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UTILIZING THE METABOLIC SYNDROME COMPONENT COUNT IN WORKERS' HEALTH SURVEILLANCE: AN EXAMPLE OF DAY-TIME VS. DAY-NIGHT ROTATING SHIFT WORKERS

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Abstract
Objectives: To establish a practical method for assessing the general metabolic health conditions among different employee groups, this study utilized the total count of metabolic syndrome (MetS) elements as a parameter, and performed a retrospective analysis comparing changes of MetS component count (MSC) of 5 years among day-time work (DW) and day-and-night rotating shift work (RSW) employees. **Material and Methods:** The data of personal histories, physical examinations, blood tests, abdominal sonographic examinations and occupational records were collected from a cohort of workers in an electronics manufacturing company. We first defined the arithmetic mean value of MSC as MSC density (MSCD) for the employee group; then we compared the changes of MSCD over 5 years between DW and RSW workers. Occupational, personal and health records were analyzed for the 1077 workers with an initial mean age of 32.4 years (standard deviation (SD): 6.2 years), including 565 RSW workers (52%). **Results:** The initial MSCDs were 1.26 and 1.12 ($p = 0.06$) for DW and RSW workers, respectively; after 5 years, the increments of MSCD for DW and RSW workers were 0.10 and 0.39, respectively ($p < 0.01$). By performing multivariate logistic regression analyses, and comparing with DW co-workers, final results indicated that the workers exposed to RSW have 1.7-fold increased risk of elevated MSCD (95% confidence interval (CI): 1.28–2.25, $p < 0.01$); and are 38% less likely (adjusted rate ratio (aRR) 0.62, 95% CI: 0.45–0.86, $p < 0.01$) to attain decreased MSCD. **Conclusions:** These observations demonstrate that changes of MSCD are significantly different between DW and RSW workers, and are increasingly associated with RSW exposure. In conclusion, MSCD can represent the general metabolic health conditions of a given employee group; MSC, MSCD and their transitional changes can be applied as simple and standardized tools for monitoring metabolic health risk profiles when managing employee health, at both the individual and company levels.

Key words:
Metabolic syndrome, Day-and-night rotating shift work, Occupational health, Physical examination

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INTRODUCTION

In 2013, an amendment of the Taiwan Occupational Safety and Health Act [1] required employers to adopt health management measures based on employees' health examination results to prevent work-related cardiovascular and cerebrovascular diseases. Yet, performing a proper health risk assessment can be a complicated and time-consuming process involving calculations and extrapolations from surveys of detailed health examination items [2].

In order to implement workplace health management in various workplaces, it is helpful to develop a simple, standardized and practical general metabolic health [3,4] risk assessment tool for different worksites. The count (from 0 to 5) of metabolic syndrome (MetS) [5,6] components [7–9] have been reported to be associated with a wide-range of risks of unfavorable health outcomes including cardiovascular, cerebrovascular diseases [2,10–12] and several malignancies [13,14], of which the risks rise in proportion to the count of MetS components.

In the interest of simplifying health managing processes and multi-functionalizing data from general health screening for health management in modern workplaces, we decided to investigate whether the records from a MetS screening program [15,16] can be practically applied to the health risk assessment of different employee groups. Given that Taiwan's government legislation views shift work as an important health hazard [1] in workplaces, together with the fact that periodic routine health examinations [17] are compulsory for workers in Taiwan, we conducted a workplace-based retrospective follow-up study to evaluate the changes of MSC among workers with and without rotating shifts, an important occupational exposure.

MATERIAL AND METHODS

Study populations

On-site workers in 1 electronics manufacturing company received compulsory periodic health checkups to monitor general health conditions. The retrospective analysis of this cohort included only individuals who responded to work-status questionnaires and attended annual health examinations in both 2002 and 2007. The endpoint analysis included the records of 1077 workers, including 255 females and 822 males. The health examinations were open to all registered employees on working days over a 1-month duration in any given year. Subjects' identities were anonymous and unlinked to the data. This analytical study followed the ethical criteria for human research; the study protocol (TYGH09702108) was reviewed and approved by the Ethics Committee of the Tao-Yuan General Hospital, Taiwan.

Demographics, lifestyle data, job-type, biological measurements and sonogram examinations

In 2002, baseline personal-history questionnaires that included questions about smoking habits, physical exercise, and dietary habits were completed by all participants. The types of job schedules, day-time work (DW) or day-and-night rotating shift work (RSW), were determined from self-reported questionnaires in 2002 and 2007. In 2002, a questionnaire about baseline personal history, including physical exercise, smoking and dietary habits, was completed by the examinees. Physical examinations and blood tests were performed in all participants in both 2002 and 2007.

The participants arrived at the health care unit of the factory in the morning 7:30–9:30 a.m., after an overnight 8 h fast. The physical examination records included measurements of waist circumference, weight, height, and blood pressure. Waist circumferences were measured midway between the lowest rib and the superior border of the iliac crest. After being seated for 5 min, sitting blood pressure was measured on the dominant arm using digital automatic sphygmomanometers (model HEM 907, Omron, Japan) 2 times at 5-min intervals; the mean of the reading was used for data analysis.

After the physical examination, participants were placed in a reclining position, and venous blood (20 ml) from an antecubital vein of the arm was collected for subsequent tests. Blood specimens were centrifuged immediately thereafter and shipped frozen in dry ice to the central clinical laboratory (certified by ISO 15189 and ISO 17025) in Tao-Yuan General Hospital. Glucose, triglyceride, high-density lipoprotein (HDL) cholesterol, alanine aminotransferase (ALT), and uric acid analyses were conducted by a Hitachi autoanalyzer, model 7150 (Hitachi, Tokyo, Japan).

Since sonographic diagnosis for fatty liver has acceptable agreement among operators [18] and is widely accepted in many epidemiological surveys [19], this noninvasive method was used to diagnose fatty liver, an important risk factor of MetS [20]. In 2002, abdominal ultrasound examinations were performed for all examinees, using convex-type real-time electronic scanners (Toshiba SSA-340 with 3.75 MHz convex-type transducer).

Definitions

Self-reported occupational risk factors

Information regarding the type of work schedule (RSW or DW) and basic personal data were collected from self-reported questionnaires in 2002 and 2007. Health examinations were given annually for workers in this company. Most employees of factories with automatic production lines are engaged in either light manual labor jobs or purely sedentary work.

Work schedules on the 24-h production line are based on a 3-team/2-shift plan: a repeating sequence of 6 day-time shifts followed by 3 off days, 6 night-time shifts, and then another 3 off days. The day-time and night-time shifts begin at 7:30 a.m. and 7:30 p.m., respectively. In the questionnaire employees indicated they had worked on a rotating shift for at least 1 year by responding "yes" to "I work on a rotating shift." Generally, this shift schedule is maintained in this type of factory unless family events or work promotions bring a change. Individuals not on rotating schedules for at least 1 year at the beginning and at the end of our follow-up were likely to have continued on with the same job description and day-time only work schedule. For these reasons, we divided work schedules into the following 2 categories:

– persistent DW rotating shift work not indicated in the records from 2002 and 2007,
– persistent RSW where rotating shift work was indicated in both records.

We excluded the data of intermittent shift workers (shift work indicated only in 2002 or only in 2007) from our final analysis to minimize the uncertainty of this occupational exposure.

We defined "having routine physical exercise" as, "doing exercise more than 3 times every week." To define "ever been a smoker," the 1st question was "Do you smoke?" (1. "Never," 2. "Currently smoke," 3. "Previously smoked, have since quit")," and this was followed by questions about frequency. We defined "ever been a smoker" as answering "yes" to question 2 or 3 and consuming at least 6 cigarettes daily for over 1 year. For defining "have the habit of snacking," the 1st questions were "Do you have the habit of snacking before sleeping?" and "Do you have the habit of snacking between meals?". These were followed with questions regarding quantity. We defined a "snacking habits" in the present study as snacking more than 3 times per week. The standard portions of examples for snacks (fruit products, milk products, fried food, nuts, beans products, meat, and alternatives) were explained to examinees in questionnaires.

Metabolic syndrome

Metabolic syndrome components were noted if the examinees had any following risk determinants:

– central obesity (COB – waist circumference more than 90 cm in men and 80 cm in women),
– high blood pressure (HBP – systolic blood pressure (SBP) ≥ 130 mm Hg or diastolic blood pressure (DBP) ≥ 85 mm Hg),

- hyperglycemia (hyper-GL – fasting sugar ≥ 100 mg/dl),
- hypertriglyceridemia (hyper-TG – triglycerides ≥ 150 mg/dl),
- low-HDL cholesterolemia (low-HDL – HDL < 40 mg/dl in men and < 50 mg/dl in women) [21].

We specified the MetS component count (MSC) as a summation of the numbers of MetS 5 components for an individual or a worker group, and the arithmetic mean value of MSC for a worker group was defined as MSC density (MSCD).

Sonographic fatty liver was assessed using the following 5 parameters: liver–kidney contrast, gall bladder wall masking, blurring of wall of hepatic and portal veins and far attenuation of the diaphragm. Diagnosis was made according to previous reports [22].

Statistical analysis

Baseline characteristics and abnormal rates were compared between DW and RSW workers within 5 years using the t-test and the Chi^2 test for categorical and continual variables as appropriate. Multivariate logistic regression was used to estimate the adjusted rate ratio (aRR), and 95% confidence intervals (CI) of risk factors were used for predicting increased or decreased MSCD, after adjusting for gender, initial age, each MetS component, uric acid, alanine aminotransferase, sonographic fatty liver and occupational and lifestyle factors [23,24]. A p-value < 0.05 was considered statistically significant.

RESULTS

Records were analyzed for 1077 employees with an average term of employment of 7.7 years (SD = 5.7 years) and an initial mean age of 32.4 years (SD = 6.2 years). Table 1 summarizes data in 2002 obtained from the baseline health check-ups and personal and occupational records of 255 female and 822 male workers. There were 565 employees (52%) engaged in RSW during this 5-year follow-up.

Insignificant differences in measurements of general health conditions were found between female DW and RSW workers, with the exception that RSW workers showed higher diastolic blood pressure, higher rates of having snacks before sleeping, smoking and a lower rate of physical exercise at the baseline survey.

Among male workers, RSW workers were significantly younger, thinner and had more favorable blood test results for sugar and lipids and lower abnormality rates of sonographic fatty liver, while having higher rates of snacks before sleeping, smoking and a lower rate of physical exercise than did their DW co-workers.

Table 2 presents abnormality rates of individual MetS components among the total sample population, female and male workers at baseline in 2002 and at endpoint in 2007. The changes of MSCD between the DW and RSW workers are also shown in Table 2. The initial abnormality rates of each MetS component were significantly unfavorable for the DW workers (DW vs. RSW workers: hyper-GL: 32.8% vs. 25.1%, p < 0.01; low-HDL: 34.4% vs. 28%, p = 0.02). Similar abnormality rates of MetS components existed between female DW and RSW workers, with the exception that RSW workers showed a higher rate of HBP (DW vs. RSW workers: 9.5% vs. 18.6%, p < 0.01). Among male workers, the initial abnormality rates of each MetS component were also significantly unfavorable for the DW workers (hyper-GL: 34.7% vs. 25.3%, p < 0.01; hyper-TG: 32% vs. 24.4%, p = 0.02; low-HDL: 32% vs. 25.7%, p = 0.05; DW vs. RSW workers).

In 2007, none of the abnormality rates of MetS components except HBP were significantly different between DW and RSW workers. Table 2 also shows the significant 5-year changes of MCSD between DW and RSW workers for the total population: 0.10 vs. 0.39, p < 0.01; female workers: –0.10 vs. 0.29, p < 0.01; and male workers: 0.17 vs. 0.41, p < 0.01 (Table 2, the lowest rows).

Details of the prevalence rates of increased and decreased MSC among the total, female and male worker

Table 1. Basic characteristics of sample population

Variable	Respondents (total) (N = 1 077)	Females (N = 255)			Males (N = 822)		
		DW (N = 137)	RSW (N = 118)	p (t-test)	DW (N = 375)	RSW (N = 447)	p (t-test)
Male gender [%]	76	n.a.	n.a.		n.a.	n.a.	
Seniority [years] (M±SD)	7.7±5.7	9.4±6.0	8.3±5.1	0.13	7.7±6.0	7.1±5.4	0.13
Age [years] (M±SD)	32.4±6.2	31.7±6.3	32.5±8.5	0.40	33.8±5.4	31.5±5.9	< 0.01*
Rotating shift work exposure [%]	52	n.a.	n.a.		n.a.	n.a.	
Waist [cm] (M±SD)	77.4±9.4	69.3±8.3	70.6±8.1	0.22	80.9±8.1	78.8±8.6	< 0.01*
Blood pressure [mm Hg] (M±SD)							
systolic	119.5±15.9	111.0±14.4	114.3±15.6	0.08	121.4±15.5	121.8±15.7	0.69
diastolic	73.3±10.2	68.0±8.9	71.3±10.9	< 0.01*	74.5±10.1	74.5±9.9	1.00
Fasting blood sugar [mg/dl] (M±SD)	96.3±16.8	96.6±17.2	93.9±8.9	0.12	98.1±21.4	95.2±13.4	0.02*
Triglyceride [mg/dl] (M±SD)	121.7±95.9	87.6±78.0	85.2±58.7	0.78	140.6±100.3	125.9±99.8	0.04*
HDL cholesterol [mg/dl] (M±SD)	48.7±12.5	54.9±14.0	54.4±12.4	0.76	46.6±11.8	47.2±11.6	0.44
Alanine aminotransferase [U/l] (M±SD)	25.8±22.5	22.2±10.7	20.3±6.9	0.09	26.0±14.0	28.2±31.4	0.17
Uric acid [mg/dl] (M±SD)	6.8±1.6	5.4± 1.3	5.3±1.2	0.31	7.2±1.6	7.2±1.4	0.58
Sonographic fatty liver [%]	33	19	21	0.66	41	34	0.02*
Snacks (≥ 3 days/week) [%]							
before sleeping	40	25	36	0.04	35	49	< 0.01*
between meals	46	66	63	0.62	41	39	0.68
Ever been a smoker (≥ 6 cigarettes/day for ≥ 1 year) [%]	34	2	9	0.02	32	52	< 0.01*
Taking exercise (≥ 3 days/week) [%]	32	33	21	0.04	39	29	< 0.01*

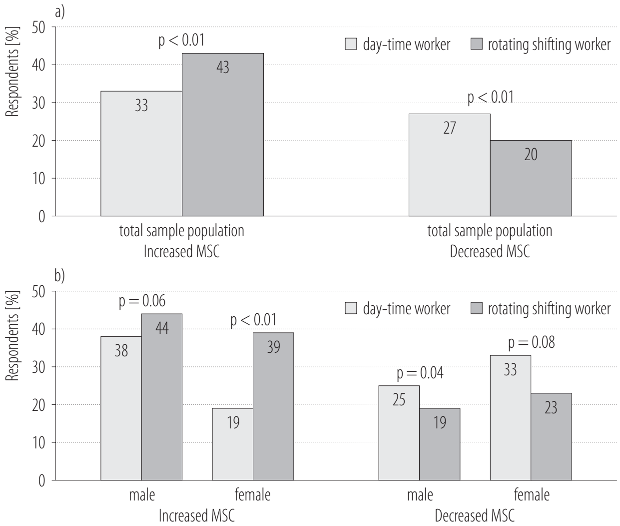
M – mean; SD – standard deviation; HDL – high-density lipoprotein.
DW – day-time work; RSW – day-and-night rotating shift work; n.a. – not applicable.
* $p < 0.05$ is considered statistically significant.

Table 2. Prevalent rates and changes of metabolic syndrome components in 2002 and 2007

Abnormality	Respondents (total) (N = 1 077)			Females (N = 255)			Males (N = 822)		
	DW (N = 512)	RSW (N = 565)	p	DW (N = 137)	RSW (N = 118)	p	DW (N = 375)	RSW (N = 447)	p
MetS-component abnormality 2002 [%]									
COB	10.2	9.4	0.67	10.2	12.7	0.53	10.1	8.5	0.42
HBP	22.9	28.3	0.04*	9.5	18.6	0.03*	27.7	30.9	0.33
hyper-GL	32.8	25.1	< 0.01*	27.7	24.6	0.57	34.7	25.3	< 0.01*
hyper-TG	25.4	21.1	0.09	7.3	8.5	0.73	32.0	24.4	0.02*
low-HDL	34.4	28.0	0.02*	40.9	36.4	0.47	32.0	25.7	0.05*
MetS-component abnormality 2007 [%]									
COB	25.8	28.9	0.26	19.7	35.6	< 0.01*	28.0	27.1	0.77
HBP	46.3	54.3	< 0.01*	19.7	41.5	< 0.01*	56.0	57.7	0.62
hyper-GL	20.7	22.0	0.62	14.6	22.0	0.12	22.9	21.9	0.73
hyper-TG	30.3	30.4	0.95	15.3	13.6	0.69	35.7	34.9	0.80
low-HDL	12.1	14.9	0.19	16.1	17.0	0.85	10.7	14.3	0.12
Group MetS component [count]									
2002	643	632	–	131	119	–	512	513	–
2007	692	850	–	117	153	–	575	697	–
Δ	49	218	–	14	34	–	63	184	–
MetS component density [count/person]									
2002	1.26	1.12	0.06	0.96	1.01	0.70	1.37	1.15	< 0.01*
2007	1.35	1.50	0.05*	0.85	1.30	< 0.01*	1.53	1.56	0.76
Δ	0.09	0.38	< 0.01*	–0.11	0.29	< 0.01*	0.16	0.41	< 0.01*

MetS – metabolic syndrome; COB – central obesity; HBP – high blood pressure; hyper-GL – hyperglycemia; hyper-TG – hypertriglyceridemia; low-HDL – low-HDL cholesterolemia. Other abbreviations as in Table 1.

* T-test and the Chi^2 test were conducted for continuous and categorical variables between groups with/without RSW; $p < 0.05$ is considered statistically significant.



P value is result of Chi^2 test.
DW – day-time work; RSW – day-and-night rotating shift work.

Fig. 1. Prevalence rates of increased and decreased metabolic syndrome component count (MSC) among a) total sample population and b) each gender

subgroups are shown in Figure 1. Similarly, in the total, female and male worker populations, RSW employees had significantly higher rates of increased MSC and lower rates of reduced MSC than did their DW co-workers.

Table 3 shows the adjusted RRs for increased and decreased MSCs among worker groups. After controlling for confounding factors (age, occupational factors, lifestyle, MetS components, liver enzyme, uric acid abnormality and sonographic fatty liver), multivariate analysis indicated that the workers exposed to RSW had a 1.7-fold higher risk for increased MSCD (95% CI: 1.28–2.25, $p < 0.01$) and were 38% less likely (aRR: 0.62, 95% CI: 0.45–0.86, $p < 0.01$) to attain decreased MSCD within this 5-year interval. Similarly, among female and male workers, female RSW workers had a 2.1-fold higher risk for increased MSCD (95% CI: 1.06–4.15, $p = 0.03$) and were 51% less likely (aRR: 0.49, 95% CI: 0.25–0.96, $p = 0.04$) to attain decreased MSCD; male RSW workers had a 1.5-fold increased risk for elevated MSCD (95% CI: 1.12–2.12, $p < 0.01$) and were 33% less likely (aRR: 0.67, 95% CI: 0.46–0.99, $p = 0.05$) to attain decreased MSCD.

DISCUSSION

Conventionally, MetS is a good risk predictor of cardiocerebrovascular disease for an individual. In the present study, in epidemiological terms, we demonstrate that the changes of MSCD, much simpler than other complicated evaluating index [2], are significantly different among workers with or without a specific occupational exposure.

Many credible studies have closely linked MSC with various unfavorable health outcomes of the whole human body, including malignancies [13,14], cardiovascular diseases [25,26], cognitive impairment [27], respiratory diseases [12,28], kidney diseases [29,30], insulin resistance [7,31], diabetes mellitus [8,11], increased oxidative stress [32,33], inflammatory reactions [34,35] as well as mutations on genetic levels [36–38], of which the risks rise proportionally associated with MSC.

In accordance with our findings and the above mentioned epidemiological observations, and since all the standardized measurements of MetS elements are accessible in most medical settings [39], MSC, MSCD and their changes can serve as basic and practical parameters for evaluating the general health conditions of employees in various workplaces.

In terms of occupational exposure, our observations support the previous studies highlighting the potentially worrying effects of night shift work schedules on employee health [15,40–45]. We demonstrate that even though that the RSW workers were significantly younger, thinner, and had a lower prevalence rate of preexisting health abnormalities than their coworkers involved in DW works (Table 1) at baseline, they showed increased MSC, and lower presence of decreased MSC (Table 2 and 3, Figure 1) after 5 years. Circadian disruption has been linked with premature aging process [46], high blood pressure [47], obesity [48], abnormal blood lipids and sugar [49,50]. We recommend every risk factor of MetS should be managed among workers; furthermore, with the knowledge

Table 3. Adjusted rate ratio for the increased and decreased metabolic syndrome component densities among employee groups

Respondents	Increased MetS component count			Decreased MetS component count		
	aRR	95% CI	p	aRR	95% CI	p
Total						
male vs. female	1.58	1.04–2.41	0.03	0.31	0.19–0.50	< 0.010
RSW vs. DW	1.70	1.28–2.25	< 0.01	0.62	0.45–0.86	< 0.010
Female employee						
RSW vs. DW	2.10	1.06–4.15	0.03	0.49	0.25–0.96	0.040
Male employee						
RSW vs. DW	1.54	1.12–2.12	< 0.01	0.67	0.46–0.99	0.046

aRR – rate ratio adjusted for gender, initial age, each MetS component, uric acid abnormality, elevated liver enzymes, sonographic fatty liver, occupational and lifestyle factors including snacking, smoking and exercising.
Other abbreviations as in Table 1.

of MSCD increasing among RSW workers, thorough health promotion efforts are needed, particularly for shift workers.

Comparing the gender differences of MetS component abnormalities among these worker populations, our findings are similar to those of many previous large-scale studies [15,51], which show that male workers have higher risk of developing MetS-related abnormalities than do female workers (Table 3). Sex-specific [52] risk predictors should be considered in primary prevention for incidence of MetS in workplaces.

Each component of MetS intervention has independent goals to be achieved, while no single effective pharmacological treatment simultaneously affecting all components of MetS equally has yet been found. Worksite health promotion programs for MetS have been reported to achieve substantial risk reduction [53,54].

Prevention and treatment [55] of the predictive factors together with enhanced lifestyle-modification [56,57] and intervention [58] may jointly reduce the prevalence of MetS risk factors [59]. A good example of significant decreases in MSC (from 2.1 down to 1.1) can be found in a study of subjects who completed a weight loss program [60]; similarly, for many health conditions, it is worthwhile to put greater efforts into addressing obesity [61]. On the other hand, dietary therapies, such as salt restriction [51] or increased fiber consumption [54], are essential for reducing MSC in subjects with risk factors [62]. For shift workers, due to the complex nature of gene-nutrition-environment interactions [63–65], MetS treatments including dietary adjustment may require a personalized approach [66–69].

In addition to the aspects of employees' health, elevated MSC is associated with increased medical costs [70,71]. Milani et al. reports decreased total health risk and markedly reduced medical claim costs through worksite health programs [72]. Whether RSW significantly inflates economic burden in workplaces in Taiwan, and whether reductions of MSCD lower medical costs among workers are interesting issues for further investigation.

This is the 1st large-scale observational research utilizing MSC, MSCD and their changes to evaluate general health conditions among workers. The conclusions drawn from our observations of a stable, relatively young and healthy worker population may benefit employees in similar workplaces. However, retrospective epidemiological surveys are fundamentally not as compelling as prospective investigations in the identification of causal associations; hence, some potential limitations of our analysis need to be considered.

At the commencement of this study, the elder male DW had a significantly larger MSCD than the younger RSW did. However, after 5 years, MSCDs became similar between male DW and RSW workers. Aging process might partially explain the higher MSCD of DW than RSW at baseline. The specific comparisons between DW and RSW at baseline may involve a future prospective study for a cohort who developed MS from the baseline of 0 MSC. In addition, since we did not obtain the accurate chemical exposure data and information of sleep quality, we cannot derive the health effects from chemical exposures and sleep quality here. Future studies need to take these potential confounders of MetS development into consideration.

Due to the convenient, comprehensive medical care in Taiwan, one limitation of this investigation is that we did not consider potential protective effects [73–76] of treatment among workers with abnormal MetS components over the 5-year study interval. Thus, we may have underrated the risk of shift work for increased risk of each MetS component. Additionally, this is a workplace follow-up survey for relatively healthy workers. Therefore, the application of our conclusions to the general population should be a conservative one.

CONCLUSIONS

Metabolic syndrome component count density can potentially be a good indicator of the general metabolic health conditions of a given group of workers. To practically satisfy the legal requirements of managing employees' health, we suggest using MSC and MSCD as a simple tool for general metabolic health assessments in various workplaces.

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