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Original article

Association between serum uric acid and relative hand grip strength in comparison with metabolic syndrome components

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A B S T R A C T

Objectives: To investigate the association between serum uric acid (UA) and relative hand grip strength (HGS) in comparison with metabolic syndrome components.
Methods: We analyzed the data of 5247 Korean adults aged ≥ 20 years (2422 men and 2825 women) who participated in the KNHNES VII (2018).
Results: Among women, relative HGS was significantly lower in participants with hyperuricemia (1.65 ± 0.04) than in those without (1.95 ± 0.01) and was significantly decreased in the highest quartile (4Q: 1.77 ± 0.02) of serum UA compared with that in the lowest quartile (1Q: 1.98 ± 0.02). Among men, relative HGS was lower in participants with hyperuricemia (3.09 ± 0.04 vs. 3.16 ± 0.02) and decreased in 4Q (3.08 ± 0.03) of serum UA compared with that in 1Q (3.15 ± 0.03); however, these results were not statistically significant. In age- and multivariate-adjusted analyses in men, relative HGS was significantly lower in 4Q compared with that in 1Q in model 1 (adjusted for age), but there were no significant differences in model 2 (adjusted for age, BMI, and waist circumference) and model 3 (adjusted for age, BMI, waist circumference, systolic and diastolic blood pressure, fasting blood glucose, triglycerides, and high-density lipoprotein cholesterol). Meanwhile, in women, relative HGS was significantly decreased in 4Q compared with that in 1Q in all models.
Conclusions: A significant inverse correlation was observed between serum UA levels and relative HGS in women, and their significance was maintained even after adjusting for age and metabolic syndrome components.

1. Introduction

Uric acid (UA) is produced during the purine metabolism [1]. Although UA is a powerful anti-oxidant [2], it can also induce systemic inflammation [3] as a pro-oxidant [4]. Furthermore, elevated serum UA levels are associated with hypertension [5], impaired fasting glucose [6], increased cardiovascular disease mortality [7,8], and metabolic syndrome (MetS), which is a cluster of cardiometabolic risks [9].

Sarcopenia is defined as a decrease in muscle mass and strength [10]. Hand grip strength (HGS), a measure of the maximum voluntary force of the hands, is a convenient and direct method for assessing total muscle strength [10,11]. Generally, HGS is accepted as a recommended tool in diagnostic algorithms for sarcopenia [12,13]. Although there is no standardized method yet, various methods for assessing HGS, such as dominant HGS (maximal HGS of the dominant hand), absolute HGS (summation of maximal HGS of each hand), and relative HGS (absolute HGS divided by body mass index), have been used in previous studies. Among these, relative HGS has been known to have a stronger correlation with cardiovascular biomarkers [14,15]. However, few studies have evaluated the relationship between serum UA levels and relative HGS.

In the present study, we investigate the association between serum UA levels and relative HGS through MetS components using cross-sectional data of the Korea National Health and Nutrition Examination Survey (KNHANES) VII 2018.

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2. Methods

2.1. Study population

We analyzed data from the third year (2018) of the KNHANES VII. The KNHANES is an annual nationwide survey to monitor the health and nutrition status of the general population of South Korea. Data were obtained using complex, stratified, multistage probability sampling to reach the representativeness of the population. In 2018, a total of 7992 (76.5% of the total target population of 10,453) people participated in the survey. Of these, those aged ≥ 20 years (n = 6424) were selected for analysis of this study. We excluded those who were pregnant (n = 23) and had missing data on measurements, including HGS (n = 565), serum UA (n = 159), body mass index (BMI) (n = 29), waist circumference (WC) (n = 3), blood pressure (n = 24), high-density lipoprotein cholesterol (HDL-C) (n = 3), and creatinine ≥ 1.5 mg/dL (n = 39). There was no data on the gout treatment history, which could affect the serum uric acid levels; therefore, we further excluded those who have a history of rheumatoid arthritis or osteoarthritis treatment. (n = 332). Finally, a total of 5247 participants (2422 men and 2825 women), with a weighted total of 36,754,366 participants (19,220,793 men and 17,533,573 women), were included in the analysis (Fig. 1). All the KNHANES participants provided written informed consent and the Institutional Review Board of the Korea Centers for Disease Control and Prevention approved using the KNHANES data (2018-01-03-P-A). The Institutional Review Board of Pusan National University Yangsan Hospital exempted this study's approval requirement (IRB No. 05-2022-100).

2.2. Data collection

The KNHANES data consisted of health interviews, health examinations, and nutrition surveys. Physical examination and blood sampling were performed by trained medical personnel with standardized procedures. The data on health-related behaviors, including cigarette smoking, alcohol consumption, and regular exercise, were obtained through personal interviews. Smoking status was defined as “yes” when the participants were smoking at the time of the survey or had previously smoked more than 100 cigarettes. Heavy alcohol consumption was defined as “yes” when the participant had at least seven drinks (one drink means a single glass of beer, wine, liquor, or Korean distilled liquor, Soju) for men and at least 5 drinks for women at 1 time more than twice a week. Regular exercise was defined as “yes” when the participant regularly performed moderate (doing exercise for more than 210 minutes/week, which causes slightly increased respiration and heart rate) or strenuous (doing exercise for more than 75 minutes/week, which causes rapid respiration and a substantial increase in heart rate) exercise, or when the participant walked for more than 30 minutes daily for 5 days/week.

2.3. Anthropometric and biochemical data

The height and weight were measured with light clothing and barefooted. BMI was calculated as weight (kg) divided by height squared (m^2). WC was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest during exhalation. Blood pressure was measured using a standard mercury sphygmomanometer after 5 minutes of rest in the sitting position. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were obtained twice at 5-minute intervals and averaged. All blood samples were collected after 8-hour fasting and analyzed within 24 hours after sampling. Measurements of serum UA, FBG, TG, HDL-C, and creatinine levels were performed using a Hitachi automatic analyzer 7600-210 (Hitachi Ltd, Tokyo, Japan). Hyperuricemia was defined as a serum UA level of ≥ 7.0 mg/dL for men and ≥ 6.0 mg/dL for women [16,17]. Serum UA levels were classified into the following quartiles according to their distribution: first quartile (1Q); 2.0–5.0, second quartile (2Q); 5.1–5.9, third quartile (3Q); 6.0–6.8, and fourth quartile (4Q); 6.9–11.2 mg/dL in men and 1Q; 1.7–3.8, 2Q; 3.9–4.4, 3Q; 4.5–5.1, and 4Q; 5.2–10.1 mg/dL in women.

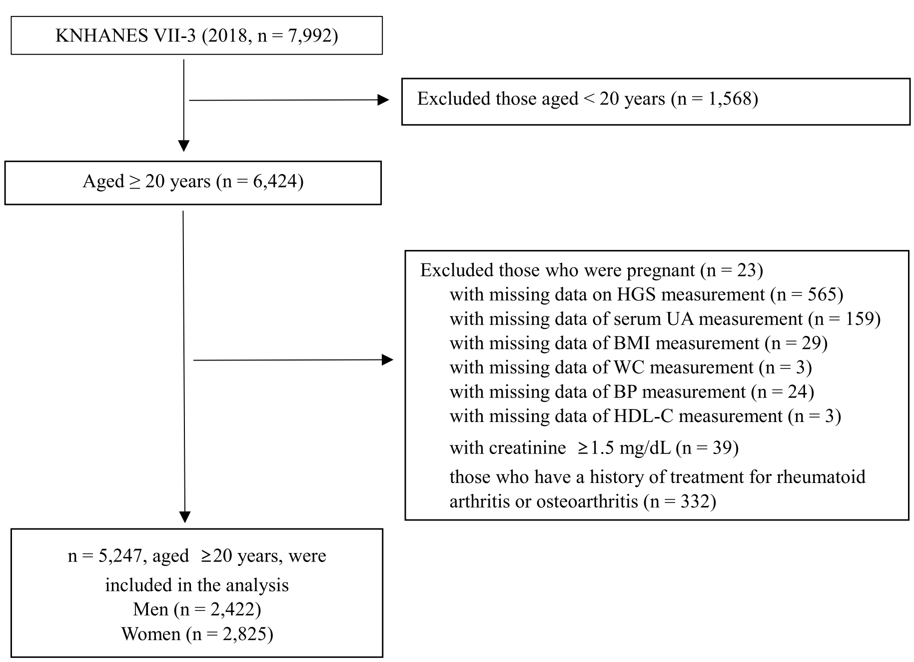

Fig. 1. Flowchart of participants throughout the study.
KNHANES, Korea National Health and Nutrition Examination Survey; HGS, hand grip strength; UA, uric acid; BMI, body mass index; WC, waist circumference; BP, blood pressure; HDL-C, high-density lipoprotein cholesterol.

2.4. Measurement of HGS

A digital hand grip dynamometer (TKK 5401, Takei Scientific Instruments Co, Ltd, Tokyo, Japan) was used to measure HGS. The grip strength was measured with the arms fully extended at the sides without touching the body in a standing position. The trained staff guided the participants to squeeze the dynamometer as firmly as they could, for more than 3 seconds, 3 times with each hand alternatively, with at least a 30-second rest period. Absolute HGS (kg) was calculated as the summation of the maximal value for each hand. Relative HGS (kg/BMI) was defined as the absolute HGS divided by BMI.

2.5. Statistical analysis

Statistical analyses were performed using SPSS statistics for Windows, version 18.0 (SPSS Inc., Chicago, IL, USA), using sampling weights from the KNHANES data to obtain nationally representative estimates. In this study, the data were indicated as weighted means with standard errors (SE) for continuous variables and percentages for categorical. Data for men and women were separated for further analysis owing to significant differences in serum UA and HGS by sex. In the general linear model, the *t*test and ANOVA were used for continuous variables, and the chi-square test was used for categorical variables. ANCOVA was performed using a general linear model approach to determine the association between serum UA levels and relative HGS with progressive levels of adjustment for age and MetS components.

The primary independent variable was serum UA level (categorized into sex-specific quartiles) in each model, and the dependent variable was relative HGS. Model 1 was adjusted for age, model 2 was adjusted for age, BMI, WC, and model 3 was adjusted for age, BMI, WC, SBP, DBP, FBG, TG, and HDL-C. All statistical tests were two-tailed, and statistical significance was defined as $P < 0.05$.

3. Results

3.1. Clinical characteristics of the subjects by sex

Characteristics of the 5247 individuals (2422 men and 2825 women) included in the study are shown in Table 1. The mean age was 46.0 ± 0.4 years in men and 47.3 ± 0.4 years in women. Serum UA was 6.0 ± 0.0 mg/dL in men and 4.5 ± 0.0 mg/dL in women. The absolute HGS was 76.54 ± 0.43 kg in men and 43.83 ± 0.29 kg in women. The relative HGS was 3.15 ± 0.02 in men and 1.92 ± 0.01 in women. Mean BMI, WC, SBP, DBP, FBG, and TG levels were significantly higher in men than in women. In contrast, the mean HDL-C levels were significantly lower. The proportions of current smoking (70.9% vs 11.0%), heavy alcohol consumption (51.4% vs 27.3%), and regular exercise (34.0% vs 23.5%) were significantly higher in men.

Table 1
Clinical characteristics between men and women.

	Men	Women	P-value
N/weighted	2422/19,220,793	2825/17,533,573	
Age, yr	46.0 (0.4)	47.3 (0.4)	0.004
BMI, kg/m^2	24.6 (0.1)	23.2 (0.1)	< 0.001
WC, cm	86.4 (0.2)	77.5 (0.2)	< 0.001
SBP, mmHg	119.5 (0.4)	114.5 (0.5)	< 0.001
DBP, mmHg	78.4 (0.3)	73.6 (0.2)	< 0.001
FBG, mg/dL	102.9 (0.6)	97.0 (0.4)	< 0.001
TG, mg/dL	160.6 (3.0)	109.5 (1.7)	< 0.001
HDL-C, mg/dL	47.2 (0.3)	55.1 (0.3)	< 0.001
UA, mg/dL	6.0 (0.02)	4.5 (0.04)	< 0.001
AHGS, kg	76.54 (0.43)	43.83 (0.29)	< 0.001
RHGS	3.15 (0.02)	1.92 (0.01)	< 0.001
Smoking status, %			< 0.001
Yes	70.9 (1.1)	11.0 (0.8)	
No	29.1 (1.1)	89.0 (0.8)	
Heavy alcohol consumption, %			< 0.001
Yes	51.4 (1.2)	27.3 (1.2)	
No	48.6 (1.2)	72.7 (1.2)	
Regular exercise, %			< 0.001
Yes	34.0 (1.3)	23.5 (1.0)	
No	66.0 (1.3)	76.5 (1.0)	

Values are expressed as mean (SE).
N, number; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; UA, uric acid; AHGS, absolute hand grip strength; RHGS, relative hand grip strength.

3.2. Differences in clinical characteristics between participants with and without hyperuricemia by sex

The differences in clinical characteristics between participants with and without hyperuricemia according to sex are shown in Table 2. The mean age was significantly lower in participants with hyperuricemia in men (41.2 ± 0.8 years vs 47.4 ± 0.5 years) but higher in participants with hyperuricemia in women (51.1 ± 1.4 years vs 47.0 ± 0.4 years). The mean BMI, WC, SBP, DBP, and TG levels were significantly higher in participants with hyperuricemia, whereas the mean HDL-C level was significantly lower in both sexes. The mean FBG level was significantly lower in participants with hyperuricemia but higher in women. The proportion of heavy alcohol consumption was significantly higher in men with hyperuricemia than in men without hyperuricemia (56.2% vs 50.0%). There were no specific differences in the proportions of current smoking, heavy alcohol consumption, or regular exercise in women. Absolute HGS was significantly higher in participants with hyperuricemia in men (78.91 ± 0.81 vs 75.85 ± 0.46) but lower in women (42.26 ± 0.81 vs 43.95 ± 0.30). Relative HGS was significantly lower in participants with hyperuricemia in women (1.65 ± 0.04 vs 1.95 ± 0.01). In men, relative HGS was lower in participants with hyperuricemia (3.09 ± 0.04 vs 3.16 ± 0.02) but not significantly.

3.3. Comparisons among the quartiles of serum UA levels

The participants were classified according to the quartiles of serum UA levels, and their clinical characteristics were compared by sex (Tables 3 and 4). In men, the mean age decreased significantly with increasing quartiles of serum UA level. The mean BMI, WC, DBP, and TG were significantly higher in the 4Q than in the 1Q. Mean FBG and HDL-C levels were significantly lower in the 4Q than in the 1Q. The proportion of heavy alcohol consumption was significantly higher in 4Q (56.1%) than in 1Q (45.7%). The absolute HGS increased significantly with increasing quartiles of serum UA levels. Relative HGS decreased in 4Q (3.08 ± 0.03) compared with that in 1Q (3.15 ± 0.03), but the difference was not statistically significant (Table 3). In women, the mean age showed no significant difference between the 1Q and 4Q. Mean BMI, WC, SBP, DBP, FBG, and TG levels were significantly higher in 4Q than in 1Q. The mean HDL-C level was significantly lower in the 4Q than in the 1Q. The proportion of heavy alcohol consumption was significantly higher in 4Q (30.4%) than in 1Q (20.3%). Absolute HGS decreased in 4Q (42.82 ± 0.53 kg) compared with that in 1Q (43.63 ± 0.46 kg), but the difference was not statistically significant. Relative HGS significantly decreased in 4Q (1.77 ± 0.02) compared with that in 1Q (1.98 ± 0.02) (Table 4).

Table 2
Comparisons between subjects with and without hyperuricemia in each sex.

	Men			Women		
	Without hyperuricemia	With hyperuricemia	P-value	Without hyperuricemia	With hyperuricemia	P-value
N/weighted	1920/14,909,893	502/4,310,899		2614/16,308,873	211/1,224,700	
Age, yr	47.4 (0.5)	41.2 (0.8)	< 0.001	47.0 (0.4)	51.1 (1.4)	0.004
BMI, kg/m^2	24.3 (0.1)	26.0 (0.2)	< 0.001	23.0 (0.1)	26.1 (0.4)	< 0.001
WC, cm	85.5 (0.2)	89.3 (0.5)	< 0.001	77.0 (0.2)	85.2 (0.9)	< 0.001
SBP, mmHg	119.2 (0.5)	120.6 (0.7)	0.070	113.8 (0.5)	122.7 (1.8)	< 0.001
DBP, mmHg	77.8 (0.3)	80.6 (0.6)	< 0.001	73.3 (0.2)	77.2 (0.8)	< 0.001
FBG, mg/dL	103.6 (0.7)	100.4 (0.9)	0.009	96.5 (0.4)	103.1 (2.0)	0.001
TG, mg/dL	151.4 (3.3)	192.1 (7.6)	< 0.001	106.5 (1.7)	148.8 (8.4)	< 0.001
HDL-C, mg/dL	47.8 (0.3)	45.2 (0.5)	< 0.001	55.5 (0.3)	50.1 (1.0)	< 0.001
UA, mg/dL	5.5 (0.05)	7.8 (0.05)	< 0.001	4.3 (0.04)	6.6 (0.04)	< 0.001
AHGS, kg	75.85 (0.46)	78.91 (0.81)	< 0.001	43.95 (0.30)	42.26 (0.81)	0.035
RHGS	3.16 (0.02)	3.09 (0.04)	0.052	1.95 (0.01)	1.65 (0.04)	< 0.001
Smoking status, %			0.330			0.620
Yes	71.5 (1.2)	68.7 (2.7)		11.1 (0.8)	9.9 (2.3)	
No	28.5 (1.2)	31.3 (2.7)		88.9 (0.8)	90.1 (2.3)	
Heavy alcohol consumption, %			0.035			0.334
Ye	50.0 (1.3)	56.2 (2.7)		27.0 (1.3)	30.8 (3.9)	
No	50.0 (1.3)	43.8 (2.7)		73.0 (1.3)	69.2 (3.9)	
Regular exercise, %			0.483			0.297
Yes	33.5 (1.5)	35.5 (2.5)		23.7 (1.1)	20.1 (3.2)	
No	66.5 (1.5)	64.5 (2.5)		76.3 (1.1)	79.9 (3.2)	

Values are expressed as mean (SE).
N, number; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; UA, uric acid; AHGS, absolute hand grip strength; RHGS, relative hand grip strength.

Table 3
Comparisons among the quartiles of serum uric acid levels in men.

	1Q (2.0–5.0)	2Q (5.1–5.9)	3Q (6.0–6.8)	4Q (6.9–11.2)	P-value
N/weighted	605/4,338,874	625/4,913,491	632/5,175,231	560/4,793,196	
Age, yr	52.6 (0.8)	47.1 (0.7) *	43.5 (0.8) *	41.5 (0.7) *	< 0.001
BMI, kg/m^2	23.7 (0.1)	24.1 (0.1)	24.7 (0.2) *	25.9 (0.2) *	< 0.001
WC, cm	84.6 (0.4)	85.1 (0.4)	86.4 (0.4) *	89.3 (0.5) *	< 0.001
SBP, mmHg	120.2 (0.8)	118.3 (0.7)	119.4 (0.7)	120.3 (0.6)	0.177
DBP, mmHg	76.6 (0.5)	77.5 (0.5)	79.0 (0.5) *	80.4 (0.5) *	< 0.001
FBG, mg/dL	110.1 (1.5)	102.7 (1.4) *	99.7 (0.8) *	100.1 (0.9) *	< 0.001
TG, mg/dL	144.6 (6.9)	147.6 (6.4)	159.1 (4.9)	189.8 (7.2) *	< 0.001
HDL-C, mg/dL	49.0 (0.5)	48.2 (0.6)	46.8 (0.5) *	45.2 (0.5) *	< 0.001
UA, mg/dL	4.3 (0.03)	5.5 (0.01) *	6.4 (0.01) *	7.8 (0.04) *	< 0.001
AHGS, kg	74.02 (0.71)	76.13 (0.80) *	77.12 (0.74) *	78.59 (0.74) *	< 0.001
RHGS	3.15 (0.03)	3.19 (0.03)	3.16 (0.03)	3.08 (0.03)	0.087
Smoking status, %					0.131
Yes	75.7 (2.1)	69.9 (2.1)	68.9 (2.2)	69.6 (2.5)	
No	24.3 (2.1)	30.1 (2.1)	31.1 (2.2)	30.4 (2.5)	
Heavy alcohol consumption, %					0.006
Yes	45.7 (2.2)	49.1 (2.3)	53.9 (2.2)	56.1 (2.4)	
No	54.3 (2.2)	50.9 (2.3)	46.1 (2.2)	43.9 (2.4)	
Regular exercise, %					0.247
Yes	29.9 (2.2)	35.4 (2.3)	34.5 (2.4)	35.5 (2.3)	
No	70.1 (2.2)	64.6 (2.3)	65.5 (2.4)	64.5 (2.3)	

Values are expressed as mean (SE).
*; P < 0.05 vs 1Q.
N, number; 1Q, first quartile; 2Q, second quartile; 3Q, third quartile; 4Q, fourth quartile; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; UA, uric acid; AHGS, absolute hand grip strength; RHGS, relative hand grip strength.

3.4. *Sex-specific regression coefficients for relative HGS and clinical characteristics*

The regression coefficients between the relative HGS and clinical variables are shown in Table 5. Age, BMI, and SBP showed a significant negative correlation with relative HGS, while DBP showed a positive correlation with relative HGS in both sexes. HDL-C levels were positively correlated in women.

3.5. *Age and multivariate-adjusted relative HGS of participants categorized by sex and quartiles of serum UA*

Table 6 shows the age and multivariate-adjusted relative HGS of men and women categorized by serum UA quartile. In men, the relative HGS was significantly decreased in 4Q compared with that in 1Q in model 1 (adjusted for age), but there were no significant differences in models 2 (adjusted for age, BMI, and WC) and 3 (adjusted for age, BMI, WC, SBP, DBP, FBG, TG, and HDL-C). However, relative HGS was significantly decreased in women in 4Q compared with that in 1Q in models 1, 2, and 3.

Table 4
Comparisons among the quartiles of serum uric acid levels in women.

	1Q (1.7–3.8)	2Q (3.9–4.4)	3Q (4.5–5.1)	4Q (5.2–10.1)	P-value
N/weighted	759/4,749,989	692/4,196,203	734/4,612,029	640/3,975,352	
Age, yr	48.0 (0.8)	45.9 (0.6) *	46.9 (0.7)	48.5 (0.8)	0.019
BMI, kg/m^2	22.4 (0.1)	22.7 (0.1)	23.2 (0.1) *	24.8 (0.2) *	< 0.001
WC, cm	75.1 (0.4)	76.1 (0.4)	77.5 (0.4) *	81.9 (0.5) *	< 0.001
SBP, mmHg	112.7 (0.7)	113.0 (0.7)	114.5 (0.7) *	118.0 (0.9) *	< 0.001
DBP, mmHg	72.5 (0.4)	73.0 (0.4)	73.7 (0.4) *	75.5 (0.4) *	< 0.001
FBG, mg/dL	96.2 (0.8)	95.4 (0.6)	96.6 (0.7)	99.8 (1.0) *	0.001
TG, mg/dL	100.5 (3.5)	99.9 (2.3)	107.7 (3.1)	132.4 (3.8) *	< 0.001
HDL-C, mg/dL	56.4 (0.5)	56.0 (0.6)	55.1 (0.5)	52.4 (0.5) *	< 0.001
UA, mg/dL	3.4 (0.01)	4.2 (0.01) *	4.7 (0.01) *	5.8 (0.03) *	< 0.001
AHGS, kg	43.63 (0.46)	44.55 (0.37)	44.26 (0.47)	42.82 (0.53)	0.013
RHGS	1.98 (0.02)	1.99 (0.02)	1.94 (0.02)	1.77 (0.02) *	< 0.001
Smoking status, %					0.173
Yes	8.8 (1.2)	11.0 (1.4)	12.6 (1.4)	12.0 (1.5)	
No	91.2 (1.2)	89.0 (1.4)	87.4 (1.4)	88.0 (1.5)	
Heavy alcohol consumption, %					< 0.001
Yes	20.3 (1.9)	27.6 (2.1)	31.4 (2.1)	30.4 (2.3)	
No	79.7 (1.9)	72.4 (2.1)	68.6 (2.1)	69.6 (2.3)	
Regular exercise, %					0.258
Yes	24.7 (1.7)	24.0 (1.8)	20.6 (1.8)	24.8 (2.1)	
No	75.3 (1.7)	76.0 (1.8)	79.4 (1.8)	75.2 (2.1)	

Values are expressed as mean (SE).
*; P < 0.05 vs. 1Q.
N, number; 1Q, first quartile; 2Q, second quartile; 3Q, third quartile; 4Q, fourth quartile; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; UA, uric acid; AHGS, absolute hand grip strength; RHGS, relative hand grip strength.

Table 5
Regression coefficients for relative hand grip strength and various characteristics by sex.

Variables	Men (N/weighted = 2422/19,220,793)				Women (N/weighted = 2825/17,533,573)			
	Beta	95% CI		P-value	Beta	95% CI		P-value
		Lower	Upper			Lower	Upper	
Age, yr	−.011	−.013	−.009	< 0.001	−.008	−.009	−.006	< 0.001
BMI, kg/m^2	−.061	−.078	−.044	< 0.001	−.053	−.062	−.043	< 0.001
WC, cm	−.014	−.020	−.007	< 0.001	−.002	−.006	.002	0.279
SBP, mmHg	−.003	−.005	−.001	0.013	−.002	−.004	.000	0.011
DBP, mmHg	.008	.004	.011	< 0.001	.003	.001	.006	0.013
FPG, mg/dL	.000	−.001	.001	0.469	.000	−.001	.001	0.812
TG, mg/dL	.000	.000	.001	< 0.001	.000	.000	.000	0.587
HDL-C, mg/dL	.002	.000	.005	0.067	.002	.001	.004	0.003

N, number; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol.

Table 6
Comparisons of adjusted relative handgrip strength among the quartiles of serum uric acid levels in each sex.

Quartile	1Q	2Q	3Q	4Q	P-value
Men					
Model 1	3.24 (0.03)	3.20 (0.03)	3.13 (0.03) *	3.02 (0.03) *	< 0.001
Model 2	3.16 (0.02)	3.15 (0.03)	3.13 (0.03)	3.14 (0.03)	0.891
Model 3	3.17 (0.03)	3.16 (0.03)	3.13 (0.03)	3.13 (0.03)	0.552
Women					
Model 1	1.99 (0.02)	1.97 (0.02)	1.94 (0.02) *	1.78 (0.02) *	< 0.001
Model 2	1.94 (0.02)	1.95 (0.01)	1.94 (0.02)	1.87 (0.02) *	0.002
Model 3	1.94 (0.02)	1.95 (0.01)	1.94 (0.02)	1.87 (0.02) *	0.004

Values are expressed as mean (SE).
Model 1: adjusted for age.
Model 2: adjusted for age, BMI, and WC.
Model 3: adjusted for age, BMI, WC, SBP, DBP, FBG, TG, and HDL-C.
*; P < 0.05 vs. 1Q.
1Q, first quartile; 2Q, second quartile; 3Q, third quartile; 4Q, fourth quartile; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol.

4. Discussion

The principal finding of this study was a significant inverse correlation between serum UA levels and relative HGS in women, and their significance was maintained even after adjusting for age and MetS components. Our study mainly focuses on relative HGS because it can minimize the confounding effect of body size and has been known to reflect cardiovascular risk better than other HGS indices [14,15].

Several previous studies have shown that an increase in serum UA level is associated with increased HGS, mainly in older adults [18–20]. However, few studies have investigated the relationship between serum UA levels and HGS in adults over 20 years of age. One study of 3595 participants in the NHANES study reported that a negative association was observed between serum UA and dominant HGS in adults aged 20–40 years, and this association was reversed after the age of 60 years, suggesting that the association between UA and muscle strength differed depending on age [21]. Another study showed that a high serum UA level is independently associated with increased dominant HGS in the older Korean population, but no significant relationship was found in young people [22].

In our study, which analyzed participants aged ≥ 20 years, the relative HGS decreased with an increase of serum UA levels, and the relative HGS was also lower in the hyperuricemia group. This negative association between serum UA levels and relative HGS was more significant in women than in men. On the other hand, in absolute HGS, a significant positive association, showing an increased absolute HGS with the increase of serum UA levels and the higher in the hyperuricemia group, was observed only in men. This finding is consistent with that of Lee et al [22], which showed that low serum UA level was a risk factor for low HGS only in the older male population. The possible explanations for this result could be that firstly, the more elevated serum UA levels, the lower the mean age in the comparison among serum uric acid quartiles, and the mean age was also lower in the hyperuricemia group in men. Therefore, especially in the case of absolute HGS, it is likely that the grip strength is higher when the participant is younger. Secondly, the differences in the proportion of heavy alcohol consumption and current smoking according to serum UA levels, and the natural difference of hormones between sexes may affect.

Huang et al [23] reported that HGS was much lower in subjects with hyperuricemia than in those without hyperuricemia, and HGS showed a high value in the second serum UA quartile compared with the first quartile and lowered with an increase in serum UA quartiles after the second quartile, like an inverted J-shaped curve. Our findings in relative HGS, an adjusted HGS by body size, are consistent with this study in comparison between with and without hyperuricemia (men: 3.16 vs 3.08; women 1.95 vs 1.65), and among serum uric acid quartiles (men: 1Q 3.15, 2Q 3.19, 3Q 3.16, 4Q 3.08; women: 1Q 1.98, 2Q 1.99, 3Q 1.94, 4Q 1.77). These results were also similar to previous epidemiologic studies, which showed a J-shaped association of serum UA with cardiovascular events [24] and all-cause mortality [25], suggesting that both a low and a high UA level may be related to higher cardiovascular risks. Higher-than-normal serum UA levels are related to high inflammatory cytokines [23,26], which could contribute to poor muscle strength and having UA as the role of a pro-oxidant. It is also consistent with our previous study, which demonstrated that relative HGS has an inverted relationship with Mets [27]. Meanwhile, UA also has an anti-oxidant capacity [2]. If serum UA levels are lowered than normal, the anti-oxidant capability may be decreased, and it could be the possible reason for low muscle strength [23]. Therefore, it could be assumed that the best muscle strength may be maintained at the optimal serum UA levels.

In our study, the negative associations of serum UA levels with relative HGS were more prominent, and these significances were maintained after adjustment of age and Mets components in women. Kawamoto et al [19] also reported that the serum UA level was independently associated with HGS only in women. We also suggest that the combined effects of the differences in hormones, alcohol consumption rate, mean serum UA levels, and smoking habits between genders may be the explanation for these findings as Lee et al previously described [22].

This study had a few limitations. First, we could not clarify the causal relationship because we used cross-sectional data. Second, it was impossible to obtain the data which could diagnose sarcopenia directly since KNHANES did not include a variable such as muscle mass evaluation using a dual energy X-ray absorptiometry. Third, we used the national population-based data; therefore, our results may have some differences in other ethnic groups. Despite these limitations, the strength of this study is that, to the best of our knowledge, it is the first large-scale study to show an inverse relationship between serum UA levels and relative HGS, which could minimize the effect of body size and have a better relationship with cardiovascular risks.

5. Conclusions

There was a significant inverse correlation between serum UA levels and relative HGS in women, and their significance was maintained even after adjusting for age and metabolic syndrome components. In addition, relative HGS could be a better indicator of muscle strength than other HGS indexes.

CRediT author statement

Dongwon Yi: Conceptualization, Resources, Writing-original draft. **Min Jin Lee:** Resources, Supervision. **Ah Reum Khang:** Resources, Supervision. **Yang Ho Kang:** Resources, Formal analysis, Writing-review & editing, Supervision.

Conflicts of interest

The authors declare no competing interests.

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