Comparison of the Diagnostic Value between Serum Uric Acid Level and Triglyceride/High-Density Lipoprotein Cholesterol Ratio in Nuclear Power Plant Workers with Metabolic Syndrome

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1. Introduction

Metabolic syndrome (MetS) comprised of abdominal obesity, high blood pressure (BP), high fasting plasma glucose (FPG), high triglyceride (TG) and low high-density lipoprotein cholesterol (HDL-C). Insulin resistance (IR) is considered as the main cause of MetS. To prevent and identify early MetS, associated many factors have been investigated. Of those, serum uric acid level (SUA) and TG/HDL-C ratio was investigated by us previously, respectively [1, 2]. The significant association between MetS and SUA was shown in different populations including workers [3, 4]. Dyslipidemia showed significant association with SUA in both groups [5]. TG/HDL-C ratio was considered as an independent risk factor of MetS in workers [6]. In this study, we compared the diagnostic value of SUA and TG/HDL-C ratio in nuclear power plant workers (NPW) with MetS.

2. Methods and Results

2.1 Participants

From March 2023 to December 2023, 10,965 Korea Hydro & Nuclear Power Company (KHNP) workers underwent regular health check-up. Of those, the number of NPW was 7,464 and 7,443 NPW (male vs. female, 6,343 vs. 1,100) were enrolled, excluding 8 who did not complete questionnaire, 13 who did not take physical measurement or blood test. The number of daytime workers (DW) and shift workers (SW) was 5,603 and 1,840, respectively.

2.2 Measurements

Participants fasted for at least 8h before the examination. Body mass index (BMI) was defined as body weight (BW) divided by height squared (kg/m^2). Waist circumference (WC), systolic and diastolic blood pressure (BP) were measured. We measured white blood cell count (WBC), liver enzymes including gamma-glutamyl transpeptidase (GGT), alanine aminotransferase (ALT), aspartate aminotransferase (AST), fasting plasma glucose (FPG), serum creatinine (Cr) and lipid profiles including HDL-C, TG, total cholesterol (T-chol) and low-density lipoprotein cholesterol (LDL-C) were measured. A questionnaire on health-related behaviors including alcohol consumption, smoking status and recommended physical activity was administered to all participants. We applied the criteria for MetS based on the 2009 harmonized definition and the appropriate central obesity criteria of the Korean Society for the study of obesity as a cut-off for WC.

2.3 Statistical analysis

For the comparison between participants with and without MetS, the student's test was performed for continuous variables and the chi-square test for categorical variables. SUA and TG/HDL-C levels were divided into quartiles, respectively. We performed multiple logistic regression analysis to compare the association between variables and the prevalence of MetS. Six models were used to correct for confounding factors (Model 1: unadjusted; Model 2: age; Model 3: Model 2 + WBC, ALT, AST, GGT; Model 4: Model 3 + Cr; Model 5: Model 4 + alcohol consumption, smoking status and recommended physical activity). Odds ratio (OR) and 95% confidence interval (CI) were used to estimate the MetS risk in each quartile. All analyses were computed using SPSS for windows (version 26.0; SPSAS Inc., Chicago, IL, USA).

2.4 Characteristics of the participants

Workers with Mets showed significantly increased age, BMI, WC, BP, WBC, AST, ALT, GGT, FPG, TG, SUA, the number of metabolic components (MS) and TG/HDL-C ratio in comparison with workers without MetS (P<0.001) (Table 1). Smoking status and the number of workers with below recommended physical activity (PA) was significantly higher in MetS group (P<0.001). DW showed significantly increased age, BMI, DBP, FPG, T-Chol, LDL-C, MS, TG/HDL-C ratio in comparison with SW (Table 2). The number of workers with below recommended physical activity (PA) was significantly higher in DW (P<0.001). WBC, SUA, Cr was significantly increased in SW in

comparison with DW (P<0.001). Smoking status was significantly higher in SW (P<0.001). There were no significant differences in TG and HDL-C of both groups. However, TG/HDL-C ratio in DW was significantly higher than in SW. SUA in SW was significantly lower than in DW.

Table 1. Clinical characteristics of the workers

Variables	Workers		*P* value
	without MetS (n = 5,960)	with MetS (n = 1,483)	
Age (year)	40.1 ± 9.9	45.9 ± 9.3	< 0.001
BMI (kg/m^2)	23.9 ± 2.8	27.5 ± 3.5	< 0.001
WC (cm)	80.2 ± 8.1	90.9 ± 8.4	< 0.001
SBP (mmHg)	118 ± 11.9	128± 12.3	< 0.001
DBP (mmHg)	73.4 ± 9.0	80.8 ± 9.5	< 0.001
WBC (n/μL)	5,697 ± 1,430	6,393 ± 1,617	< 0.001
AST (U/L)	25.1 ± 75.1	29.3 ± 14.6	0.029
ALT (U/L)	24.2 ± 59.6	37.7 ± 27.1	< 0.001
GGT (U/L)	27.9 ± 26.4	49.5 ± 44.8	< 0.001
FPG (mg/dL)	94 ± 11	109.± 23	< 0.001
T-Chol (mg/dL)	200 ± 35	199 ± 42	0.085
HDL-C (mg/dL)	58 ± 13	47 ± 11	< 0.001
LDL-C (mg/dL)	125 ± 33	118± 39	< 0.001
TG (mg/dL)	107 ± 63	201 ± 114	< 0.001
SUA (mg/dL)	5.92 ± 1.37	6.49 ± 1.47	< 0.001
Cr (mg/dL)	0.91 ± 0.17	0.96 ± 0.20	< 0.001
MS (number)	0.79 ± 0.79	3.55 ± 0.71	< 0.001
TG/HDL-C ratio	2.04 ± 1.55	4.66 ± 3.27	<0.001
Alcohol consumption			0.181
≥Twice a week (%)	3,386 (56.8)	871 (58.7)	
≤Once a week (%)	2,574 (43.2)	612 (41.3)	
Smoking status			< 0.001
Non-smoker (%)	3,438 (57.7)	532 (35.9)	
Former smoker (%)	1,446 (24.3)	513 (34.6)	
Current smoker (%)	1,076 (18.1)	438 (29.5)	
Exercise			< 0.001
Above recommended PA (%)	1,635 (27.4)	313 (21.1)	
Below recommended PA (%)	4,325 (72.6)	1,170 (78.9)	

Table 2. Comparisons of clinical characteristics between DW and SW

Variables	Workers		*P* value
	DW (n = 5,603)	SW (n = 1,840)	
Age (year)	42.8 ± 9.9	36.6 ± 9.4	< 0.001
BMI (kg/m^2)	24.5 ± 3.3	24.7 ± 3.3	0.034
WC (cm)	82.4 ± 9.3	82.4 ± 9.2	0.967
SBP (mmHg)	120 ± 12.8	120± 12.3	0.244
DBP (mmHg)	75.1 ± 9.6	74.3 ± 9.4	0.001
WBC (n/μL)	5,790 ± 1,509	5,974 ± 1,444	< 0.001
AST (U/L)	25.5 ± 16.8	27.3 ± 132.7	0.330
ALT (U/L)	26.6 ± 26.5	27.8 ± 100.4	0.403
GGT (U/L)	32.4 ± 32.3	31.5 ± 31.5	0.312
FPG (mg/dL)	98.16 ± 16.3	96.1 ± 16.3	< 0.001
T-Chol (mg/dL)	201 ± 37	197 ± 34	< 0.001
HDL-C (mg/dL)	55.9 ± 13.6	56.1 ± 13.2	0.528
LDL-C (mg/dL)	124 ± 34	121 ± 31	0.004
TG (mg/dL)	126 ± 85	122 ± 79	0.068
SUA (mg/dL)	5.96 ± 1.41	6.26 ± 1.37	< 0.001
Cr (mg/dL)	0.92 ± 0.18	0.94 ± 0.16	< 0.001
MS (number)	1.39 ± 1.37	1.19 ± 1.28	< 0.001
TG/HDL-C ratio	2.59 ± 2.34	2.46 ± 2.05	0.020
MetS			
Yes (%)	1,178 (21.0)	305 (16.6)	< 0.001
No (%)	4,425 (79.0)	1,535 (83.4)	
Alcohol consumption			0.427
≥Twice a week (%)	3,190 (56.9)	1,067 (58.0)	
≤Once a week (%)	2,413 (43.1)	773 (42.0)	
Smoking status			< 0.001
Non-smoker (%)	2,938 (52.4)	1,032 (56.1)	
Former smoker (%)	1,563 (27.9)	396 (21.5)	
Current smoker (%)	1,102 (19.7)	412 (22.4)	
Exercise			< 0.001
Above recommended PA (%)	1,386 (24.7)	562 (30.5)	
Below recommended PA (%)	4,217 (75.3)	1,278 (69.5)	

2.5 Association of MetS according to TG/HDL-C ratio quartiles in DW and SW

Table 3 shows ORs with 95% confidence interval (CI) for prevalence of MetS depending on quartiles of TG/HDL-C ratio in DW. The unadjusted OR in the Q4 is 28.92 (95% CI, 21.51 to 38.88) compared with Q1 which is reference group (P<0.001). Prevalence of MetS also significantly increased in Q3 and Q2 (P<0.001). The ORs after adjustment for confounding factors were decreased but remained significance and finally the OR in Q4 after adjusting for BMI was 6.57 (95%CI, 4.75 to 9.08) (P<0.001). Even the ORs in Q3 was 1.71 (95%CI, 1.23 to 2.38) (P = 0.002).

Table 3. Odds ratios of metabolic syndrome depending on TG/HDL-C ratio quartiles in DW

	TG/HDL-C ratio of DW			
	Q1	Q2	Q3	Q4
Ratio	**≤1.18**	**1.19-1.89**	**1.90-3.17**	**≥3.18**
Number	1,388	1,400	1,393	1,422
Model 1	1.000			
Exp(B)		2.019	6.206	28.918
Lower		1.433	4.564	21.510
Upper		2.844	8.437	38.878
P value		<0.001	<0.001	<0.001
Model 2	1.000			
Exp(B)		1.818	5.291	24.658
Lower		1.288	3.882	18.304
Upper		2.566	7.211	33.219
P value		0.001	<0.001	<0.001
Model 3	1.000			
Exp(B)		1.249	2.835	11.278
Lower		0.878	2.056	8.254
Upper		1.777	3.910	15.411
P value		0.216	<0.001	<0.001
Model 4	1.000			
Exp(B)		1.231	2.777	10.883
Lower		0.865	2.013	7.960
Upper		1.752	3.832	14.878
P value		0.248	<0.001	<0.001
Model 5	1.000			
Exp(B)		1.224	2.753	10.768
Lower		0.859	1.994	7.867
Upper		1.743	3.800	14.739
P value		0.263	<0.001	<0.001
Model 6	1.000			
Exp(B)		0.904	1.709	6.569
Lower		0.630	1.225	4.752
Upper		1.297	2.383	9.080
P value		0.584	0.002	<0.001

Table 4 shows ORs with 95% confidence interval (CI) for prevalence of MetS depending on quartiles of TG/HDL-C ratio in SW. The unadjusted OR in the Q4 is 46.93 (95% CI, 23.64 to 93.19) compared with Q1 which is reference group (P<0.001). Prevalence of MetS also significantly increased in Q3 and Q2 (P<0.001). The ORs after adjustment for confounding factors were decreased but remained significance and finally the OR in Q4 after adjusting for BMI was 8.57 (95%CI, 4.09 to 17.93) (P<0.001).

Table 4. Odds ratios of metabolic syndrome depending on TG/HDL-C ratio quartiles in SW

	TG/HDL-C ratio of SW			
	Q1	Q2	Q3	Q4
Ratio	**≤1.18**	**1.19-1.89**	**1.90-3.17**	**≥3.18**
Number	472	464	468	436
Model 1	1.000			
Exp(B)		2.806	8.150	46.932
Lower		1.290	4.005	23.637
Upper		6.104	16.583	93.185
P value		0.009	<0.001	<0.001
Model 2	1.000			
Exp(B)		2.418	6.318	34.265
Lower		1.107	3.087	17.156
Upper		5.281	12.933	68.437
P value		0.027	<0.001	<0.001
Model 3	1.000			
Exp(B)		1.402	2.866	13.494
Lower		0.631	1.368	6.581
Upper		3.116	6.002	27.670
P value		0.407	0.005	<0.001
Model 4	1.000			
Exp(B)		1.407	2.872	13.579
Lower		0.633	1.370	6.614
Upper		3.127	6.017	27.876
P value		0.402	0.005	<0.001
Model 5	1.000			
Exp(B)		1.403	2.870	13.234
Lower		0.631	1.367	6.424
Upper		3.124	6.025	27.260
P value		0.406	0.005	<0.001
Model 6	1.000			
Exp(B)		1.132	1.674	8.574
Lower		0.503	0.782	4.099
Upper		2.550	3.584	17.933
P value		0.765	0.185	<0.001

2.6 Association of MetS according to SUA quartiles in DW and SW

Table 5 shows the ORs with 95% CIs for the prevalence of MetS according to the SUA quartile in DW. Quartiles with the lowest SUA level were used as reference groups. As the SUA level in the quartiles increased, the OR for MetS increased in the crude model (Model 1). The unadjusted OR of MetS in the highest SUA quartile compared with the lowest quartile was 3.15 (95% CI, 2.61-3.79). After adjusting Model 1 for age (Model 2), the OR increased to 3.71 (95% CI, 3.06-4.51). After adjusting for WBC, ALT, AST, GGT (Model 3), and Cr (Model 4) levels, alcohol consumption, smoking status, and exercise (Model 5), the ORs of MetS in the highest SUA quartile were attenuated, but significant associations remained

between MetS and SUA levels. After additional adjustment for BMI (Model 6), the OR decreased to 1.20 (95% CI, 0.94-1.53), which showed no significant association.

Table 5. Odds ratios of metabolic syndrome depending on SUA quartiles in DW

	SUA (mg/dL) of DW			
	Q1	Q2	Q3	Q4
Ratio	**≤5.1**	**5.2-6.0**	**6.1-6.9**	**≥7.0**
Number	1,621	1,361	1,321	1,300
Model 1	1.000			
Exp(B)		1.583	2.051	3.147
Lower		1.296	1.689	2.610
Upper		1.932	2.490	3.794
P value		<0.001	<0.001	<0.001
Model 2	1.000			
Exp(B)		1.530	2.096	3.713
Lower		1.248	1.718	3.059
Upper		1.875	2.556	4.506
P value		<0.001	<0.001	<0.001
Model 3	1.000			
Exp(B)		1.193	1.365	2.103
Lower		0.961	1.103	1.702
Upper		1.480	1.689	2.597
P value		0.109	0.004	<0.001
Model 4	1.000			
Exp(B)		1.183	1.319	1.942
Lower		0.949	1.057	1.551
Upper		1.475	1.646	2.431
P value		0.135	0.014	<0.001
Model 5	1.000			
Exp(B)		1.152	1.282	1.896
Lower		0.923	1.026	1.513
Upper		1.437	1.601	2.275
P value		0.211	0.029	<0.001
Model 6	1.000			
Exp(B)		0.944	0.938	1.200
Lower		0.749	0.742	0.944
Upper		1.189	1.186	1.526
P value		0.623	0.592	0.136

Table 6 shows the ORs with 95% CIs for the prevalence of MetS according to the SUA quartile in SW. As the SUA level in the quartiles increased, the OR for MetS increased in the crude model (Model 1). The unadjusted OR of MetS in the highest SUA quartile compared with the lowest quartile was 2.45 (95% CI, 1.69-3.58). After adjusting for age (Model 2), the OR increased to 2.51 (95% CI, 1.70-3.70). In Model 3, 4 and 5, the ORs of MetS in the highest SUA quartile were attenuated and significant associations did not remain between MetS and SUA levels. In Model 6, the OR decreased to 0.73 (95% CI, 0.45-1.17), which showed no significant association.

Table 6. Odds ratios of metabolic syndrome depending on SUA quartiles in SW

	SUA (mg/dL) of SW			
	Q1	Q2	Q3	Q4
Ratio	**≤5.1**	**5.2-6.0**	**6.1-6.9**	**≥7.0**
Number	367	483	442	548
Model 1	1.000			
Exp(B)		1.268	1.286	2.455
Lower		0.841	0.847	1.685
Upper		1.913	1.953	3.577
P value		0.258	0.237	<0.001
Model 2	1.000			
Exp(B)		1.209	1.256	2.505
Lower		0.792	0.817	1.697
Upper		1.846	1.931	3.699
P value		0.380	0.300	<0.001
Model 3	1.000			
Exp(B)		0.868	0.751	1.222
Lower		0.552	0.472	0.795
Upper		1.365	1.194	1.879
P value		0.541	0.226	0.361
Model 4	1.000			
Exp(B)		0.887	0.774	1.271
Lower		0.561	0.483	0.815
Upper		1.401	1.242	1.981
P value		0.606	0.289	0.291
Model 5	1.000			
Exp(B)		0.887	0.760	1.258
Lower		0.561	0.473	0.807
Upper		1.402	1.220	1.964
P value		0.607	0.256	0.311
Model 6	1.000			
Exp(B)		0.697	0.543	0.730
Lower		0.431	0.329	0.454
Upper		1.127	0.894	1.173
P value		0.141	0.016	0.194

2.7 Receiver operating characteristic (ROC) curve analysis

In DW, the area under the curve (AUC) of SUA and TG/HDL-C ratio was 0.624 (95%CI, 0.606 to 0.642) and 0.824 (95%CI, 0.810 to 0.837), respectively (P<0.001) (Fig. 1). In SW, they were 0.590 (95%CI, 0.555 to 0.626) and 0.848 (95%CI, 0.825 to 0.871), respectively (P<0.001) (Fig. 2). The best cut-off values of TG/HDL-C ratio for diagnosis of MetS in DW and SW were 2.562 and 2.649, respectively. In both groups, the sensitivity and specificity were 75.4% and 75.4% in DW and 78.4% and 78.1% in SW, respectively.

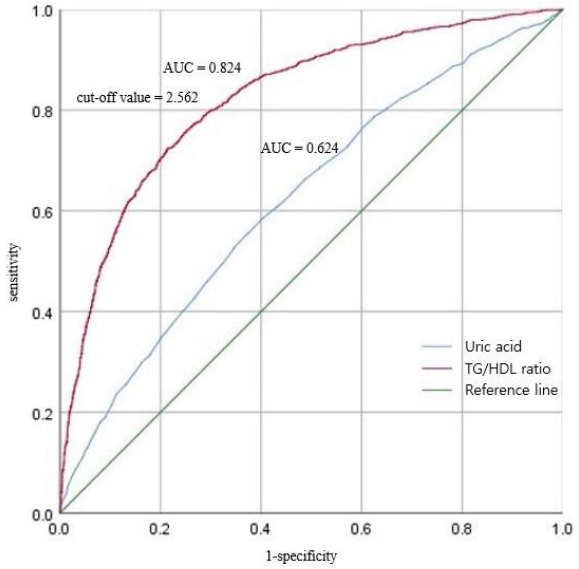

Fig 1. ROC curve analysis for diagnosis of MetS in DW

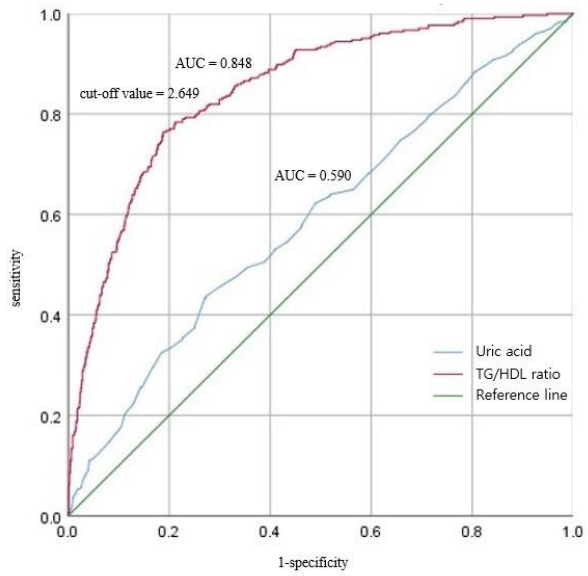

Fig 2. ROC curve analysis for diagnosis of MetS in SW

3. Discussion

Both TG/HDL-C ratio and SUA were significantly increased in workers with MetS compared to workers without MetS. TG/HDL-C ratio was significantly increased in DW than in SW, and SUA was significantly increased in SW than in DW. Alcohol consumption was not associated with MetS, and smoking status was significantly increased in SW, and below recommended PA was significantly increased in DW. In the multiple logistic regression analysis performed after correction with potential confounding factors, the UA of DW was attenuated by model 6 (BMI), and SW had no significant association after model 2 (age). On the other hand, TG/HDL-C ratio showed a significant association up to model 6 in both groups. According to ROC analysis, TG/HDL-C ratio showed superior diagnostic accuracy compared to SUA.

4. Conclusions

TG/HDL-C ratio is considered a superior diagnostic marker in workers with MetS compared to SUA. In the future, a prospective study of the large population is needed.

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