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Original Article

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The association of shift work and TyG index among male workers in a chemical plant of Korea: a cross-sectional study

Gwangin Baek, Yong-Jin Lee, Soon-Chan Kwon, Young-Sun Min, Jisuk Yun, Tae Jin Ahn, and Eun-Chul Jang *

Department of Occupational and Environmental Medicine, Soonchunhyang University Cheonan Hospital, Cheonan, Korea

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***Correspondence:**
Eun-Chul Jang
Department of Occupational and Environmental Medicine, Soonchunhyang University Cheonan Hospital, 31 Suncheonhyang 6-gil, Dongnam-gu, Cheonan 31151, Korea.
Email: oemdr10@gmail.com

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ORCID iDs
Gwangin Baek
https://orcid.org/0000-0001-6457-7210
Yong-Jin Lee
https://orcid.org/0000-0001-6712-7696
Soon-Chan Kwon
https://orcid.org/0000-0002-5782-6087
Young-Sun Min
https://orcid.org/0000-0003-1508-0608
Jisuk Yun
https://orcid.org/0000-0003-2526-104X
Tae Jin Ahn
https://orcid.org/0009-0007-1110-5560

ABSTRACT

Background: Disturbance of circadian rhythms caused by shift work has adverse effects on insulin resistance. Many previous studies have confirmed that shift work and insulin resistance are related using homeostasis model assessment-insulin resistance, one of the insulin resistance indicators. However, the triglycerides and glucose index (TyG index) has recently been studied as an insulin resistance indicator. The aim of this study is to investigate the association of shift work and TyG index, one of the indirect indicators of insulin resistance, using results of health checkups in one workplace.
Methods: Based on medical examination data collected in February 2019, a total of 3,794 subjects from one chemical plant in Korea were selected for this study. Cut-off value of TyG index for predicting development of diabetes mellitus (DM) was 4.69. A multiple logistic regression analysis was performed after adjusting for age, employment period, obesity, abdominal obesity, smoking, drinking, physical activity, hypertension, stroke, heart disease.
Results: As a result of logistic regression analysis, compared to day workers, odds ratio (OR) with a TyG index above cut-off value for predicting development of DM in shift workers was 1.220 after adjusting for age, employment period, obesity, abdominal obesity, smoking, drinking, physical activity, hypertension, stroke, heart disease (Model 1, OR: 1.276; 95% confidence interval [CI]: 1.099–1.482; Model 2, OR: 1.232; 95% CI: 1.055–1.438; Model 3, OR: 1.220, 95% CI: 1.030–1.444).
Conclusions: There was a significant association between shift work and TyG index among male workers in a chemical plant. More research studies on the association between shift work and TyG index are needed in the future.

Keywords: Shift work; Insulin resistance; Triglycerides and glucose index (TyG index)

BACKGROUND

In today's modern society, many people work as shift workers in various occupations. In industrialized societies, shift workers account for approximately 15%–20% of all workers.[1] In Korea, shift workers account for 11.6%–13.9% of wage workers according to 8th Korea National Health and Nutrition Examination Survey and the 6th Korean Working Condition

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Eun-Chul Jang
https://orcid.org/0000-0002-8153-2134

Abbreviations

BMI: body mass index; CI: confidence interval; DBP: diastolic blood pressure; DM: diabetes mellitus; FBS: fasting blood sugar; HDL: high-density lipoprotein; HIEC: hyperinsulinemic euglycemic clamp; HOMA-IR: homeostasis model assessment-insulin resistance; LDL: low-density lipoprotein; OR: odds ratio; SBP: systolic blood pressure; TG: triglyceride; TyG index: triglycerides and glucose index; VIF: variance inflation factor.

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Competing interests

The authors declare that they have no competing interests.

Authors contributions

Conceptualization: Baek G, Jang EC; Data curation: Baek G, Lee YJ, Jang EC, Kwon SC, Min YS, Yun J, Ahn TJ; Formal analysis: Baek G, Lee YJ, Jang EC, Kwon SC, Min YS, Yun J, Ahn TJ; Investigation: Baek G, Jang EC; Writing - original draft: Baek G; Writing - review & editing: Jang EC.

Survey.[2] According to the International Labour Office, shift work is defined as a method of organization of working time in which workers succeed one another at the workplace so that the establishment can operate longer than the hours of work of individual workers at different daily and night hours.[3] Health effects of shift work have been studied steadily. Results have shown that shift work is associated with diabetes.[4-6]

In terms of pathophysiological causes of diabetes, insulin resistance is a hallmark of type 2 diabetes.[7]

Several methods can be used to assess insulin resistance, including insulin tolerance test, hyperinsulinemic euglycemic clamp (HIEC) technique, insulin suppression test, and so on. Of these methods, the HIEC technique is the gold standard for assessing insulin resistance. However, these methods are time-consuming, labor intensive, and expensive to use clinically.[8,9] For these reasons, indirect methods have been proposed for estimating insulin resistance, including homeostasis model assessment-insulin resistance (HOMA-IR), visceral adiposity index, lipid accumulation product, and recently triglycerides and glucose (TyG) index.[10] Among them, HOMA-IR is a currently widely used indirect indicator of insulin resistance.[11] TyG index was made with the idea that insulin action based on lipids may help identify subjects with insulin resistance and that hypertriglyceridemia is the characteristic dyslipidemia in subjects with insulin resistance. Also, it has been reported that elevated triglycerides (TGs) levels interfere with glucose metabolism in muscles, consistent with the hypothesis that TG elevation in serum and tissue is related to decreased insulin sensitivity. And in 2010, Unger et al.[12] showed that TyG index could be a useful estimate of insulin resistance. TyG index was compared to the HIEC technique, and was shown to have good sensitivity and specificity for insulin resistance detection. However, in a study including HOMA-IR which has previously been used as a representative of indirect indicators of insulin resistance, the TyG index was a better predictor than other indirect indicators of insulin resistance for predicting the development of diabetes mellitus (DM).[13] In addition, when calculating HOMA-IR, fasting insulin and fasting blood sugar (FBS) levels are required, but when calculating the TyG index, only TG and FBS levels are required instead of fasting insulin, which are values that are examined during special health examinations of shift workers, so there is an advantage that it can be obtained only by special health examination results. Therefore, the purpose of this study is to investigate the association of shift work and TyG index, one of the indirect indicators of insulin resistance, using results of health checkups in one workplace.

METHODS

Study populations

This study used health examination records of workers in a chemical plant of Korea. The medical examination period was from February 11, 2019 to February 28, 2019. A total of 3,794 people aged 21 to 62 years underwent health examinations. Among them, 8 subjects were excluded due to insufficient data. In addition, 234 subjects with lipid-lowering medications and 118 subjects with a clinical history of DM were excluded.[13] And the chemical plant, the subject of this study is a company that manufactures various batteries and electronic materials. In this study, workers were exposed to a total of 42 hazardous substances including noise, organic compounds such as methanol, acetonitrile, metals such as iron oxide, acids such as hydrogen chloride, gases such as sulfur dioxide, dusts such as mineral

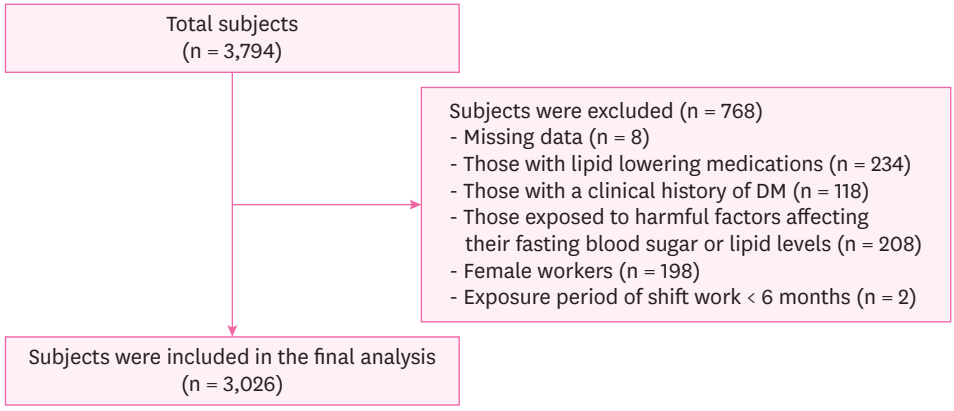

Fig. 1. Flowchart showing the final selection.
DM: diabetes mellitus.

dusts. Based on guidelines for worker's health examination published in December 2021 by Korea Occupational Safety & Health Agency, harmful factor affecting their FBS or lipid levels was acetonitrile.[14] Accordingly, 208 people who were exposed to acetonitrile were excluded. Female workers were excluded because among the final 3,226 subjects, there were only 198 (6.1%) female workers. Among male workers, there were 1,094-day workers and 1,934 shift workers. Thus, the number of shift workers was approximately 1.8 times the number of day workers. Among female workers, there were 167-day workers and 31 shift workers, with the majority being day workers. Female workers were excluded because the ratio of day workers to shift workers in female workers was significantly different from that in male workers. And for shift work, the minimum exposure period was established as 6 months, and 2 subjects were excluded accordingly. Finally, a total of 3,026 subjects were analyzed in this study (**Fig. 1**).

Data collection and measurements

Age, employment period, smoking, drinking, physical activity, body mass index (BMI), and waist circumference were obtained from measurements and questionnaires. Age was classified into 4 groups: "20–29 years," "30–39 years," "40–49 years," and "50 years or older." Employment period was defined as the period from the start of work to the date of health examination. Employment period was classified into 3 groups: "less than 10 years," "10–19 years," and "20 years or more." Physical activity was classified into 3 groups of "risk," "recommended exercise," and "strong recommendation" according to the criteria of the World Health Organization guidelines on physical activity by examining weekly aerobic activity information through a health examination questionnaire.[15] "Risk" was defined as < 150 minutes of moderate-intensity aerobic physical activity, or < 75 minutes of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate-intensity and vigorous-intensity activity throughout the week. "Recommended exercise" was defined as 150–300 minutes of moderate-intensity aerobic physical activity, or 75–150 minutes of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate-intensity and vigorous-intensity activity throughout the week. "Strong recommendation" was defined as moderate-intensity aerobic physical activity to > 300 minutes, or vigorous-intensity aerobic physical activity > 150 minutes, or an equivalent combination of moderate-intensity and vigorous-intensity activity throughout the week. Smoking status was classified into 3 groups: "non-smokers," "past-smokers," and "current-smokers." Drinking status was classified into 3 groups: "non-drinkers," "people who drink equal to or less than once a week," and "people who drink more than once a week." BMI was classified into 2 groups: "<

25 kg/m^2(non-obesity)" and "≥ 25 kg/m^2(obesity)."[16] Waist circumference was classified into 2 groups: "< 90 cm (non-abdominal obesity)" and "≥ 90 cm (abdominal obesity)."[16]

Shift work

Shift workers were defined as workers if they performed a monthly average of more than four 8-hour work shifts that included hours from 12 a.m. to 5 a.m. for 6 months or if they worked more than 60 hours per month on average between 10 p.m. and 6 a.m. for 6 months.[17] The shift work at this workplace had a 3-group-3-shift system. Shift workers' work schedule was 06:00–14:00 for day shift, 14:00–22:00 for evening shift, and 22:00–06:00 for night shift.

Definitions

Those with a clinical history of DM had at least one of the following conditions: fasting glucose concentration was ≥ 126 mg/dL or the use of glucose-lowering medication at the time of examination.[13]

TyG index was calculated with the following formula[13]:

$$\text{TyG Index} = \text{Ln (Fasting Glucose (mg/dL)} \times \text{Triglycerides (mg/dL))/2}$$

The cut-off value of TyG index for predicting development of DM was 4.69.[13]

Statistical analysis

Student's t-test and χ^2 test were conducted to compare general characteristics, occupational characteristics, physical examination, and laboratory test values after dividing subjects according to shift work. The χ^2 test was also conducted to examine variables of study subjects according to the TyG index. Continuous variables were expressed as mean and standard deviation. Categorical variables were expressed as numbers and proportion.

Logistic regression analysis was conducted to investigate the relationship between shift work and TyG index. In the crude model (Model 1), a simple logistic regression analysis was performed to evaluate the association between shift work and TyG index. In Model 2, multiple logistic regression analysis was performed by adjusting for age. In Model 3, multiple logistic regression analysis was performed by adjusting for age, employment period, obesity, abdominal obesity, smoking, drinking, physical activity, hypertension,[18] stroke,[19] and heart disease.[20] All Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA) and *p*-values of less than 0.05 were considered to be statistically significant.

Ethics statement

This study was approved by the Institutional Review Board (IRB) review of Soonchunhyang University Cheonan Hospital (IRB No. 2023-05-027).

RESULTS

Characteristics of study subjects by shift work

Table 1 shows general characteristics and occupational characteristics of subjects according to the presence or absence of shift work. A total of 3,026 people were finally analyzed, of which 1,094 were day workers and 1,932 were shift workers. Regarding age, the average age was 34.47 ± 7.73 years for all workers. Regarding average age, there was no difference

Table 1. Characteristics of study subjects by shift work

Variable	Categories	Total (n = 3,026)	Day workers (n = 1,094)	Shift workers (n = 1,932)	*p*-value
Age (years)		34.47 ± 7.73	34.23 ± 8.14	34.61 ± 7.48	0.209[a]
	20–29	888 (29.3)	363 (33.2)	525 (27.2)	0.001[b]
	30–39	1,477 (48.8)	493 (45.1)	984 (50.9)	
	40–49	491 (16.2)	166 (15.2)	325 (16.8)	
	50 over	170 (5.6)	72 (6.6)	98 (5.1)	
Employment period (years)		109.93 ± 92.01	84.84 ± 94.27	124.13 ± 87.60	< 0.001[a]
	< 10	2,202 (72.8)	881 (80.5)	1,321 (68.4)	< 0.001[b]
	10–19	531 (17.5)	122 (11.2)	409 (21.2)	
	≥ 20	293 (9.7)	91 (8.3)	202 (10.5)	
Smoking	No	1,320 (43.6)	539 (49.3)	781 (40.4)	< 0.001[b]
	Past	641 (21.2)	229 (20.9)	412 (21.3)	
	Current	1,065 (35.2)	326 (29.8)	739 (38.3)	
Drinking (day/week)	No	214 (7.1)	53 (4.8)	161 (8.3)	0.001[b]
	≤ 1	1,071 (35.4)	384 (35.1)	687 (35.6)	
	> 1	1,741 (57.5)	657 (60.1)	1,084 (56.1)	
Physical activity	Risk	1,523 (50.3)	612 (55.9)	911 (47.2)	< 0.001[b]
	Recommended exercise	646 (21.3)	232 (21.2)	414 (21.4)	
	Strong recommendation	857 (28.3)	250 (22.9)	607 (31.4)	
BMI (kg/m^2)	< 25	1,587 (52.4)	600 (54.8)	987 (51.1)	0.047[b]
	≥ 25	1,439 (47.5)	494 (45.2)	945 (48.9)	
Waist circumference (cm)	< 90	2,349 (77.6)	847 (77.4)	1,502 (77.7)	0.839[b]
	≥ 90	677 (22.4)	247 (22.6)	430 (22.3)	

Categorical variables are presented as number (%). Continuous variables are presented as mean ± standard deviation.
BMI: body mass index.
[a]Calculated by Student's t-test; [b]Calculated by χ^2 test.

statistically. Regarding employment period, the average employment period of day workers was 84.84 ± 94.27 months, which was shorter than the average employment period of shift workers at 124.13 ± 87.60 months. The proportion of those with long-term employment periods of 10–19 years and 20 years or more was higher in shift workers than in day workers. Regarding smoking status, past smokers and current smokers had higher proportions in shift workers than in day workers. For drinking status, "more than once a week" had a higher proportion in day workers than in shift workers. For physical activity, percentage of "risk" was higher in day workers than in shift workers. For BMI, the rate of obesity was higher in shift workers than in day workers. Regarding the rate of abdominal obesity, there was no difference statistically.

Results of physical examination and laboratory tests of subjects by shift work

Table 2 shows results of physical examination and laboratory tests of subjects according to the presence or absence of shift work. Systolic blood pressure (SBP) was 128.95 ± 8.59 mmHg in day workers and 129.97 ± 9.22 mmHg in shift workers. Diastolic blood pressure (DBP) was 79.69 ± 7.36 mmHg in day workers and 81.03 ± 7.51 mmHg in shift workers. Both SBP and DBP were higher in shift workers. Regarding the FBS and total cholesterol and low-density lipoprotein cholesterol and high-density lipoprotein cholesterol, there were no differences statistically. TG was higher in shift workers than in day workers (143.34 ± 92.39 mg/dL in shift workers vs. 135.30 ± 109.77 mg/dL in day workers). TyG index was higher in shift workers than in day workers (4.69 ± 0.27 in shift workers vs. 4.66 ± 0.28 in day workers).

Variables of study subjects by TyG index

Table 3 shows variables of study subjects according to TyG index. There were 1,626 subjects with a TyG index lower than 4.69 and 1,400 subjects with a TyG index higher than 4.69.

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Table 2. Results of the physical examination and laboratory tests of the subjects by shift work

Physical examinations and laboratory test	Total (n = 3,026)	Day workers (n = 1,094)	Shift workers (n = 1,932)	*p*-value
SBP (mmHg)	129.60 ± 9.01	128.95 ± 8.59	129.97 ± 9.22	0.003
DBP (mmHg)	80.54 ± 7.49	79.69 ± 7.36	81.03 ± 7.51	< 0.001
FBS (mg/dL)	96.69 ± 8.53	96.69 ± 8.56	96.70 ± 8.51	0.967
Total cholesterol (mg/dL)	194.17 ± 32.67	193.02 ± 33.03	194.82 ± 32.46	0.146
LDL cholesterol (mg/dL)	128.50 ± 31.02	128.00 ± 31.44	128.78 ± 30.79	0.564
TG (mg/dL)	140.43 ± 99.08	135.30 ± 109.77	143.34 ± 92.39	0.032
HDL cholesterol (mg/dL)	53.86 ± 12.71	54.10 ± 12.88	53.72 ± 12.61	0.435
TyG index	4.68 ± 0.28	4.66 ± 0.28	4.69 ± 0.27	< 0.001

Values are presented as mean ± standard deviation. Calculated by Student's t-test.
SBP: systolic blood pressure; DBP: diastolic blood pressure; FBS: fasting blood sugar; LDL: low-density lipoprotein; TG: triglycerides; HDL: high-density lipoprotein; TyG index: triglycerides and glucose index.

Regarding shift work, the proportion of shift workers was higher in high TyG index than in low TyG index. Regarding age, the proportion of age groups over 30s was higher in high TyG index than in low TyG index. Regarding employment period, the proportion of those with long-term employment periods of 10–19 years and 20 years or more was higher in high TyG index than in low TyG index. Regarding smoking status, past smokers and current smokers had higher proportions in high TyG index than in low TyG index. For drinking status, "more than once a week" had a higher proportion in high TyG index than in low TyG index. For physical activity, percentage of "risk" was higher in high TyG index than in low TyG index. For BMI, the rate of obesity (BMI ≥ 25) was higher in high TyG index than in low TyG index. Regarding waist circumference, the rate of abdominal obesity (a waist circumference of ≥ 90 cm) was higher in high TyG index than in low TyG index. Regarding hypertension, the rate of hypertension was higher in high TyG index than in low TyG index. Regarding stroke and heart disease, there were no differences statistically.

Association between shift work and TyG index

Table 4 shows results of logistic regression analysis to investigate the relationship between shift work and TyG index. In Model 1, a simple logistic regression analysis was performed without adjusting for any factors. Compared to day workers, odds ratio (OR) with a TyG index above cut-off value for predicting development of DM was higher in shift workers (OR: 1.276; 95% confidence interval [CI]: 1.099–1.482). In Model 2, multiple logistic regression analysis was performed by adjusting for age. Compared to day workers, OR with a TyG index above cut-off value for predicting development of DM was higher in shift workers (OR: 1.232; 95% CI: 1.055–1.438). In Model 3, multiple logistic regression analysis was performed by adjusting for age, employment period, obesity, abdominal obesity, smoking, drinking, physical activity, hypertension,[18] stroke,[19] heart disease.[20] Compared to day workers, OR with a TyG index above cut-off value for predicting development of DM was higher in shift workers (OR: 1.220; 95% CI: 1.030–1.444). To exclude the problem of multicollinearity between age and employment period, and between obesity and abdominal obesity, variance inflation factors (VIFs) were calculated. VIF values were 2.106 and 1.395, respectively.

DISCUSSION

In this study, there was a relationship between shift work and TyG index. As shown in **Table 4**, the OR of TyG index above the cut-off value for predicting development of DM for shift workers was 1.220 (95% CI: 1.030–1.444), even after adjusting for age, employment period, obesity, abdominal obesity, smoking, drinking, physical activity, hypertension, stroke, heart disease.

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Table 3. Variables of study subjects by TyG index

Variable	Categories	Total (n = 3,026)	TyG index < 4.69 (n = 1,626)	TyG index ≥ 4.69 (n = 1,400)	*p*-value
Shift work	No	1,094 (36.2)	630 (38.7)	464 (33.1)	0.001
	Yes	1,932 (63.8)	996 (61.3)	936 (66.9)	
Age (years)	20–29	888 (29.3)	634 (39.0)	254 (18.1)	< 0.001
	30–39	1,477 (48.8)	752 (46.2)	725 (51.8)	
	40–49	491 (16.2)	179 (11.0)	312 (22.3)	
	50 over	170 (5.6)	61 (3.8)	109 (7.8)	
Employment period (years)	< 10	2,202 (72.8)	1,310 (80.6)	892 (63.7)	< 0.001
	10–19	531 (17.5)	216 (13.3)	315 (22.5)	
	≥ 20	293 (9.7)	100 (6.2)	193 (13.8)	
Smoking	No	1,320 (43.6)	858 (52.8)	462 (33.0)	< 0.001
	Past	641 (21.2)	295 (18.1)	346 (24.7)	
	Current	1,065 (35.2)	473 (29.1)	592 (42.3)	
Drinking (day/week)	No	214 (7.1)	119 (7.3)	95 (6.8)	< 0.001
	≤ 1	1,071 (35.4)	645 (39.7)	426 (30.4)	
	> 1	1,741 (57.5)	862 (53.0)	879 (62.8)	
Physical activity	Risk	1,523 (50.3)	736 (45.3)	787 (56.2)	< 0.001
	Recommended exercise	646 (21.3)	361 (22.2)	285 (20.4)	
	Strong recommendation	857 (28.3)	529 (32.5)	328 (23.4)	
BMI (kg/m^2)	< 25	1,587 (52.4)	1,034 (63.6)	553 (39.5)	< 0.001
	≥ 25	1,439 (47.6)	592 (36.4)	847 (60.5)	
Waist circumference (cm)	< 90	2,349 (77.6)	1,402 (86.2)	947 (67.6)	< 0.001
	≥ 90	677 (22.4)	224 (13.8)	453 (32.4)	
Hypertension	No	2,722 (90.0)	1,541 (94.8)	1,181 (84.4)	< 0.001
	Yes	304 (10.0)	85 (5.2)	219 (15.6)	
Stroke	No	3,025 (100.0)	1,626 (100.0)	1,399 (99.9)	0.463
	Yes	1 (0.0)	0 (0.0)	1 (0.1)	
Heart disease	No	3,013 (99.6)	1,619 (99.6)	1,394 (99.6)	0.994
	Yes	13 (0.4)	7 (0.4)	6 (0.4)	

Categorical variables are presented as number (%). Calculated by χ^2 test.
TyG index: triglycerides and glucose index; BMI: body mass index.

Table 4. Association between shift work and triglycerides and glucose index

Group	Model 1	Model 2	Model 3
Day workers	1.000 (reference)	1.000 (reference)	1.000 (reference)
Shift workers	1.276 (1.099–1.482)**	1.232 (1.055–1.438)**	1.220 (1.030–1.444)*

Values are presented as odds ratio (95% confidence interval).
Model 1: crude; Model 2: adjusted for age; Model 3: adjusted for age, employment period, obesity, abdominal obesity, smoking, drinking, physical activity, hypertension, stroke, heart disease.
*p < 0.05, **p < 0.01.

In this study, the cut-off value of TyG index for predicting development of DM was 4.69. This was a value derived from a study by Kim et al.[13] reporting cut-off values of surrogate measures for insulin resistance. Kim et al.[13] have suggested that the valid cut-off value of TyG index for predicting development of DM is 4.69 using data from a population-based longitudinal study. In their study, this cut-off value had a sensitivity of 62.1% and a specificity of 63.1% with a hazard ratio of 2.17 (95% CI: 1.92–2.45).

Additionally, we analyzed the cut-off value not at 4.69, but at 4.64, which is the 50th percentile of the TyG index value in the study by Kim et al.,[13] and 4.49, which is the 25th percentile. When 4.64, the 50th percentile value, was set as the cut-off value, the OR of TyG index above the 4.64 for shift workers was 1.190 (95% CI: 1.006–1.407), even after adjusting for age, employment period, obesity, abdominal obesity, smoking, drinking, physical activity, hypertension, stroke, heart disease. When 4.49, the 25th percentile value, was set as the cut-off value, the OR of TyG index above the 4.49 for shift workers was 1.374 (95% CI: 1.143–1.652), even after adjusting for age, employment period, obesity, abdominal obesity,

smoking, drinking, physical activity, hypertension, stroke, heart disease. Both studies showed statistically significant results, and in particular, when the 25th percentile value of 4.49 was used as the cut-off value, the result was more statistically significant than the result of this study. In study by Kim et al.,[13] the cut-off value of TyG index for predicting development of DM was 4.69, but additional researches may be needed to find the optimal cut-off value.

As can be seen in **Table 3**, relationships between heart disorder, stoke, and TyG index were not significant. This was in contrast to previous studies. Such difference might be because subjects of the present study were young with few people having a history of heart disease and stroke. If they had previously suffered from these diseases, they were likely to be not working currently. In addition, the actual number of people diagnosed with those diseases might have been underestimated as it was the result of a survey through a self-report-based questionnaire. According to a Korean stroke epidemiological report in 2018, the prevalence rate of stroke was 1.90% in adult men with age over 19 years, 0.71% in the age group of 19–54, and 4.48% in the age group of 55–74 years.[21] However, the prevalence rate of stroke was lower in subjects of this study.

There have been studies on mechanism between shift work and insulin resistance, which is considered pathophysiological cause of diabetes. Circadian rhythm is known to be involved in the mechanism by which shift work affects insulin resistance.[22] The shift work at this workplace had a 3-group-3-shift system. In this study, the reason for the relationship between shift work and TyG index might be due to desynchronization of circadian rhythm known as misalignment of internal rhythm and external environments caused by shift work.

Diabetes is a chronic disease that requires lifelong management. It can cause complications. Thus, early detection is important in early stages. However, early detection might be difficult because there are no special subjective symptoms. Thus, the use of TyG index can help us select and manage subjects at high risk of developing diabetes. TyG index can be monitored by periodic health checkups.

Similar to results of this study, previous studies have also confirmed that shift work and insulin resistance indicators are related. In a study conducted by Ledda et al.,[23] on healthcare workers in the city of Catania, Italy, there was a positive association between shift work and HOMA-IR, one of the insulin resistance indicators. In a study conducted by Sadeghniiat-Haghighi et al.,[24] on professional drivers, shift drivers displayed higher levels of HOMA-IR. However, the majority of previous studies mainly used HOMA-IR as an indicator of insulin resistance, with most previous studies confirming the relationship between shift work and HOMA-IR.

However, in this study, the TyG index rather than the mainly used HOMA-IR was used as an insulin resistance index. This is because the TyG index, like HOMA-IR, is simple, non-invasive, and in-expensive compared to direct indicators of insulin resistance.[8,9] In addition, it is a better predictor for diabetes than HOMA-IR.[13] Also, according to a study of TyG index as a predictor of diabetes compared to fasting plasma glucose and TGs by Navarro-González et al.,[25] the areas under the receiver operating characteristic curves (95% CI) were 0.75 (0.70–0.81) for TyG index, 0.66 (0.60–0.72) for fasting plasma glucose and 0.71 (0.65–0.77) for TGs. The TyG index was a better predictor for diabetes than fasting plasma glucose or TGs. Moreover, the TyG index does not require fasting insulin measurement which is required when calculating HOMA-IR. Only TGs and FBS, which can be tested more easily, are used for calculating TyG index, making it simpler and less expensive than HOMA-IR. And TGs

and FBS are values that are examined during special health examinations of shift workers, so there is an advantage that it can be obtained only by special examination results.

This study has several limitations. First, since this study was a cross-sectional study, there was a limit in inferring a causal relationship. Secondly, this study was conducted using medical examination records with a limit to information on shift work. There were limitations due to the nature of medical examinations that provide fixed questionnaires. At the time of medical examination, it was possible to confirm whether the workers were day workers or shift workers, but it was impossible to verify whether day workers exclusively engage in day work and shift workers solely in shift work. And it was also impossible to verify past experiences with shift work. In addition, we could not obtain information on the duration of shift work among employment periods. The employment periods of workers were calculated as the period from the start of work to the date of health examination, and it was not possible to distinguish between pure day working years and pure shift working years. Since there is a study showing that longer duration of shift work is associated with DM,[26] the inability to confirm the duration of shift work can be seen as a limitation of this study. Third, in a previous study using TyG index as a predictor for DM, those with glucose concentration ≥ 200 mg/dL in an oral 75-g 2-hour glucose tolerance test and those with HbA1c ≥ 6.5% were also excluded in that study.[13] However, this figure was not reflected in the present study because it could not be confirmed in health examination data. Finally, subjects of this study had an average age of 34.47 years, which was younger than the average age of manufacturing workers at 42.1 years in the year of health check-up (in 2019).[27] Therefore, it is difficult to generalize these fragmentary research results. In addition, since the average age of the subjects of the existing researches studied on TyG index is significantly higher than that of this study, there is a lack of researches that can be compared with the results of this study. It is thought that further researches are needed in the future

Despite these limitations, this study is significant in that it is a study using TyG index which is not yet widely used because it is relatively recent index, which is easier and cheaper to calculate and simpler than using previously widely used indicators such as HOMA-IR because TyG index can be calculated only with FBS and TGs. In addition, this is the first study on the relationship between shift work and TyG index using more than 3,000 workers in a single workplace.

CONCLUSIONS

There was a significant association between shift work and TyG index among male workers in a chemical plant. Based on previous studies showing that TyG index is valuable as a predictor for diabetes,[13,25,28] it will be necessary to consider ways to pay attention to and manage TyG index in terms of health care for shift workers. However, as mentioned earlier, this study had several limitations. Further studies are needed to correct limitations of this study.

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