Multimorbidity and its associated factors in Korean shift workers: A population-based study

Hye Chong Hong, Young Man Kim

Submitted to: JMIR Public Health and Surveillance
on: November 30, 2023

Table of Contents

Multimorbidity and its associated factors in Korean shift workers: A population-based study

Hye Chong Hong[1] PhD, MSN; Young Man Kim[2] PhD, MSN

[1]Department of Nursing Chung-Ang University Seoul KR
[2]College of Nursing | Research Institute of Nursing Science Jeonbuk National University Jeonju KR

Corresponding Author:
Young Man Kim PhD, MSN
College of Nursing | Research Institute of Nursing Science
Jeonbuk National University
567 Baekje-daero
Deokjin-gu
Jeonju
KR

Abstract

Background: Multimorbidity is a crucial factor that influences premature death rates, poor health, and healthcare utilization. Approximately one-fifth of the global workforce is involved in shift work which is associated with increased risk for several chronic diseases and multimorbidity.

Objective: This study aimed to identify multimorbidity patterns and examine the factors associated with multimorbidity among shift workers in Korea.

Methods: Data from the Korea National Health and Nutrition Examination Surveys (KNHANES) from 2016 to 2020 were utilized. The study included n = 1,704 (Weighted N = 2,697,228) Korean shift workers aged 19 and older. Multimorbidity patterns were identified by network analysis, and a survey-corrected logistic regression analysis was performed to identify influencing factors of multimorbidity among the workers.

Results: The overall prevalence of multimorbidity was 13.7%. Network analysis results revealed that chronic diseases clustered into three groups: 1) cardiometabolic multimorbidity 2) musculoskeletal multimorbidity, and 3) an unclassified disease group. Logistic regression indicated that age, income, regular work, and obesity were significant factors influencing multimorbidity.

Conclusions: The findings revealed that several socioeconomic and behavioral factors were associated with multimorbidity among shift workers indicating the need for policy development related to work schedule modification. Further organization-level screening and intervention programs are needed to prevent and manage multimorbidity among shift workers.

(JMIR Preprints 30/11/2023:55014)
DOI: https://doi.org/10.2196/preprints.55014

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Multimorbidity and its associated factors in Korean shift workers: A population-based study

ABSTRACT

Background: Multimorbidity is a crucial factor that influences premature death rates, poor health, depression, quality of life, and healthcare utilization. Approximately one-fifth of the global workforce is involved in shift work which is associated with increased risk for several chronic diseases and multimorbidity. About 12% to 14% of wage workers are shift workers in Korea. However, the prevalence of multimorbidity and its associated factors are rarely reported in Korean shift workers.

Objectives: This study aimed to assess multimorbidity prevalence and examine the factors associated with multimorbidity and identify multimorbidity pattern among shift workers in Korea.

Methods: This study is a population-based cross-sectional study using Korea National Health and Nutrition Examination Survey data from 2016 to 2020. The study included n = 1,704 (Weighted N = 2,697,228) Korean shift workers aged 19 and older. Multimorbidity was defined if participants had two or more chronic diseases. Demographic and job-related variables including regular work status, average working hours per week, and shift work type, and health behaviors including body mass index, smoking status, alcohol use, physical activity and sleep duration were included in the analysis. A survey-corrected logistic regression analysis was performed to identify influencing factors of multimorbidity among the workers and multimorbidity patterns were identified by network analysis.

Results: The overall prevalence of multimorbidity was 13.7%. Logistic regression indicated that age, income, regular work, and obesity were significant factors influencing multimorbidity. Network analysis results revealed that chronic diseases clustered into three groups: 1) cardiometabolic multimorbidity (hypertension, dyslipidemia, diabetes, coronary heart disease, and stroke), 2) musculoskeletal multimorbidity (arthritis and osteoporosis), and 3) unclassified disease group (depression, chronic liver disease, thyroid disease, asthma, cancer, and chronic kidney disease).

Conclusions: The findings revealed that several socioeconomic and behavioral factors were

associated with multimorbidity among shift workers indicating the need for policy development related to work schedule modification. Further organization-level screening and intervention programs are needed to prevent and manage multimorbidity among shift workers. We also recommend longitudinal studies to confirm the effects of job-related factors and health behaviors on multimorbidity among shift workers in the future.

Keywords: chronic disease, multimorbidity, shift work schedule

1 INTRODUCTION

Shift work includes any work schedule that is outside of the conventional 7 a.m. to 6 p.m. working hours. Shift work is prevalent and inevitable in some workforces, including healthcare, law enforcement, and manufacturing [1]. Globally, a total of approximately one-fifth of the workforce is involved in shift work [2]. While shift work allows workplace flexibility and may provide economic benefits, it may also be associated with adverse chronic health outcomes [3].

Shift work is known to disrupt circadian rhythms and affect sleep patterns, hormone secretion, and other biological processes [4]. Furthermore, these disruptions have been associated with chronic diseases such as metabolic disorders, diabetes, cardiovascular disease, stroke, cancer, and depression among shift workers [5, 6]. However, most epidemiological and systematic review studies examining the relationships between shift work and chronic diseases only examined the effect of shift work on a single chronic disease despite potential chronic disease comorbidities existing. Few studies have examined the coexistence of chronic disease and shift work. For example, Yang et al. (2022) examined shift work and the risk of cardiometabolic multimorbidity among patients with hypertension and found that shift work was associated with cardiometabolic multimorbidity [7]. In Korean population, shift work was found to be associated with mental health problems such as depression and suicide ideation in electronic workers [8], chronic kidney disease in female manual labor workers [9], and metabolic syndrome in female Korean workers [10].

Multimorbidity refers to the existence of two or more chronic diseases in an individual [11, 12]. Unlike comorbidity which examines the combined effects of chronic diseases related to a primary chronic disease, multimorbidity examines all chronic diseases simultaneously which means that no single condition is more important than others [13]. Multimorbidity is person-centered and does not assign priority to a single condition [14]. Globally, approximately 37% of the general population has multimorbidity [15] and it is associated with premature death [16], poor health [17, 18] depression [19], poor quality of life [20], and increased healthcare utilization [21]. Additionally,

age, gender, educational level, smoking, and obesity were associated with multimorbidity in previous research among adults aged 50 and over [22]. Multimorbidity has become increasingly important as changing health behaviors, such as physical activity and obesity, are a core focus in multimorbidity prevention. Screening and behavioral changes, as well as developing intervention programs, may be important for prevention among people with multimorbidity.

About 12% to 14% of wage workers are shift workers in Korea, and weekly working hours varied from 50 hours to 58 hours depending upon the shift types which were significantly higher than day workers [23]. Shift work and long working hours are well-known risk factors for increasing several chronic diseases. However, the prevalence of multimorbidity and its associated factors are rarely reported in Korean shift workers. Identifying and understanding the prevalence multimorbidity may yield important information for focused care of shift workers and help develop policies related to shift work schedules and interventions needed to prevent and manage shift workers' multimorbidity in Korea. We additionally performed the network analysis to show the multimorbidity pattern as certain chronic diseases are likely to co-occur as the pathophysiological pathways are similar [24]. Understanding the patterns of these co-occurred chronic diseases may be beneficial as it may provide vital information for clinicians and policy makers to develop and implement intervention programs for specific groups with similar multimorbidity. Therefore, the purpose of this study is to 1) Assess the prevalence of multimorbidity, 2) examine the factors associated with multimorbidity among shift workers in Korea, and 3) identify the patterns of multimorbidity.

2 METHODS

This study follows the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines [25].

2.1 Design

This is a population-based, cross-sectional study using Korea National Health and Nutrition Examination Survey (KNHANES) data from 2016 to 2020.

2.2 Data source

KNHANES uses a nationally representative sample based on a complex, stratified, multistage cluster sampling method that includes geographical area, gender, and age to provide a representation of the Korean population which is freely available to public. KNHANES utilizes a series of cross-sectional national surveys that have been conducted by the Korean Centers for Disease Control and Prevention (KCDC). These consist of a health survey, a health examination, and a nutrition survey [26].

2.3 Study sample

The participants of this study were shift workers aged 19 and older. Shift workers were defined as those who work at night or are non-day workers. This included both evening work, night work, day/night regular shift work, and irregular shift work. Exclusion criteria were: (1) those who were younger than 19 years of age, (2) those who were non-workers, and (3) those with missing data on any of the chronic diseases. The detailed sample selection flow is shown in Supplementary Figure 1.

2.4 Ethical considerations

The ethical review and approval were exemption from the institutional review board of the first author's institution (no. 1041078-20230518-HR-139) as this study was a secondary analysis of a pre-existing data. The primary data (KNHANES) included anonymous data and informed consent was obtained prior to the data collection.

2.5 Measures

2.5.1 Multimorbidity

We defined multimorbidity as when participants had two or more chronic conditions simultaneously. Based on previous studies [27-29], 13 globally common chronic diseases were

included. These included hypertension (HTN), dyslipidemia, diabetes, arthritis, cancer, asthma, depression, osteoporosis, thyroid disease, coronary heart disease (CHD), chronic liver disease (CLD), stroke, and chronic kidney disease (CKD). The presence of disease was determined by self-reporting by the participants of whether they had ever been diagnosed with each disease by a physician. The multimorbidity group was operationally defined as shift workers with two or more of the 13 diseases. The non-multimorbidity group was defined as healthy participants or participants with only one chronic condition among the 13 diseases.

2.5.2 Demographic and job-related variables

Sex, age, household income, education, and marital status were considered as demographic characteristics. Household income was divided into quartiles, which are calculated annually to evenly distribute the population into four groups by sex and age, using the monthly average equivalized income. Education was divided into four groups consisting of less than elementary school, middle school, high school, and university and above. Marital status was categorized as married or single. Job-related variables included regular work and average working hours per week. The type of shift work was divided into evening work, night work, regular shift work, and irregular shift work. Regular work was defined as that conducted by permanent workers or full-time employees while non-regular work included work conducted by contract workers, contractors, and part-time workers.

2.5.3 Health behaviors

This study utilized multiple health behavior variables, including body mass index (BMI), smoking status, alcohol use, physical activity, and poor sleep duration. BMI was categorized as underweight (<18.5 kg/m^2), normal (≥18.5 to <23 kg/m^2), overweight (≥23 to <25 kg/m^2), and obese (≥25 kg/m^2) based on the WHO cutoffs for Asia-Pacific countries [30]. Smoking status was categorized as non-smoker, ex-smoker, and current smoker. Alcohol use was categorized into low-risk drinking, at-risk drinking, alcohol abuse, and alcohol dependence using the Korean version of

the Alcohol Use Disorders Identification Test-Concise (AUDIT-C) [31]. Physical activity was measured by aerobic physical activity rate. If participants exercised for at least 2 h and 30 min of moderate-intensity physical activity per week, or at least 1 h and 15 min of high-intensity physical activity, or a mixture of moderate and high-intensity physical activities (1 min of high-intensity activity equals 2 min of moderate-intensity activity), then it was counted as "Yes" for aerobic physical activity rate. Poor sleep duration reflects either less than 7 h or more than 9 h per day, therefore 7–9 h of sleep per day is considered a good sleep duration [32, 33].

2.6 Data analysis

Data were analyzed using Stata version 16.1 (StataCorp LP, College Station, TX, USA) and JASP (Version 0.17.1). Additionally, KNHANES analytic guidelines were followed with the data to adjust for complex sampling designs to estimate the population-level statistics for Korea. We conducted a complete case analysis without any imputation, following the analytic guidelines [26]. All statistical tests were based on point estimation using a two-sided *p* value (< .05) and interval estimation using 95% confidence intervals (CI). Specific analysis was conducted as follows. First, descriptive statistics were utilized, including weighted *N*, *n*, weighted percentage, weighted mean, and standard error (*SE*) to present population characteristics and their multimorbidity characteristics. Second, univariate analyses using the survey-corrected, Rao-Scott chi-square test and adjusted Wald test were conducted to reveal the different characteristics between the multimorbidity and the non-multimorbidity shift workers groups. Third, survey-corrected logistic regression analyses were used to identify influencing factors of multimorbidity among shift workers. In the final model, variables that were statistically significant in the univariate analysis were included. We additionally conducted subgroup analysis based on age, using 50 years as the threshold. Lastly, network analysis was employed for exploring the pattern of multimorbidity clusters among shift workers. The network model was graphically represented by nodes (circles, representing each morbidity) and edges (lines connecting the nodes). The structural importance of multimorbidity patterns was analyzed using node

centrality measures including closeness, betweenness, strength, and expected influence. Clustering and naming of subgroups within multimorbidity were determined through discussion among researchers based on prior studies [7, 34].

3 RESULTS

3.1 Participant characteristics

The final selected shift worker sample size was *n* =1,704 and the weighted population size was *N* = 2,697,228. The weighted percentage of males (56.7%) was slightly more than females and the mean age of the participants was 41.93 (*SE* = 0.42), with an age range of 19 to 80 (Table 1). The majority of the participants' household incomes indicated that they belonged to the third (32.9%) and the fourth quartile (33.4%). As for educational attainment levels, 87.2% of participants graduated from high school or higher. Additionally, there were more married (64.6%) than single participants. Participants were divided into shift work types with 920 (53.4%) in evening work, 191 (12.2%) in night work, 454 (27.3%) in regular shift work, and 139 (7.1%) in irregular shift work. The proportion of non-regular workers was high at 63.7%, and the average working hours per week was 38.01 h.

The mean BMI was 24.20, and overweight and obese participants with a BMI of 23.0 or higher accounted for 60.3% of the total. Non-smokers were the most common at 51.9%, and low-risk drinking was engaged in by the majority of the workers at 67.2%. The proportion of workers engaged in aerobic physical activity was 50.05%, which was similar to the proportion of participants not engaged in aerobic physical activity. The average sleep time was 7.34 h, and workers who showed a poor sleep pattern accounted for the majority at 55.9%.

Table 1. General Characteristics of Shift Workers

(*N* = 1,704, *Weighted N* = 2,697,228)

Variables	Characteristics	*n* (weighted %)	*M*±*SE*
Demographics	Sex		
	Male	849 (56.7)	
	Female	855 (43.3)	
	Age		41.93±0.42
	House income (Quartile)		

	Low (1Q)	170 (9.3)	
	Lower middle (2Q)	432 (25.4)	
	Higher middle (3Q)	538 (32.9)	
	High (4Q)	561 (33.4)	
	Education		
	≤ Elementary school	153 (5.7)	
	Middle school	132 (6.1)	
	High school	743 (46.4)	
	≥ University	676 (41.8)	
	Marital status		
	Married	1,209 (64.6)	
	Single	495 (35.4)	
Occupational status	Shift work type		
	Evening work	920 (53.4)	
	Night work	191 (12.2)	
	Regular shift work	454 (27.3)	
	Irregular shift work	139 (7.1)	
	Regular work		
	Yes	417 (36.3)	
	No	821 (63.7)	
	Working hours per week		38.01±0.59
Health behaviors	BMI		24.20±0.11
	Normal	618 (35.7)	
	Underweight	70 (4.0)	
	Overweight	410 (23.6)	
	Obese	600 (36.7)	
	Smoking		
	Non-smoker	954 (51.9)	
	Ex-smoker	331 (19.9)	
	Current smoker	419 (28.2)	
	Alcohol use		
	Low risk drinking	969 (67.2)	
	At-risk drinking	133 (10.5)	
	Alcohol abuse	192 (15.2)	
	Alcohol dependence	84 (7.1)	
	Physical activity		
	Yes	808 (50.05)	
	No	890 (49.95)	
	Sleep hours		7.34±0.04
	Poor sleep		
	Yes (< 7hrs or > 9hrs)	940 (55.9)	
	No (7 to 9 hours)	758 (44.1)	

Notes. *M* = mean, *SE* = standard error

3.2 Multimorbidity characteristics of shift workers

Table 2 shows the multimorbidity characteristics of the shift workers. Hypertension (14.2%)

was the most common of the 13 chronic conditions, followed by dyslipidemia (11.0%), diabetes (5.3%), and arthritis (5.1%). The multimorbidity prevalence in shift workers was found to be 13.7% and the number of chronic conditions ranged from 0 to 6.

Table 2. Multimorbidity Characteristics of Shift Workers

(*N* = 1,704, *Weighted N* = 2,697,228)

Variables	*n*	Prevalence (Weighted %)
Chronic Conditions		
Hypertension	287	14.2
Dyslipidemia	235	11.0
Diabetes	107	5.3
Arthritis	126	5.1
Cancer	90	3.9
Asthma	50	3.3
Depression	60	3.1
Osteoporosis	68	2.7
Thyroid disease	52	2.7
Coronary heart disease	33	1.3
Chronic liver disease	14	0.9
Stroke	12	0.5
Chronic kidney disease	10	0.5
Number of Chronic Conditions		
Zero	1,046	67.1
One	356	19.2
Two	175	8.3
Three	84	3.8
Four	32	1.2
Five	8	0.3
Six	3	0.1
The average number of chronic conditions: 0.54±0.02 (range 0–6 from a total of 13 chronic conditions)		

Notes. The order of chronic conditions are presented from the highest weighted percentage to lowest.

3.3 Differences in characteristics by multimorbidity presence

The differences between the multimorbidity group and the non-multimorbidity group are presented in Table 3. The average age of the multimorbidity group was 57.21 years, which was statistically significantly higher than that of the non-multimorbidity group (*M* = 39.51). The multimorbidity group had lower household incomes and educational levels, lower numbers of

unmarried people, higher irregular work levels, higher BMI, fewer current smokers, less physical activity, and a higher proportion of poor sleep compared to the non-multimorbidity group, with all differences being statistically significant.

Table 3. Differences of Characteristics in Multimorbidity vs Non-multimorbidity Group among Shift Workers

(*N* = 1,704, *Weighted N* = 2,697,228)

Characteristics	NMG 1,402 (86.3%)	MG 302 (13.7%)	*F*	*P value*
	Weighted (weighted %)	*M*±*SE* or *n*		
Sex				
Male	710 (49.7)	139 (7.1)	2.71	.10
Female	139 (36.6)	163 (6.6)		
Age	39.51±0.42	57.21±0.69	497.79†	<.001
< 50	956 (64.4)	45 (2.7)	240.28	<.001
≥ 50	446 (21.9)	257 (11.0)		
House income (Quartile)				
Low (1Q)	113 (6.9)	58 (2.4)	10.03	<.001
Lower middle (2Q)	330 (20.3)	102 (4.1)		
Higher middle (3Q)	458 (28.9)	80 (4.0)		
High (4Q)	499 (30.2)	62 (3.2)		
Education				
≤ Elementary school	67 (2.7)	86 (3.0)	55.52	<.001
Middle school	82 (4.1)	50 (2.0)		
High school	632 (40.8)	111 (5.6)		
≥ University	621 (38.7)	55 (3.1)		
Marital status				
Married	922 (51.7)	287 (12.9)	92.36	<.001
Single	480 (34.6)	15 (0.8)		
Shift work type				
Evening work	769 (46.4)	151 (7.0)	1.59	.19
Night work	162 (10.9)	29 (1.3)		
Regular shift work	369 (23.1)	85 (4.2)		
Irregular shift work	102 (5.8)	37 (1.3)		
Regular work				
Yes	369 (33.0)	48 (3.3)	8.10	.005
No	652 (53.7)	169 (10.0)		
Working hours per week	37.90±0.62	38.72±1.42	0.30†	.58
BMI	23.98±0.12	25.57±0.24	34.45†	<.001
Normal	536 (32.5)	82 (3.3)	11.87	<.001
Underweight	67 (3.9)	3 (0.1)		
Overweight	330 (19.9)	80 (3.7)		
Obese	463 (30.0)	137 (6.7)		
Smoking				
Non-smoker	780 (44.7)	174 (7.2)	5.90	.003

Characteristics	NMG 1,402 (86.3%)	MG 302 (13.7%)	*F*	*P* value
	Weighted (weighted %)	*M*±*SE* or *n*		
Ex-smoker	257 (16.1)	74 (3.8)		
Current smoker	365 (25.5)	54 (2.7)		
Alcohol use				
Low risk drinking	830 (59.5)	139 (7.7)	1.19	.31
At-risk drinking	116 (9.5)	17 (1.0)		
Alcohol abuse	169 (13.7)	23 (1.5)		
Alcohol dependence	67 (5.9)	17 (1.2)		
Physical activity				
Yes	688 (44.2)	120 (5.8)	5.50	.02
No	708 (42.0)	182 (7.9)		
Poor sleep				
Yes (< 7 h or > 9 h)	595 (36.6)	163 (7.5)	10.21	.002
No (7 to 9 h)	801 (49.7)	139 (6.2)		

Notes. *M* = mean, *SE* = standard error, NMG = non-multimorbidity group, MG = multimorbidity group

[†]Adjusted Wald test

3.4 Influencing factors for multimorbidity in shift workers

Table 4 presents the factors affecting multimorbidity in shift workers. Examining the relationship between each influencing factor and the two variables (crude odds ratio) of multimorbidity, age, household income, education, marital status, regular work, BMI, smoking, physical activity, and poor sleep quality were all factors influencing multimorbidity. In the final adjusted logistic model, factors affecting multimorbidity were age (odds ratio [OR] 1.106, 95% CI 1.069 to 1.144, $p < .001$) 3Q (OR 0.302, 95% CI 0.119 to 0.768, $p = .012$) vs. 1Q of house income, and 4Q (OR 0.366, 95% CI 0.142 to 0.942, $p = .037$) vs. 1Q, non-regular work (OR 1.804, 95% CI 1.008 to 3.228, $p = .047$), and obese BMI (OR 2.152, 95% CI 1.155 to 4.010, $p = .016$) vs. normal BMI. That is, when the age increased by 1 year, the risk of multimorbidity increased by 1.11 times, and the risk of multimorbidity in the 3Q and 4Q household income groups decreased by 69.8% and 63.4%, respectively, compared to low household income (1Q). The risk of multimorbidity in the non-regular work group increased by 1.8 times compared with the regular work group, and the risk of

multimorbidity in the obese group increased by 2.15 times compared to the normal BMI group. Subgroup analysis results showed that age, regular work, BMI (obese) was associated with multimorbidity in the younger than 50 years old age, while house income, education, marital status, BMI (obese) was associated in 50 years or older age subgroup (Supplementary Table 1).

Table 4. Factors affecting Multimorbidity in Shift Workers

(*N* = 1,704, *Weighted N* = 2,697,228)

Factors	Crude OR	95% CI		*P* value	Adjusted OR	95% CI		*P* value
Age	1.106	1.091	to	<.001	1.106	1.069	to	<.001
		1.120				1.144		
House income (Quartile)								
Low (1Q)	Ref.							
Lower middle (2Q)	0.597	0.378	to	.03	0.467	0.193	to	.09
		0.943				1.129		
Higher middle (3Q)	0.406	0.261	to	<.001	0.302	0.119	to	.01
		0.630				0.768		
High (4Q)	0.311	0.195	to	<.001	0.366	0.142	to	.04
		0.496				0.942		
Education								
≤ Elementary school	Ref.							
Middle school	0.439	0.257	to	.003	0.503	0.202	to	.14
		0.750				1.255		
High school	0.126	0.082	to	<.001	0.611	0.293	to	.19
		0.196				1.276		
≥ University	0.074	0.046	to	<.001	0.528	0.213	to	.17
		0.119				1.304		
Marital status								
Married	Ref.							
Single	0.089	0.049	to	<.001	0.749	0.245	to	.61
		0.164				2.292		
Regular work								
Yes	Ref.							
No	1.847	1.199	to	.006	1.804	1.008	to	.047
		2.847				3.228		
BMI								
Normal	Ref.							
Underweight	0.251	0.074	to	.03				
		0.859						
Overweight	1.815	1.261	to	.001	0.918	0.466	to	.81
		2.612				1.809		
Obese	2.216	1.581	to	<.001	2.152	1.155	to	.02
		3.106				4.010		

Factors	Crude OR	95% CI		*P* value	Adjusted OR	95% CI		*P* value
Smoking								
Non-smoker	Ref.							
Ex-smoker	1.472	1.025 2.115	to	.04	0.950	0.474 1.903	to	.89
Current smoker	0.668	0.446 0.999	to	.05	0.987	0.490 1.990	to	.97
Physical activity								
No	Ref.							
Yes	0.701	0.516 0.951	to	.02	1.435	0.819 2.514	to	.21
Poor sleep								
No (7 to 9 h)	Ref.							
Yes (< 7 h or > 9 h)	1.650	1.213 2.245	to	.001	1.467	0.880 2.445	to	.14

Notes. OR = odds ratio, CI = confidence interval, Ref = reference.

3.5 Network analysis

As presented in Figure 1, network analysis results revealed that chronic diseases were clustered into three groups: 1) cardiometabolic multimorbidity (HTN, dyslipidemia, diabetes, CHD, and stroke), 2) musculoskeletal multimorbidity (arthritis and osteoporosis), and 3) unclassified disease group (depression, CLD, thyroid disease, asthma, cancer, and CKD). A centrality plot of multimorbidity patterns in shift workers shows HTN, dyslipidemia, arthritis, diabetes, and osteoporosis by strength and expected influence in order (Supplementary Figure 2).

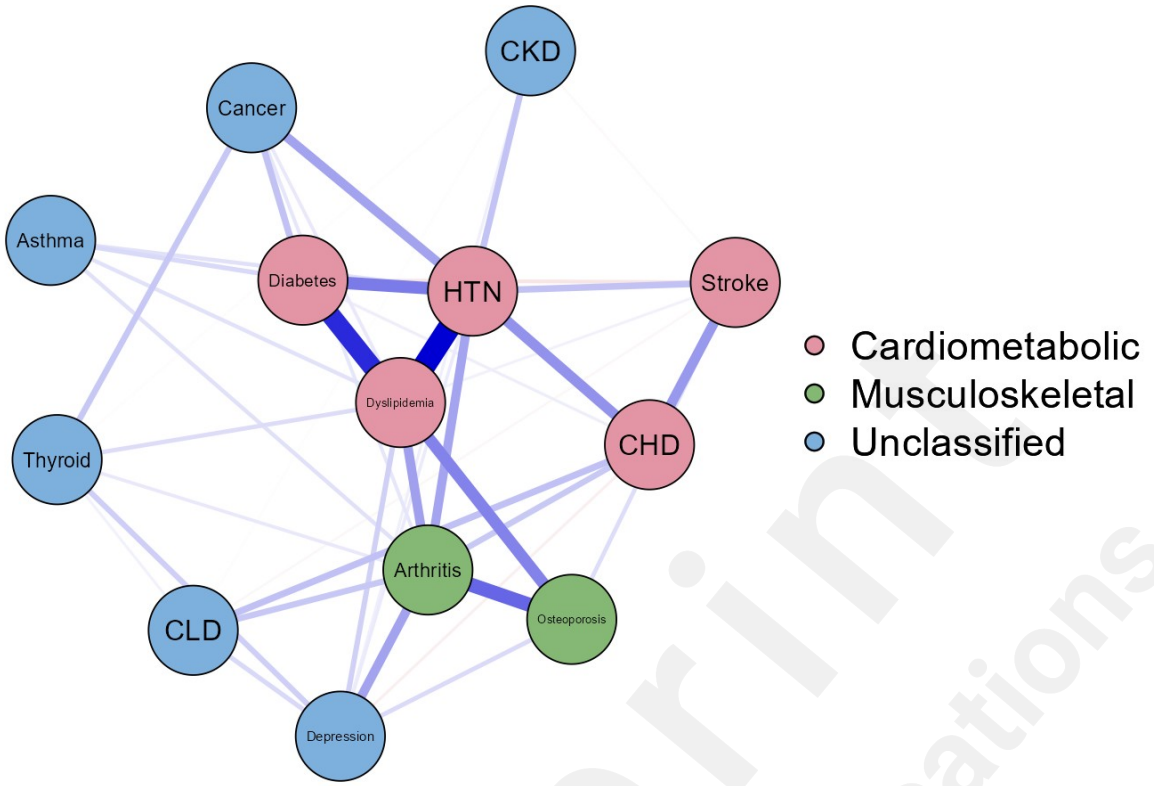


Fig 1. Multimorbidity network in shift workers. Network analysis results revealed three pattern groups: 1) cardiometabolic multimorbidity (HTN, dyslipidemia, diabetes, CHD, and stroke), 2) musculoskeletal multimorbidity (arthritis and osteoporosis), and 3) unclassified disease group (depression, CLD, thyroid disease, asthma, cancer, and CKD)
Notes. CKD = chronic kidney disease, HNT = hypertension, CHD = coronary heart disease, CLD = chronic liver disease

4 DISCUSSION

This study aimed to identify patterns of multimorbidity and examine the factors associated with multimorbidity among shift workers in Korea. Among the 1,704 shift workers included in the study, approximately 14% had multimorbidity. In a recent meta-analysis on the global prevalence of multimorbidity in the adult population, approximately 37% had multimorbidity [15]. The difference in prevalence could be due to several factors. First, the mean age of our sample was relatively low at 41.9 years compared to 56.9 years in the meta-analysis. It has been recognized that older age is associated with an increased number of chronic diseases [35]. Furthermore, women are more prone to get chronic diseases compared with men [36, 37] and a higher proportion of our samples were

male.

It is recognized that shift work is associated with adverse health outcomes. Previous research reported that shift work increases the risk of cardiovascular incidence and mortality, cancer, and stroke [1, 7, 38-40]. Approximately 14% of the Korean population is involved in shift work, and although some shift work is inevitable and may provide economic benefits, policies are needed to modify and manage shift schedules. Socioeconomic and behavioral factors are also known to increase the risk for multimorbidity. Consistent with previous research, we found that shift workers in the low-income and obese groups had increased risks of developing multimorbidity. The relationship between low income and the development of chronic diseases and multimorbidity may be explained by less physical activity and lower fruit and vegetable consumption in the low-income group [41, 42]. Furthermore, obesity is a major risk factor associated with developing several chronic diseases including diabetes, heart disease, asthma, arthritis, and depression [43]. We found a high proportion of Korean workers are involved in non-regular work (63.7%) and a regular work status was a significant factor influencing multimorbidity. Many non-regular workers are paid low wages (less than US$ 10 per hour), employed on 2-year fixed-term contracts, and may be able to extend their employment or ask to terminate the employment every two years. Those who work less than a certain number of hours per week are not covered by social insurance and are not entitled to weekly holidays and paid annual leave which could be important factors contributing to poor health outcomes among non-regular workers in Korea [44]. Labor laws may require reformation so that non-regular workers are guaranteed stability in their jobs, social insurance coverage, and proper wages to enable a minimum standard of living. However, longitudinal and cohort studies are needed to assess and analyze the relationships between shift work, socioeconomic and behavioral factors, and multimorbidity. Further, the subgroup analysis revealed that education and marital status were significant factor influencing multimorbidity in shift workers aged 50 years and older. Consistent with previous research, the risk of multimorbidity increase when they are less educated and when

they are single [45, 46]. A deeper understanding of these relationship may require further analysis to identify the sub-group at greatest risk for multimorbidity and develop targeted intervention as there could be interaction between socioeconomic and demographic factors.

The most common chronic disease in the present study was HTN followed by dyslipidemia, diabetes, and arthritis. This is similar to the findings of a previous meta-analysis of multimorbidity found in United States, United Kingdom, and Spain [20]. Additionally, we performed a network analysis and found three distinct groups and that HTN, dyslipidemia, diabetes, CHD, and stroke clustered as a group, and arthritis and osteoporosis as a group. Previous research found that the coexistence of hypertension and at least one other comorbidity was most common among patients with multimorbidity [47]. Similar with our findings, Yang et al. (2022) found that shift workers with hypertension in United Kingdom were more prone to cardiometabolic multimorbidity including diabetes, coronary artery disease, and stroke [7]. However, the only multimorbidity cluster known is cardiovascular multimorbidity, and the evidence of multimorbidity with other chronic diseases and its clusters in shift workers remains limited. In general population, cardiovascular diseases and metabolic diseases tend to cluster together and osteoarthritis tend to cluster together in Australian sample which was similar to our study findings [48]. Some chronic diseases are more likely to cluster together as seen in our study and the studies in United Kingdom and Australia. Some chronic diseases are more likely to cluster together as they may share similar pathophysiological pathways [24]. Also, shift work is known to disrupt circadian rhythm and sleep, and associated with overweight, and blood glucose which are the important factors for developing cardiometabolic diseases [49, 50]. Although controversial, the patients with arthritis may have greater bone loss [51]. Considering the relationships between arthritis and osteoporosis and that the incidence of both arthritis and osteoporosis increase with age [52, 53] and the mean age of our multimorbid participants was 57 years, the co-occurrence of these chronic disease may be understandable. Identifying these disease clusters can be important as we can target and tailor intervention for

specific groups. However, caution is needed interpreting and comparing multimorbid clusters or patterns across studies as researchers uses different statistical method to analysis clusters or patterns and may include a different list of chronic diseases in the analysis. Further research is needed to better understand and assess the multimorbidity clusters and their trajectories and patterns over time among shift workers using unified and valid analytic method with most prevalent chronic diseases in shift workers.

Most chronic care models and guidelines focus on the treatment and management of individual chronic diseases [54]. The care of multimorbidity requires more complex care that prioritizes what is most important for each patient. Several types of interventions for multimorbidity have been implemented in the past but the evidence to deliver specific interventions remains limited. Furthermore, interventions specific for shift workers with multimorbidity are relatively unknown, despite shift workers being at risk for developing multimorbidity compared with non-shift workers. Nevertheless, occupation or organization-based interventions may benefit shift workers. These potentially include policy development regarding shift schedules, early screening diagnostic interventions, and diet and physical activity programs. However, additional research remains necessary to confirm the multimorbidity clusters in shift workers and to confirm the differences between socioeconomic and behavioral factors to enable the development of specific intervention programs for each cluster group.

To our knowledge, this study is the first to assess multimorbidity and their associated factors in Korean shift workers. We analyzed a 2016–2020 series of national population-based study data (KNHANES) using network analysis to reveal multimorbidity patterns. However, the present study has some limitations. First, KNHANES is a cross-sectional study, thus we cannot assume temporal relationships between variables. We also could not assess the long-term patterns of multimorbidity development and the effect of socioeconomic behavioral factors on multimorbidity. Therefore, we recommend longitudinal studies of multimorbidity among shift workers in the future. Second, the

data were based on the self-report of participants. Thus, the recall-bias cannot be excluded. Some objective data, for example, medical records to identify multimorbidity may be needed in the future study. Third, the specific patterns of shift work were not specified in the current dataset. For example, we do not know if shift workers are involved in rotating shifts, only night shifts, or how many night or evening shifts are included per work schedules. Further studies should specify the shift work schedules and subgroup analysis may be beneficial. Fourth, we also recommend subgroup analysis of different work sectors since working conditions and shift schedules may differ. For example, the healthcare and manufacturing industries may utilize more complex shift schedules and require more specific interventions based on subgroup analysis. Fifth, network analysis provides only a graphical presentation of multimorbidity patterns and does not allow for statistical analyses, such as regression, to identify factors associated with each multimorbidity pattern. Future studies may consider employing other statistical analyses, such as latent class analysis, if researchers are interested in exploring factors associated with multimorbidity patterns in shift workers. Finally, the study results may have excluded some confounding variables such as family support and healthcare utilization which may have influenced multimorbidity.

5 CONCLUSION

Multimorbidity is a crucial factor influencing premature death, poor health and quality of life, and healthcare utilization. Our findings indicate that approximately 14% of Korean shift workers suffer from multimorbidity and that several socioeconomic and behavioral factors are associated with multimorbidity. This suggests that policy development regarding work schedule modification is necessary. Furthermore, screening, and tailored intervention programs at the organizational level may benefit efforts to prevent and monitor multimorbidity among shift workers. However, we also suggest the use of a longitudinal study design to assess and confirm multimorbidity patterns among shift workers in the future.

Acknowledgements

The authors would like to thank the Korea Disease Control and Prevention Agency for offering the raw data from the Korea National Health and Nutrition Examination Survey (KNHANES). The paper contents are solely the responsibility of the authors and do not necessarily represent the official view of KNHANES.

Conflict of interests

The authors declare that they have no competing interests.

Funding

This research was supported by the Chung-Ang University Research Grants in 2023 and a National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. 2022R1F1A106626211)

Data Availability

The data supporting the findings of this study are derived from the Korea National Health and Nutrition Examination Survey (KNHANES), which is publicly accessible at no cost. Interested researchers can access the data by visiting the KNHANES website: https://knhanes.kdca.go.kr/knhanes/main.do. Please note that while the data is freely available, users are encouraged to comply with the terms and conditions specified on the KNHANES portal.

Authors' contributions

H.H. and Y.M.K. conceptualized study idea; Y.M.K. collected and analyzed the data; H.H. supervised study; H.H. and Y.M.K. led manuscript writing.

REFERENCES

1. Rivera AS, Akanbi M, O'Dwyer LC, McHugh M. Shift work and long work hours and their association with chronic health conditions: a systematic review of systematic reviews with meta-analyses. *PLoS One*. 2020;15(4):e0231037. PMID: 32240254. doi: 10.1371/journal.pone.0231037.

2. Messenger J. Working time and the future of work. *ILO future of work research paper series*. 2018;6(8):33-7.

3. Crowther ME, Ferguson SA, Vincent GE, Reynolds AC. Non-pharmacological interventions to improve chronic disease risk factors and sleep in shift workers: a systematic review and meta-analysis. *Clocks Sleep*. 2021 Jan 28;3(1):132-78. PMID: 33525534. doi: 10.3390/clockssleep3010009.

4. Touitou Y, Reinberg A, Touitou D. Association between light at night, melatonin secretion, sleep deprivation, and the internal clock: Health impacts and mechanisms of circadian disruption. *Life Sci*. 2017 Mar 15;173:94-106. PMID: 28214594. doi: 10.1016/j.lfs.2017.02.008.

5. Haus EL, Smolensky MH. Shift work and cancer risk: potential mechanistic roles of circadian disruption, light at night, and sleep deprivation. *Sleep Med Rev*. 2013 Aug;17(4):273-84. PMID: 23137527. doi: 10.1016/j.smrv.2012.08.003.

6. Moreno CRC, Marqueze EC, Sargent C, Wright Jr KP, Ferguson SA, Tucker P. Working Time Society consensus statements: Evidence-based effects of shift work on physical and mental health. *Ind Health*. 2019 Apr 1;57(2):139-57. PMID: 30700667. doi: 10.2486/indhealth.SW-1.

7. Yang L, Luo Y, He L, Yin J, Li T, Liu S, et al. Shift work and the risk of cardiometabolic multimorbidity among patients with hypertension: a prospective cohort study of UK Biobank. *J Am Heart Assoc*. 2022 Sep 6;11(17):e025936. PMID: 36036170. doi: 10.1161/jaha.122.025936.

8. Kang MY, Kwon HJ, Choi KH, Kang CW, Kim H. The relationship between shift work and mental health among electronics workers in South Korea: a cross-sectional study. *PLoS One*.

2017;12(11):e0188019. PMID: 29145440. doi: 10.1371/journal.pone.0188019.

9. Uhm JY, Kim HR, Kang GH, Choi YG, Park TH, Kim SY, et al. The association between shift work and chronic kidney disease in manual labor workers using data from the Korea National Health and Nutrition Examination Survey (KNHANES 2011-2014). *Ann Occup Environ Med*. 2018;30:69. PMID: 30564370. doi: 10.1186/s40557-018-0279-z.

10. Yu KH, Yi YH, Kim YJ, Cho BM, Lee SY, Lee JG, et al. Shift work is associated with metabolic syndrome in young female Korean workers. *Korean J Fam Med*. 2017 Mar;38(2):51-6. PMID: 28360979. doi: 10.4082/kjfm.2017.38.2.51.

11. van den Akker M, Buntinx F, Metsemakers JF, Roos S, Knottnerus JA. Multimorbidity in general practice: prevalence, incidence, and determinants of co-occurring chronic and recurrent diseases. *J Clin Epidemiol*. 1998 May;51(5):367-75. PMID: 9619963. doi: 10.1016/s0895-4356(97)00306-5.

12. Mercer S, Furler J, Moffat K, Fischbacher-Smith D, Sanci L. *Multimorbidity: Technical Series on Safer Primary Care.* Geneva: World Health Organization; 2016. ISBN: 9789241511650.

13. Tugwell P, Knottnerus JA. Multimorbidity and comorbidity are now separate MESH headings. *J Clin Epidemiol*. 2019 Jan;105:vi-viii. PMID: 30522770. doi: 10.1016/j.jclinepi.2018.11.019.

14. Skou ST, Mair FS, Fortin M, Guthrie B, Nunes BP, Miranda JJ, et al. Multimorbidity. *Nat Rev Dis Primers*. 2022 Jul 14;8(1):48. PMID: 35835758. doi: 10.1038/s41572-022-00376-4.

15. Chowdhury SR, Chandra Das D, Sunna TC, Beyene J, Hossain A. Global and regional prevalence of multimorbidity in the adult population in community settings: a systematic review and meta-analysis. *EClinicalMedicine*. 2023 Mar;57:101860. PMID: 36864977. doi: 10.1016/j.eclinm.2023.101860.

16. Menotti A, Mulder I, Nissinen A, Giampaoli S, Feskens EJ, Kromhout D. Prevalence of morbidity and multimorbidity in elderly male populations and their impact on 10-year all-cause

mortality: The FINE study (Finland, Italy, Netherlands, Elderly). *J Clin Epidemiol*. 2001 Jul;54(7):680-6. PMID: 11438408. doi: 10.1016/s0895-4356(00)00368-1.

17. Sheridan PE, Mair CA, Quiñones AR. Associations between prevalent multimorbidity combinations and prospective disability and self-rated health among older adults in Europe. *BMC Geriatr*. 2019 Jul 27;19(1):198. PMID: 31351469. doi: 10.1186/s12877-019-1214-z.

18. Tang LH, Thygesen LC, Willadsen TG, Jepsen R, la Cour K, Frølich A, et al. The association between clusters of chronic conditions and psychological well-being in younger and older people-A cross-sectional, population-based study from the Lolland-Falster Health Study, Denmark. *J Comorb*. 2020 Jan-Dec;10:2235042x20981185. PMID: 33415082. doi: 10.1177/2235042x20981185.

19. Read JR, Sharpe L, Modini M, Dear BF. Multimorbidity and depression: a systematic review and meta-analysis. *J Affect Disord*. 2017 Oct 15;221:36-46. PMID: 28628766. doi: 10.1016/j.jad.2017.06.009.

20. Makovski TT, Schmitz S, Zeegers MP, Stranges S, van den Akker M. Multimorbidity and quality of life: Systematic literature review and meta-analysis. *Ageing Res Rev*. 2019 Aug;53:100903. PMID: 31048032. doi: 10.1016/j.arr.2019.04.005.

21. Pati S, Swain S, Hussain MA, van den Akker M, Metsemakers J, Knottnerus JA, Salisbury C. Prevalence and outcomes of multimorbidity in South Asia: a systematic review. *BMJ Open*. 2015 Oct 7;5(10):e007235. PMID: 26446164. doi: 10.1136/bmjopen-2014-007235.

22. Souza DLB, Oliveras-Fabregas A, Minobes-Molina E, de Camargo Cancela M, Galbany-Estragués P, Jerez-Roig J. Trends of multimorbidity in 15 European countries: a population-based study in community-dwelling adults aged 50 and over. *BMC Public Health*. 2021 Jan 7;21(1):76. PMID: 33413239. doi: 10.1186/s12889-020-10084-x.

23. Jang TW. Working hours and the regulations for night shift workers. *Ann Occup Environ Med*. 2023;35:e19. PMID: 37928372. doi: 10.35371/aoem.2023.35.e19.

24. Kessler R. *Comorbidity*. Amsterdam, NY: Elsevier Science Ltd; 2001.

25. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. 2008 Apr;61(4):344-9. PMID: 18313558. doi: 10.1016/j.jclinepi.2007.11.008.

26. Kweon S, Kim Y, Jang MJ, Kim Y, Kim K, Choi S, et al. Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). *Int J Epidemiol*. 2014 Feb;43(1):69-77. PMID: 24585853. doi: 10.1093/ije/dyt228.

27. Ho IS, Azcoaga-Lorenzo A, Akbari A, Black C, Davies J, Hodgins P, et al. Examining variation in the measurement of multimorbidity in research: a systematic review of 566 studies. *Lancet Public Health*. 2021 Aug;6(8):e587-e97. PMID: 34166630. doi: 10.1016/s2468-2667(21)00107-9.

28. Park B, Ock M, Lee HA, Lee S, Han H, Jo MW, Park H. Multimorbidity and health-related quality of life in Koreans aged 50 or older using KNHANES 2013-2014. *Health Qual Life Outcomes*. 2018 Sep 15;16(1):186. PMID: 30219061. doi: 10.1186/s12955-018-1016-6.

29. Tang F, Gates Kuliszewski M, Carrascal A, Vásquez E. Physical multimorbidity and cancer prevalence in the National Health and Nutrition Examination Survey. *Public Health*. 2021 Apr;193:94-100. PMID: 33751964. doi: 10.1016/j.puhe.2021.01.026.

30. World Health Organization. *The Asia-Pacific perspective: redefining obesity and its treatment*. 2000.

31. Seong JH, Lee CH, Do HJ, Oh SW, Lym YL, Choi JK, et al. Performance of the AUDIT alcohol consumption questions (AUDIT-C) and AUDIT-K question 3 alone in screening for problem drinking. *Korean J Fam Med*. 2009 9;30(9):695-702. doi: 10.4082/kjfm.2009.30.9.695.

32. He L, Biddle SJH, Lee JT, Duolikun N, Zhang L, Wang Z, Zhao Y. The prevalence of multimorbidity and its association with physical activity and sleep duration in middle aged and elderly adults: a longitudinal analysis from China. *Int J Behav Nutr Phys Act*. 2021 Jun 10;18(1):77.

PMID: 34112206. doi: 10.1186/s12966-021-01150-7.

33. Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, DonCarlos L, et al. National Sleep Foundation's updated sleep duration recommendations: final report. *Sleep Health*. 2015 Dec;1(4):233-43. PMID: 29073398. doi: 10.1016/j.sleh.2015.10.004.

34. Batista SR, Sousa ALL, Nunes BP, Silva RR, Jardim P. Identifying multimorbidity clusters among Brazilian older adults using network analysis: Findings and perspectives. *PLoS One*. 2022;17(7):e0271639. PMID: 35857809. doi: 10.1371/journal.pone.0271639.

35. MacNee W, Rabinovich RA, Choudhury G. Ageing and the border between health and disease. *Eur Respir J*. 2014 Nov;44(5):1332-52. PMID: 25323246. doi: 10.1183/09031936.00134014.

36. Alswat KA. Gender Disparities in Osteoporosis. *J Clin Med Res*. 2017 May;9(5):382-7. PMID: 28392857. doi: 10.14740/jocmr2970w.

37. Ballering AV, Bonvanie IJ, Olde Hartman TC, Monden R, Rosmalen JGM. Gender and sex independently associate with common somatic symptoms and lifetime prevalence of chronic disease. *Soc Sci Med*. 2020 May;253:112968. PMID: 32272303. doi: 10.1016/j.socscimed.2020.112968.

38. Ho FK, Celis-Morales C, Gray SR, Demou E, Mackay D, Welsh P, et al. Association and pathways between shift work and cardiovascular disease: a prospective cohort study of 238 661 participants from UK Biobank. *Int J Epidemiol*. 2022 May 9;51(2):579-90. PMID: 34414428. doi: 10.1093/ije/dyab144.

39. Vetter C, Devore EE, Wegrzyn LR, Massa J, Speizer FE, Kawachi I, et al. Association between rotating night shift work and risk of coronary heart disease among women. *JAMA*. 2016 Apr 26;315(16):1726-34. PMID: 27115377. doi: 10.1001/jama.2016.4454.

40. Wang D, Ruan W, Chen Z, Peng Y, Li W. Shift work and risk of cardiovascular disease morbidity and mortality: a dose-response meta-analysis of cohort studies. *Eur J Prev Cardiol*. 2018 Aug;25(12):1293-302. PMID: 29929393. doi: 10.1177/2047487318783892.

41. Leung CW, Epel ES, Ritchie LD, Crawford PB, Laraia BA. Food insecurity is inversely associated with diet quality of lower-income adults. *J Acad Nutr Diet*. 2014 Dec;114(12):1943-53.e2. PMID: 25091796. doi: 10.1016/j.jand.2014.06.353.

42. VanKim NA, Laska MN. Socioeconomic disparities in emerging adult weight and weight behaviors. *Am J Health Behav*. 2012 Jul;36(4):433-45. PMID: 22488394. doi: 10.5993/ajhb.36.4.1.

43. Keramat SA, Alam K, Rana RH, Chowdhury R, Farjana F, Hashmi R, et al. Obesity and the risk of developing chronic diseases in middle-aged and older adults: Findings from an Australian longitudinal population survey, 2009-2017. *PLoS One*. 2021;16(11):e0260158. PMID: 34784404. doi: 10.1371/journal.pone.0260158.

44. Kim, YS. The non-regular work in South Korea. Issue Paper Series: Labour and Society. 2021 Accessed June 14, 2023. https://library.fes.de/pdf-files/bueros/seoul/18415.pdf

45. Pathirana TI, Jackson CA. Socioeconomic status and multimorbidity: a systematic review and meta-analysis. *Aust N Z J Public Health*. 2018 Apr;42(2):186-94. PMID: 29442409. doi: 10.1111/1753-6405.12762.

46. Wang D, Li D, Mishra SR, Lim C, Dai X, Chen S, Xu X. Association between marital relationship and multimorbidity in middle-aged adults: a longitudinal study across the US, UK, Europe, and China. *Maturitas.* 2022 Jan;155:32-9. PMID: 34876247. doi: 10.1016/j.maturitas.2021.09.011.

47. Chudasama YV, Khunti KK, Zaccardi F, Rowlands AV, Yates T, Gillies CL, et al. Physical activity, multimorbidity, and life expectancy: a UK Biobank longitudinal study. *BMC Med*. 2019 Jun 12;17(1):108. PMID: 31186007. doi: 10.1186/s12916-019-1339-0.

48. Ng SK, Tawiah R, Sawyer M, Scuffham P. Patterns of multimorbid health conditions: a systematic review of analytical methods and comparison analysis. *Int J Epidemiol*. 2018 Oct 1;47(5):1687-704. PMID: 30016472. doi: 10.1093/ije/dyy134.

49. Cheng WJ, Liu CS, Hu KC, Cheng YF, Karhula K, Härmä M. Night shift work and the risk of

metabolic syndrome: Findings from an 8-year hospital cohort. *PLoS One*. 2021;16(12):e0261349. PMID: 34898652. doi: 10.1371/journal.pone.0261349.

50. Vyas MV, Garg AX, Iansavichus AV, Costella J, Donner A, Laugsand LE, et al. Shift work and vascular events: systematic review and meta-analysis. *BMJ*. 2012 Jul 26;345:e4800. PMID: 22835925. doi: 10.1136/bmj.e4800.

51. Ding C, Cicuttini F, Boon C, Boon P, Srikanth V, Cooley H, Jones G. Knee and hip radiographic osteoarthritis predict total hip bone loss in older adults: a prospective study. *J Bone Miner Res*. 2010 Apr;25(4):858-65. PMID: 19821767. doi: 10.1359/jbmr.091012.

52. Pouresmaeili F, Kamalidehghan B, Kamarehei M, Goh YM. A comprehensive overview on osteoporosis and its risk factors. *Ther Clin Risk Manag*. 2018;14:2029-49. PMID: 30464484. doi: 10.2147/tcrm.S138000.

53. Zhang Y, Jordan JM. Epidemiology of osteoarthritis. *Clin Geriatr Med*. 2010 Aug;26(3):355-69. PMID: 20699159. doi: 10.1016/j.cger.2010.03.001.

54. Boyd CM, Kent DM. Evidence-based medicine and the hard problem of multimorbidity. *J Gen Intern Med*. 2014 Apr;29(4):552-3. PMID: 24442331. doi: 10.1007/s11606-013-2658-z.

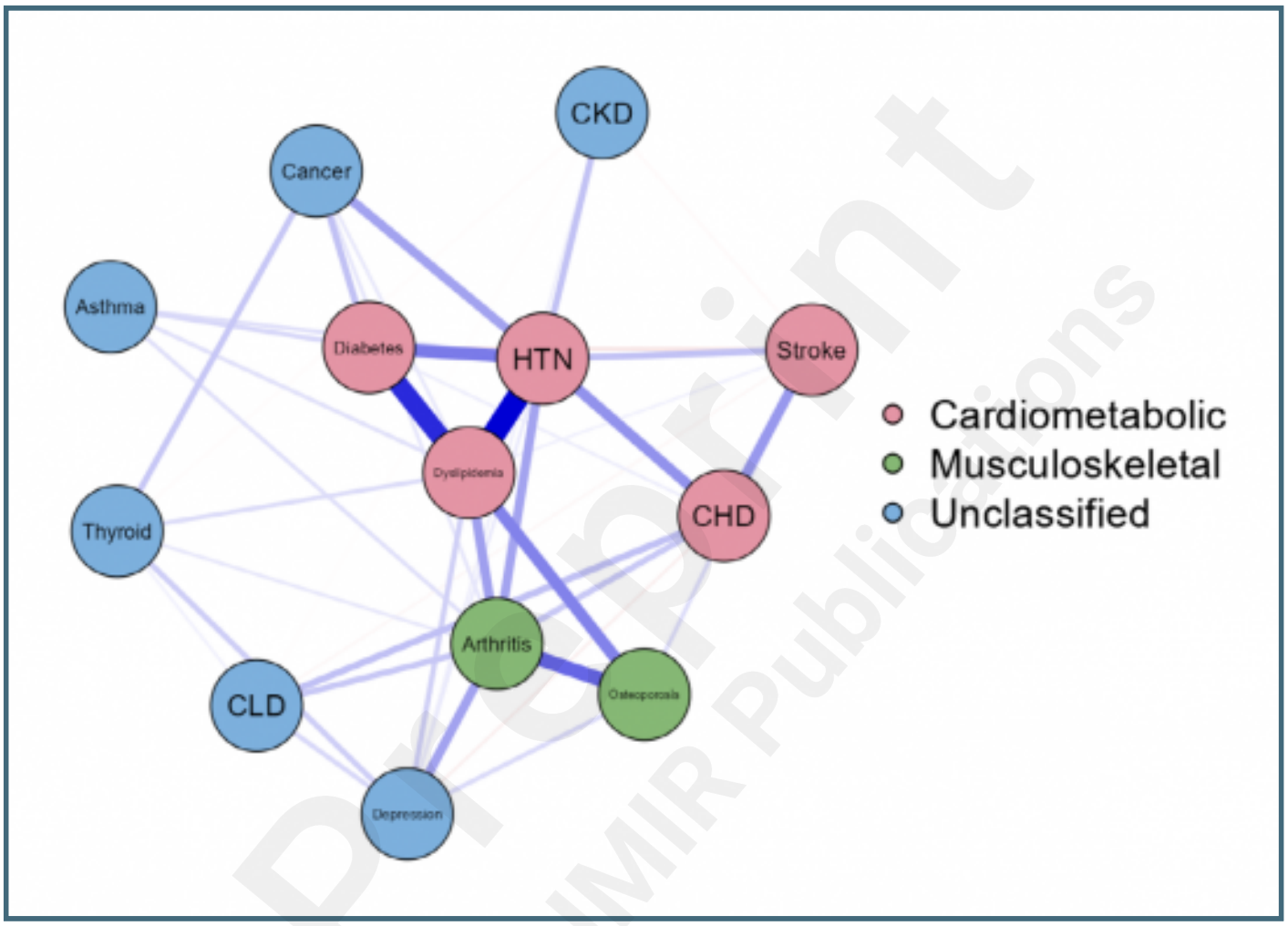
Abbreviations

AUDIT-C: Alcohol Use Disorders Identification Test-Concise; BMI: Body mass index; CHD: Coronary heart disease; CI: Confidence interval; CLD: Chronic liver disease; CKD: Chronic kidney disease; HTN: Hypertension; KCDC: Korean Centers for Disease Control and Prevention; KNHANES: Korea National Health and Nutrition Examination Survey; OR: odds ratio; Q: Quartile; SE: Standard error; STROBE: STrengthening the Reporting of OBservational studies in Epidemiology; WHO: World Health Organization

Supplementary Files

Figures

Multimorbidity network in shift workers. Network analysis results revealed three pattern groups: 1) cardiometabolic multimorbidity (HTN, dyslipidemia, diabetes, CHD, and stroke), 2) musculoskeletal multimorbidity (arthritis and osteoporosis), and 3) unclassified disease group (depression, CLD, thyroid disease, asthma, cancer, and CKD) Notes. CKD = chronic kidney disease, HNT = hypertension, CHD = coronary heart disease, CLD = chronic liver disease.



Multimedia Appendixes

Supplementary Fig 1. The flow diagram of the study sample selection Supplementary Fig 2. Centrality plot of multimorbidity patterns in shift workers Supplementary Table 1. Age-Subgroup Analysis of Factors affecting Multimorbidity in Shift Workers.
URL: http://asset.jmir.pub/assets/158c1d5397ac33883a5d4c98c55c779a.docx

CONSORT (or other) checklists

STROBE checklist for Cross-sectional study.
URL: http://asset.jmir.pub/assets/27d2d75076bb34c7d68562876140b81b.pdf