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Original article

Impact of Reduced Working Hours and Night Work Hours on Metabolic Syndrome: A Quasi-Experimental Study

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ABSTRACT

Objectives: Epidemiological evidence linking long working hours and shift work to metabolic syndrome remains inadequate. We sought to evaluate the impact of reducing working hours on metabolic syndrome.

Methods: We compared the prevalence of metabolic syndrome among male manual workers in a manufacturing company (N = 371) before and after the introduction of policy to reduce daily work hours from 10 to 8 hours. Components of metabolic syndrome were measured in periodic health examinations before the intervention, 6–9 months after, and 1.5–2 years after the intervention. Generalized estimating equation models were used to estimate changes in the prevalence of metabolic syndrome. Analyses were stratified by day work versus shift work.

Results: The results showed a significantly decreased prevalence of metabolic syndrome 6–9 months following the intervention in day workers (risk ratio = 0.68, 95% confidence interval 0.52–0.88), but the benefit disappeared after 1.5–2 years. Shift workers showed a decreased prevalence of metabolic syndrome for the whole follow-up duration after the intervention, although the change was not statistically significant.

Conclusion: Reducing working hours was associated with short-term improvement in metabolic syndrome in male manual workers.

1. Introduction

Working hours in Republic of Korea are among the highest in the Organization for Economic Cooperation and Development countries [1]. In 2019, the annual average working hours in Republic of Korea was 1,967 hours, or roughly 241 hours higher than the average working hours for Organization for Economic Cooperation and Development countries as a whole [1]. Numerous studies have suggested an association between long working hours or night shift work and adverse health outcomes [2–7]. Particular attention has been paid to increased risks of cardiovascular disease [8–10]. Long working hours and shift work are hypothesized to increase the risk of cardiovascular disease via mechanisms including short sleep duration [11], stress-related coping behavior (such as smoking and excess drinking) [8], and inadequate leisure-time physical activity [12]. The development of metabolic syndrome is further hypothesized to be on the pathway from long working hours to increased risk of cardiovascular disease. However, evidence for the impact of long working hours or night work on metabolic syndrome remains inconsistent.

The majority of studies investigating working hours and metabolic syndrome have been cross-sectional. Several cross-sectional studies found an association between long working hours and metabolic syndrome [13–15]. However, no association between working hours and metabolic syndrome was found in a longitudinal study from Spain [16], as well as in a few nationwide cross-sectional studies [17,18]. Several studies investigated the longitudinal association between long working hours and individual components of metabolic syndrome. For example, a recent meta-analysis using

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pooled data from 19 cohort studies found a small but statistically significant excess risk of overweight among participants who work long hours [19]. In a prospective multi-cohort study based in European countries, no consistent associations were observed between long working hours and cardiometabolic factors such as blood pressure or cholesterol [20].

A meta-analysis to assess the association between shift work and metabolic syndrome suggested that shift work was associated with metabolic syndrome especially in the workers who were 2-shift or 3-shift [21]. Several longitudinal studies showed the increased risk for metabolic syndrome in shift workers compared to non-shift workers [22,23].

However, few intervention studies have examined the health effect of reducing working hours or eliminating night work. An intervention study in Sweden examined the impact of reducing working hours (from 40 h/week to 37.5 h/week) in combination with mandatory physical activity on cardiometabolic risk profiles among female dental health care workers, and the results suggested some markers were improved after 1 year follow-up in the reduced working hours group [24].

Although quite a lot of study has been performed to find evidence for the impact of long working hours or night work on metabolic syndrome which is a potential mediator between long working hours and cardiovascular diseases, the results are still inconsistent in the observational studies and intervention studies are scarce.

To address this evidence gap, we leveraged a natural experiment in one manufacturing plant in Republic of Korea to observe the impact of reduced working hours and elimination of night work on metabolic syndrome among employees.

We hypothesized that metabolic syndrome would be improved following the change in the working hours and that the association would differ according to daytime work versus shift work.

2. Methods

2.1. Study design

We conducted a quasi-experimental single group pre-post interventional study, taking advantage of the introduction of a new work schedule in a single manufacturing plant in Republic of Korea.

In the updated guidance on evaluating complex interventions by the British Medical Research Council, they acknowledged that experimental designs such as randomized controlled trials are preferred to observational designs in most circumstances, but are not always practicable [25]. Organizational intervention on the work schedule is a typical complex intervention that contains many interacting components and is greatly affected by political acceptability. A control group is an important methodology needed to compare changes in outcome due to the intervention. However, it is common that the organization wants to target all employees with an intervention because the employer regards it unethical to provide the intervention to some workers only [26].

The employer as well as the workers who participated in this study also wanted everyone could get the benefit from the change of work schedule at the same time. Although we the researchers had little influence over how the intervention is performed, we decided the evaluation is still needed. Consequently, a quasi-experimental method without control group was implemented.

The Doowon Precision Industry Co. (hereafter, Doowon), an automobile engine pump manufacturer, introduced a new work schedule eliminating 2 hours of mandatory overtime per shift. The decision on the change of work schedule was the result of a labor-management agreement for improving the workers' health and well-being. The shift system changed from rotating 2 groups over 2 shifts (day and night) to two consecutive shifts (day and evening) per day. Before the new policy, the day shift began at 8:30 AM and ended at 7:30 PM, with the night shift running from 7:30 PM to 6:20 AM. This changed to a day shift from 8:00 AM to 4:00 PM, and an evening shift from 4:00 PM until midnight. In the case of non-shift workers, the work schedule followed the day shift workers' schedule. By eliminating the mandatory two-hour overtime in the work schedule, working hours dropped from 9.5 to 7 hours per day on weekdays. Considering the standard working hours in Republic of Korea has been 40 hours per week with a maximum limit of 52 hours per week, this change is remarkable.

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Public Institutional Review Board of Korea National Institute for Bioethics Policy (P01-202011-21-002).

2.2. Study population

This study used data from periodic workers' health examinations linked to the survey data of 'Risk assessment for musculoskeletal disorder', a nationwide mandatory risk assessment implemented every 3 years [27]. The workers undergo health examinations from March to December every year. As the intervention occurred in September 2010, we considered health examination data in 2010 (T_0) as baseline data. In 2010, workers had health examinations from March to September. The data in 2011 (T_1) corresponded to 6–9 months follow-up data as the workers had health exams from March to June. The data in 2012 (T_2) correspond to 1.5–2 year follow-up data as the workers had an exam from March to July in 2012. Out of 476 manual workers in the Doowon, 405 workers consented to the use of their data for the study. Individuals with no or incomplete health exam data from 2010 were excluded ($n = 18$). As most of the workers were men, female workers ($n = 7$) were excluded. Finally, workers with no data on health exams in 2011 and 2012 were excluded ($n = 9$). The analytic sample ($N = 371$) selection process is presented in Fig. 1.

2.3. Measures

We used data from the periodic health examination (the Workers' General Health Examination), which is performed every year for non-office workers in Republic of Korea by Occupational

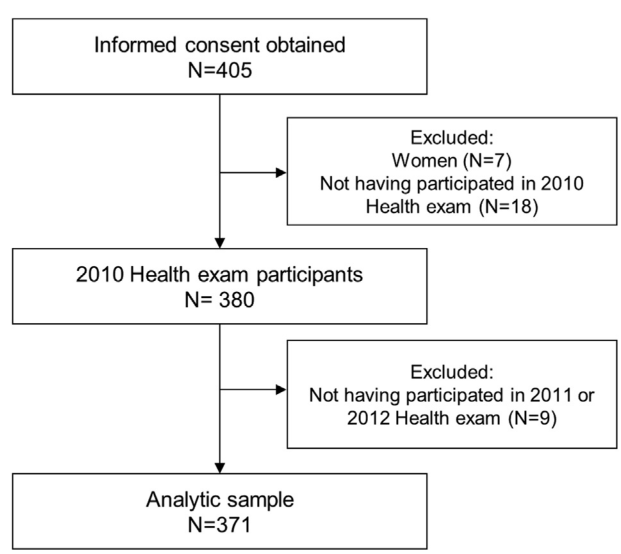

Fig. 1. Flowchart of study subjects.

Safety and Health Act. All participants in the current study were examined at one contracted university hospital. In the examination, the following data were collected: chronic disease history, height, weight and waist circumference, systolic blood pressure and diastolic blood pressure, fasting glucose, total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol (HDL-C), and triglyceride levels (Table 1). Measurements of the items were performed according to the guideline in the Public Notice on the Standard for Health Examination by the Ministry of Health and Welfare in Republic of Korea [28]. The institutions are evaluated periodically whether they follow the protocol in a quality control process. For measuring blood pressure, all the participants receive a notice that recommends they should avoid smoking, alcohol, or caffeine. They also should rest for at least 5 minutes in a seated position before the measurement. Auscultation or oscilloscopic automatic sphygmomanometer are used to take blood pressure and the instrument should be calibrated daily. In a previous study, it was found that most health examination institutions in Republic of Korea have followed the established protocol [29]. The waist circumference is measured at the horizontal line at the midpoint between the iliac crest and the inferior border of the lower rib on the mid-axillary line at the end of a normal expiration. Blood collection is performed by qualified personnel and treated appropriately to avoid hemolysis or clotting. For the reliability of laboratory test results, an institution should perform internal and external quality control procedures supervised by the Korean Association of Laboratory Quality Control [30].

We defined metabolic syndrome using the National Cholesterol Education Program Adult Treatment Panel III criteria (Table 2). A diagnosis of metabolic syndrome was given if the individual had three or more of the following criteria: (1) High blood pressure: if systolic and/or diastolic blood pressures were ≥130/85 mm Hg or receiving medication for high blood pressure; (2) Hyperglycemia: fasting plasma glucose ≥110 mg/dL or receiving glucose-lowering medications; (3) Hypertriglyceridemia: fasting plasma triglycerides ≥150 mg/dL; (4) Low HDL-C: fasting HDL-C < 40 mg/dL in males; or (5) Central obesity: waist circumference >90 cm (Asian modification) in males.

Information on education, working year, weekly working hours, and shift work were assessed by questionnaires in 2010 (before intervention) and 2013 (after intervention).

2.4. Statistical analysis

Pre- and post-intervention mean values of the components of metabolic syndrome for day workers, shift workers, and total sample were reported. Generalized estimating equation (GEE) analyses with unstructured working correlation model were used to investigate changes between baseline and post-intervention in the prevalence of metabolic syndrome. Age and shift work were included as covariates in the model for the total sample, and age was included in the stratified analysis (shift work vs. day work). As the information on health behaviors such as alcohol consumption, smoking, and exercise at T1 (2011) and T2 (2012), we could not include those covariates in the statistical model. However, health behavior could be potential mediator between reduced working hours and metabolic syndrome, the health behavior adjusted odds ratio (OR) might underestimate the impact of reduced working hours on metabolic syndrome. As a sensitivity analysis, an extended GEE model including health behavior was performed using health behavior data in 2013. The significance level for statistical analyses was $p < 0.05$ using a two-tailed test. SAS version 9.4 (SAS Institute, Cary, NC, USA) was used for statistical analysis.

Table 1
Health examination items used for measurement of metabolic syndrome

Categories	Items
Anthropometric measurement	Height, weight
	Waist circumference
	Body mass index
Questionnaire	Past medical history
Blood test	Fasting blood glucose
	Blood lipid level;
	Total cholesterol
	Triglyceride HDL-cholesterol
	LDL-cholesterol

Table 2
NCEP ATP III Diagnostic criteria for metabolic syndrome*

Criterion	Definition
Abdominal obesity	Waist circumference>90 (Asian modification)
Hypertriglyceridemia	≥150 mg/dL
Low HDL-C	<40 mg/dL
High blood pressure	Blood pressure ≥130/85 mmHg
	or hypertension medication
Hyperglycemia	Fasting glucose ≥110 mg/dL
	or glucose-lowering medications

NCEP ATP III; National Cholesterol Education Program Adult Treatment Panel III. HDL-C, high-density lipoprotein cholesterol.
* Diagnosis based on presence of three or more of five items.

3. Results

The baseline characteristics of the participants are summarized in Table 3. The average age of the workers in the study was 43.8 years and they had worked for an average of 20.1 years in the factory. Average weekly working hours were 51.2 hours before the intervention, dropping to 45.9 hours after the intervention. Day workers and shift workers accounted for 55.8% and 38.3% of the sample, respectively, and 5.9% of participants had irregular work schedules or had missing value on shift work information or crossed over between day work and shift work during the follow-up.

To examine changes in the components of metabolic syndrome for workers, the mean values of each component at baseline (T0), 2011 (T1), and 2012 (T2) are presented in Table 4. In the total sample, waist circumference, systolic blood pressure, fasting glucose, and HDL-C had improved at T1 in the linear mixed model adjusting for age and shift work. However, the improvement was no longer statistically significant at T2 except for HDL-C.

Pre-post comparisons of metabolic syndrome prevalence are presented in Table 5. GEE analyses controlling for age revealed a statistically significant decrease in the prevalence of metabolic syndrome at T_1 among day workers (Risk ratio [RR] = 0.68, 95% confidence interval [CI] 0.52–0.88) as well as the total sample (RR = 0.74, 95% CI 0.61–0.88) additionally controlling for shift work; however, the differences had disappeared by T_2. Shift workers showed a decreased prevalence of metabolic syndrome after the intervention, but the difference was not statistically significant.

A sensitivity analysis of GEE model for T2 (2012) using health behavior data in 2013 as additional covariates is shown in Supplementary Table 1. The sensitivity analysis showed similar results with the model controlled only for age.

Table 3
Baseline characters of study subjects (N = 371) and working hours before and after intervention

	Mean ± SD	*n* (%)
Age	43.8 ± 5.0	
Education		
<High school		5 (1.4)
High school		256 (69.0)
>High school		77 (20.8)
Missing		33 (8.9)
Working years	20.1 ± 4.3	
Weekly working hours*	51.2 ± 8.8 (before) 45.9 ± 3.3 (after)	
Shift work		
Day work		207 (55.8)
Shift work		142 (38.3)
Other†		22 (5.9)
Department		
Production		275 (74.1)
Maintenance		63 (17.0)
Missing		33 (8.9)

Weekly working hours and shift work were measured in 2010 (before intervention) and 2013 (after intervention).
* including overtime and weekend work.
† others: workers who had irregular work schedules or had missing value on shift work information or crossed between day work, regular, and irregular shift work before and after the intervention.

4. Discussion

The findings of this quasi-experimental study suggest a short-term (6–9 months) positive impact of reduced working hours on metabolic syndrome. According to stratified analysis, day workers experienced a more prominent drop in metabolic syndrome at 6–9 months follow-up, while shift workers continued to show a lower prevalence of metabolic syndrome through 1.5–2 years follow-up after the intervention. By the change in working schedule, day workers experienced a decrease in working hours, and shift workers experienced a decrease in working hours and the elimination of night work at the same time.

A few cross-sectional studies have revealed an association between long working hours and metabolic syndrome. Among 466 female hospital workers in Canada, working 35 or more overtime hours per year was significantly associated with metabolic syndrome [13]. In a Japanese cross-sectional study of 933 male workers at a manufacturing company, long working hours (>10 h/day) were associated with metabolic syndrome (OR 2.32, 95% CI 1.04–5.16) [14]. In a Korean cross-sectional study with a large representative data (Korean National Health and Nutrition Examination Survey, KNHANES), there was also an association between long working hours (>60 h/week) and metabolic syndrome (OR 2.21, 95% CI 1.07–4.57), but the association was found only among female workers [15]. Another cross-sectional study using KNHANES found no association between working hours and metabolic syndrome either in male or female employees [17,18]. However, it is not possible to rule out reverse causality in cross-sectional studies which means instead of exposure causing a change in outcomes, outcomes affect exposures. In this example, no association between working hours and metabolic syndrome in cross-sectional studies may have been because the participants who were diagnosed with metabolic syndrome reduced their working hours. Reverse causality is most likely to bias the association toward the null (healthy worker effect).

A longitudinal study in Spain also reported no association between working hours and metabolic syndrome [16]. Nonetheless, these results should be interpreted with caution because the study assessed the components of metabolic syndrome by self-report, and working hours were measured only once at baseline. Considering that working hours may change over time, the results may not reflect the time-varying impact of working hours.

A recent longitudinal study encompassing large data from 19 cohorts across the US, Europe, and Australia reported a significant association between overweight/obesity (body mass index >25kg/m2) and long working hours (>55 h/week) (RR 1.17, 95% CI 1.08–1.27) [19]. In our data, body mass index did not decrease during follow-up, but there was a significant drop in measured waist circumference 6–9 months after the intervention. We also observed a significant decrease in fasting glucose over the same short-term follow-up. A previous cross-sectional study using KNHANES showed an association between long working hours (>52 h/week) and pre-diabetes (HbA1c 5.7-6.4%) [31]. In the current study, HDL-C was the only indicator of metabolic syndrome that kept improving until 1.5–2 years after intervention. This finding is in line with a Swedish intervention study which showed improved HDL-C among the reduced working hour group 12 months after intervention (from 40 h/week to 35 h/week) [24].

In case of shift work, a recent meta-analysis study reported that the risk of metabolic syndrome was higher in shift workers than day workers based on the analysis of 37 observational studies, although this association remained significant only for the cross-sectional studies [32].

There are a number of plausible mechanisms through which reducing working hours or night work could impact the risk of metabolic syndrome. First, health behaviors such as smoking, drinking, diet, sleep, and physical activity could play a role in the association between working hours and metabolic syndrome. Lifestyle interventions such as improving diet and physical activity are already emphasized as a treatment for metabolic syndrome [33]. A population-based survey based in the US showed that workers with longer working hours reported more fast food intake and less consumption of fruits and vegetables, and they felt more time-related barriers to achieving a healthy diet [34]. The association between long working hours or shift work and lack of physical activity has been extensively investigated in previous studies, finding a significant negative association between long working hours and reduced leisure-time physical activity [35,36]. A study of a representative working population of German showed that workers with physically strenuous jobs and frequent overtime work were significantly less likely to exercise during leisure-time [37]. A previous Korean study with longitudinal panel data, Korean Labor and Income Panel Study, employed a fixed-effects instrumental variable analysis and the results indicated that a reduction in working hours promoted more regular exercise [38].

Second, sleep might mediate reduced working hours and improvement of metabolic syndrome. Long working hours are associated with shorter sleep [39]. A longitudinal Japanese study with 40,000 male workers reported short sleep duration (<5h/day) was significantly related to the incidence of metabolic syndrome [22]. In an intervention study assessing the impact of exercise program on metabolic syndrome, poor quality of sleep attenuated the benefit from the intervention [40]. Shift workers are more likely to be impacted by reduced working hours compared to non-shift workers, as a previous Korean study showed the interactive effect of long working hours and night shift work on quality of sleep [41].

In our data, shift workers showed a decreased prevalence of metabolic syndrome for the whole duration following the intervention, while the benefit for non-shift workers disappeared after 1.5–2 years. By contrast, non-shift workers' metabolic syndrome dropped more significantly 6–9 months after the intervention than shift workers. It is possible that the modification of health behavior

Table 4
Estimated differences between post and pre intervention for the components of metabolic syndrome

		T_0 (2010)	T_1 (2011)		T_2 (2012)	
		Mean ± SD	Mean ± SD	β	Mean ± SD	β
Total	BMI (kg/m^2)	23.9 ± 2.6	23.9 ± 2.5	−0.0	24.2 ± 2.5	0.2*
(*N* = 371)	Waist circumference (cm)	83.1 ± 6.2	82.1 ± 5.9	−1.2*	83 ± 6.5	−0.3
	Systolic BP (mmHg)	131.9 ± 10.7	129.6 ± 12.7	−2.3*	132 ± 11.3	0.4
	Diastolic BP (mmHg)	83.4 ± 7.3	83.1 ± 8.7	−0.5	84.6 ± 8.3	1.0*
	Glucose (mg/dL)	103.2 ± 22.5	102 ± 23.4	−1.9*	104.2 ± 21.4	−0.3
	LDL-cholesterol (mg/dL)	112.7 ± 29.8	111.5 ± 30.3	−1.6	116.5 ± 31.8	3.5*
	HDL-cholesterol (mg/dL)	48.6 ± 11	49.5 ± 11	0.9*	50.8 ± 12.3	2.3*
	Total cholesterol (mg/dL)	192.3 ± 33.6	190.4 ± 31.8	−2.3	199.9 ± 33.5	8.1*
	Triglyceride (mg/dL)	168.1 ± 190.5	156.3 ± 140.9	−11.8	174.7 ± 111.9	10.6
Day workers	BMI (kg/m^2)	23.7 ± 2.6	23.7 ± 2.5	−0.1	24 ± 2.6	0.2
(*N* = 207)	Waist Circumference (cm)	82.8 ± 6.5	81.8 ± 5.9	−1.2*	82.9 ± 6.7	−0.3
	Systolic BP (mmHg)	131.8 ± 12	128.7 ± 12.9	−3.2*	131.6 ± 10.9	−0.2
	Diastolic BP (mmHg)	83.4 ± 8.0	82.7 ± 8.6	−0.8	84.2 ± 8.0	0.7
	Glucose (mg/dL)	103.8 ± 22.8	103.4 ± 23.2	−1.5	105.8 ± 25.7	−0.2
	LDL-cholesterol (mg/dL)	113.3 ± 29.8	114.3 ± 28.7	0.2	117.4 ± 30.1	3.5
	HDL-cholesterol (mg/dL)	49.5 ± 10.9	49.9 ± 10.6	0.3	51.4 ± 12.4	1.8*
	Total cholesterol (mg/dL)	190.2 ± 31.9	190.9 ± 30.8	−0.1	198.6 ± 32.2	8.1*
	Triglyceride (mg/dL)	143 ± 112.4	139.3 ± 103.9	−3.6	151.3 ± 83.6	11.7
Shift workers	BMI (kg/m^2)	24.1 ± 2.4	24.1 ± 2.3	0.0	24.3 ± 2.2	0.3*
(*N* = 142)	Waist circumference (cm)	83.3 ± 5.8	82.5 ± 5.7	−1.0*	83 ± 5.8	−1.1
	Systolic BP (mmHg)	131.9 ± 8.7	130.9 ± 12.5	−0.1	132.4 ± 12.0	1.0
	Diastolic BP (mmHg)	83.5 ± 6.1	83.6 ± 9.0	−0.1	85 ± 8.9	1.2
	Glucose (mg/dL)	102.7 ± 23.5	101 ± 25.0	−2.2	102.1 ± 14.3	−1.4
	LDL-cholesterol (mg/dL)	112 ± 28.9	107.3 ± 31.7	−4.5*	113.4 ± 32.9	2.0
	HDL-cholesterol (mg/dL)	47.7 ± 11.1	48.9 ± 11.8	1.3*	50 ± 12.4	2.6*
	Total cholesterol (mg/dL)	195.2 ± 35.5	190.2 ± 33.1	−4.7*	199.9 ± 34.1	6.3*
	Triglyceride (mg/dL)	201.1 ± 267.8	185 ± 184.6	−16.8	206.9 ± 138.7	10.0

Age and shift work were adjusted in the total sample. Age was adjusted in day workers and shift workers sample. *$p < 0.05$.
BMI, body mass index; BP, blood pressure; HDL, high-density lipoprotein; LDL, low-density cholesterol.

such as diet or exercise regarding working hour reduction might be easier for non-shift workers than shift workers due to the regularity of their time schedules. However, the positive effect found among non-shift workers was not maintained 1.5–2 years after. Health promotion programs in the workplace may be a helpful complement to maintain the impact of working hour reduction over the long-term. Also, further study with larger sample size is needed to more precisely estimate the effect of shift work on the association between working hours and metabolic syndrome.

After Doowon's change in shift work system, a major automobile manufacturer in Republic of Korea, the Hyundai Motor Company, also introduced a similar shift system eliminating overnight work in 2013 [42]. Other car manufacturers and related parts manufacturers in Republic of Korea followed the model of Hyundai, and Korean workers' demand for shorter working hours has grown. The Labor Standards Act in Republic of Korea determined that 40 hours per week is the standard work hours with up to 12 overtime hours per week permissible. However, working on weekends was not considered as overtime hours regulated by the law until 2018, and therefore, many workers have worked up to 68 hours per week including weekend work. In 2018, the Korean government revised the law to include weekends determining 52 hours maximum permissible weekly working hours in Republic of Korea. The evidence of the positive effect of decreased working hours on workers' health could serve as a basis for policy change like this.

Table 5
Results of generalized estimating equations for metabolic syndrome

		Cases (%)	RR	95% CI
Day workers	2010 (T_0)	46 (22.2)	1.00	
(*N* = 207)	2011 (T_1)	32 (15.5)	**0.68**	**0.52–0.88**
	2012 (T_2)	50 (24.2)	1.07	0.81–1.41
Shift workers	2010 (T_0)	42 (29.6)	1.00	
(*N* = 142)	2011 (T_1)	33 (23.2)	0.79	0.60–1.03
	2012 (T_2)	32 (22.5)	0.79	0.58–1.07
Total	2010 (T_0)	92 (24.8)	1.00	
(*N* = 371)	2011 (T_1)	68 (18.3)	**0.74**	**0.61–0.88**
	2012 (T_2)	90 (24.3)	0.98	0.81–1.20

Age and shift work were adjusted in the total sample. Age was adjusted in day workers and shift workers sample.
T_0: Baseline; T_1: 6-9 months after the intervention; T_2: 1.5-2 years after the intervention.

The present study has certain limitations. First, our pre-post design did not have a no-intervention arm acting as the control group. Although we controlled for all observed and unobserved time-invariant confounders by examining within-individual changes over time, we could not control for time-varying confounders or other background phenomena occurring at the same time during the follow-up. For example, the company experienced a financial downturn persistently during the follow-up (unrelated to the intervention), and there is a possibility that workers' psychosocial stress might have increased during the same period.

Second, we could not examine changes in health behaviors (smoking, drinking, exercise, sleep, diet) which might have mediated the association between working hour reduction and metabolic syndrome, due to a lack of information on lifestyle factors at the two follow-up points. Further studies on the mediating effects of health behaviors will be able to elucidate the mechanism of the effect of reduced working hours on metabolic syndrome more clearly.

Third, metabolic syndrome was measured by using health examination data, which was not designed for research. Therefore, there may be concerns about the reliability of the health examination data. However, the workers received a health checkup at a single university hospital over the whole study period. As there was no change in the health screening institution and they have internal and external quality control processes, the results of health examination could be considered quite reliable.

Forth, the lack of recent data is an important limitation. We could not evaluate long-term effects of the reduced working hours. These results therefore need to be interpreted with caution.

Lastly, the participants of this study were male manual workers in Republic of Korea. The results cannot be generalized to other female workers, other industries/occupations, or countries in which the average working hours are much shorter than in Republic of Korea.

Author contribution

HEL conceived of the presented idea. HEL and IK designed the study. HEL performed statistical analysis and wrote the first draft of the manuscript. IK critically revised the manuscript. All authors read and approved the final manuscript.

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Data availability statement

The datasets analyzed during the current study are available from the corresponding author on reasonable request with permission of the labor union of Doowon and Korea Institute of Labor Safety and Health.

Conflicts of interest

HE Lee has been the Associate Editor of the journal of Safety and Health at Work since January 2022, but had no role in the decision to publish this original article. No other potential conflicts of interest relevant to this article is declared.

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Ethics approval

This study was approved by the institutional review boards of the Public Institutional Review Board of Korea National Institute for Bioethics Policy (P01-202011-21-002).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.shaw.2022.11.001.

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