between UA and MQI.Additionally, lifestyle factors, including drinking habits, and comorbidities, such as a history of stroke, markedly modify this relationship. Collectively, these insights highlight the widespread implications of elevated UA on muscle quality in various population groups.

Discussion

Our study reveals a significant, multivariate adjusted-association between elevated serum uric acid levels with a decreased Muscle Quality Index. Subjects in the highest UA quartile exhibited a greater risk of a reduced MQI compared to those in the lowest quartile. This finding contrasts with prior research primarily focused on the association of UA with grip strength or muscle mass independently.

For instance, a decade-long longitudinal investigation demonstrated a significant association between high urate concentrations and the rate of muscle strength degeneration [25] which aligns with our findings. Moreover, studies from Japan and Korea have presented mixed findings. A Japanese study identified an inverse-J relationship between serum urate quartiles and muscle strength in individuals aged 30 and above, while a Korean survey linked higher serum UA levels

with increased handgrip strength (HGS) in older populations [26, 27].

Conversely, the relationship between UA levels and muscle mass remains ambiguous. Existing research has yet to establish a definitive causal link [28, 29]. Our study contributes to this ongoing discourse by investigating the nuanced relationship between UA and MQI, a novel approach that integrates the evaluation of muscle strength and mass. By focusing on MQI, our research offers a more comprehensive perspective on UA's implications for muscle health. While the observed reduction of 0.05 in MQI per 1 mg/dL increase in UA may seem modest, recent research suggests that even small changes in MQI can have significant clinical implications. Studies have shown that higher MQI is associated with a decreased risk of depression [30], a lower likelihood of congestive heart failure [31], and reduced mortality risk [32]. For instance, individuals with lower MQI have been found to have a 50% higher risk of mortality compared to those with higher MQI. Therefore, our findings suggest that elevated UA levels, through their association with reduced MQI, may have clinically meaningful impacts on mental health, cardiovascular function, and overall longevity. These results underscore the importance of maintaining optimal UA levels for preserving muscle quality and its associated health benefits.

The exact mechanisms underlying the association between serum uric acid levels and MQI is unclear. While UA can act as an antioxidant, providing cellular protection against oxidative damage [33, 34], elevated levels are known to contribute to oxidative stress and inflammation [35–38]. These adverse conditions can impair muscle cell function and repair [35, 39], potentially reducing the MQI.

Our study employed weighted linear regression, curve fitting, and stratified analyses to ensure robustness and reliability in our conclusions, which demonstrates methodological rigor. For additional insight, we evaluated assocociations for UA with the MQI while accounting for various demographic and clinical factors.

Our study has several limitations. The cross-sectional nature limits our ability to establish causality.While NHANES is a rich database, residual confounding from unmeasured factors such as inflammatory markers or genetic predispositions to hyperuricemia cannot be ruled out. Excluding participants with missing covariate data may have introduced selection bias, potentially affecting result generalizability. Although standardized, the assessment methods for MQI and UA levels might not fully capture the complexities of muscle health or uric acid metabolism. Future studies should incorporate longitudinal designs, more comprehensive confounder analyses, and updated data to further elucidate the impact of UA on muscle health.

By addressing a gap in current knowledge, our research not only enhances understanding of UA's effects on muscle healthy but also highlights the need for continued exploration into this intricate relationship.

Conclusion

Our study identifies a notable inverse association between serum uric acid levels and the Muscle Quality Index in adults, using NHANES 2011–2014 data, and highlight a potentially important role for uric acid on assessing muscle health.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-20559-w.

Supplementary Material 1.

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Authors' contributions

Haibin Wen and Xianhua Li contributed equally to this work. They were involved in conceptualization, methodology, and writing the original draft. Ning Tan played a crucial role in the conceptualization, methodology, resources, and writing—review and editing of the manuscript.All authors reviewed the manuscript.

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Data availability

Publicly available datasets were analyzed in this study. This data can be found here: https://www.cdc.gov/nchs/nhanes/index.htm.

Declarations

Ethics approval and consent to participate

The studies involving human participants were reviewed and approved by National Center for Health Statistics Ethics Review Board Approval. The patients/participants provided their written informed consent to participate in this study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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