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Original article

An Index to Assess Overwork-Related Adverse Effects on Employees Under the Occupational Safety and Health Act in Taiwan

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ABSTRACT

Background: The present study aimed to digitally evaluate the risk of overwork-related adverse effects (OrAEs) among employees from various occupational categories in Taiwan.
Methods: Anonymous data of employees from seven companies/factories providing occupational health services were analyzed. The studied population comprised 5505 employees, and the data analyzed included employment duration, working hours, shift work schedules, and health checkup results. The risk for OrAEs was assessed by an index, Karo index (0-4, the larger the value, the higher the risk for OrAEs) obtained using a risk matrix made up of cardiocerebral and occupational risk factors. Karo index values of 3 and 4 were categorized as at high risk for OrAEs (h-OrAEs).
Results: The 5505 employees had an average employment duration of 8.5 years and a mean age of 39.4 years. The prevalence rates for h-OrAEs of the seven companies/factories ranged from 3.9% to 34.2%. There were significant differences in prevalence rates for h-OrAEs between employees of retail stores and high-tech manufacturing factories. Multivariate analysis results indicated that workers of high-tech manufacturing factories had significantly higher risk for h-OrAEs compared with retail store workers.
Conclusion: In terms of satisfying health risk management and legal requirements in Taiwan, the newly issued Karo index, which covers a wide range of occupational risk factors, can serve as an assessment and a warning tool for managing the risk of OrAEs in workplaces. To reduce risks for h-OrAEs, active and prudent control of cerebrocardiovascular risks and working hours is recommended.

1. Introduction

Adverse health effects of overwork have been widely reported in various occupational categories among modern workplaces [1–9]. Karoshi, which means “death from overwork,” first reported in Japan [10], is a rising concern in industrialized Asian countries [2,7,8]. The device-dependent method for job stress assessment has been elaborated [11], and the national research team in Japan uses a structuralized Excessive Fatigue Symptom Inventory to evaluate the factors associated with risk for Karoshi [12], yet the overwork-related risk assessments that have taken the legal compliance into account are scarcely reported. In Taiwan, the Occupational Safety and Health Act [13] required employers to provide occupational health services (OHS), adequately plan and adopt the necessary safety and health measures for preventing ailments induced by exceptional workload such as working shifts, working at night, and long working hours [14]. To implement workplace health management in various categories of occupation, it is beneficial to develop digitalized risk assessments for overwork-related adverse effects (OrAEs) on employees in different worksites [15,16]. Given that Taiwan views overwork as an important health hazard in workplaces [13], together with the fact that periodic routine health examinations [13] are compulsory for workers in Taiwan, the present study used OHS records to establish a practical assessment index for the risk for OrAEs among different employee groups.

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2. Materials and methods

2.1. Study sample

The studied population comprised 5505 employees, 2499 females and 3006 males, from two retail stores, two electronic part/component manufacturing factories, one machinery/equipment manufacturing factory, and two high-tech manufacturing factories that hired more than 300 employees and received statutory OHS from the department of occupational medicine of one hospital.

2.2. Study design and data collection

The present study extracted data from health checkup records and work status questionnaires of employees in seven companies/factories providing OHS. The compulsory health checkup was performed by a qualified medical institution in Taiwan [17]. The data analyzed included age, gender, employment duration, records of metabolic syndrome components, working hours, shift work schedules, and burnout scores. The Ethical Committee for Human Research at En Chu Kong Hospital, New Taipei City, Taiwan, approved the study protocol used in this work (ECK-IRB1040501). The En Chu Kong Hospital Institutional Review Board waived the requirement for informed consents from participants due to the retrospective and anonymous nature of this analysis.

2.3. Covariates and definitions

2.3.1. Cardiocerebral risk factors

2.3.1.1. Metabolic syndrome components. Metabolic syndrome (MetS) [18] components were noted and counted if the participants had any of the following risk determinants: (1) central obesity (waist circumference >90 cm in men and >80 in women); (2) high blood pressure (systolic blood pressure ≥130 mmHg or diastolic blood pressure ≥85 mmHg; (3) hyperglycemia (fasting sugar ≥100 mg/dL); (4) hypertriglyceridemia (triglycerides ≥150 mg/dL); and (5) low high-density lipoprotein cholesterolemia (high-density lipoprotein <40 mg/dL in men and <50 in women). This study used the MetS component count (MSC) [19], total count of the above five risk determinants, for diagnosis of MetS. Subjects with MSC >2 would be counted as having MetS.

2.3.1.2. Diabetes and hypertension. Diabetes was diagnosed if fasting glucose was ≥126 mg/dL [20,21], and hypertension was diagnosed if the blood pressure was ≥140/90 mmHg [22].

2.3.2. Occupational risk factors

2.3.2.1. Burnout scores. Self-reported burnout status was assessed using the Copenhagen Burnout Inventory (Traditional Chinese version) [23], which is officially included in the routine employees' health checkup [24]. The personal burnout score or work-related fatigue score ranged from 0 to 100. A personal burnout score <50 or a work-related fatigue score <45 was defined as at low risk. A personal burnout score between 50 and 70 or a work-related fatigue score between 45 and 60 was defined as at moderate risk. A personal burnout score >70 or a work-related fatigue score >60 was defined as at high risk [24].

2.3.2.2. Working hours. As stated in the Labor Standards Act of Taiwan, the regular working time of workers may not exceed 8 hours a day nor 40 hours a week, and the total number of working hours shall not exceed 48 hours every week [25]. The total overtime hours shall not exceed 46 hours a month [25]. Overtime hours reaching the legal upper limit were defined as at high risk in this study.

2.3.2.3. Shift work. In the present study, consistent daytime work and night shift were defined as low and moderate risk work schedules, respectively.

2.4. Karo index and score matrix

A newly issued index, Karo index, modified from guidelines for the prevention of diseases resulting from abnormal workloads [26], is calculated using a score matrix (Fig. 1.), which comprises an axis of cerebrocardiovascular risk score (0, 1, 2) and an axis of occupational risk score (category scores 0, 1, 2). Adding the two category scores yields the Karo index, ranging from 0 to 4; the larger the Karo index, the higher the risk is for OrAEs. The definitions of the category scores used in this score matrix are as follows.

2.4.1. Cerebrocardiovascular risk is defined by the highest category score

Category I (Score: 0):

- Having all health checkup items within the normal range

Category II (Score: 1):

- Having MSC 1 or 2, but no diabetes or hypertension

Category III (Score: 2 categorized as high cerebrocardiovascular risk [h-Cc]):

- Having MetS or diabetes or hypertension

2.4.2. Occupational risk score is defined by the highest category score

Category I (Score: 0):

- Fulfilling all the following criteria:
  A. Consistent daytime work
  B. No extension of standard working hours
  C. Personal burnout score <50

Occupational risk axis (columns); Cerebrocardiovascular risk axis (rows)

Karo index Score Matrix	Category I Score: 0	Category II Score: 1	Category III Score: 2
Category I Score: 0	**0**	**1**	**2**
Category II Score: 1	**1**	**2**	**3**
Category III Score: 2	**2**	**3**	**4**

Fig. 1. Score matrix and Karo index: the summation of scores of both occupational and cerebrocardiovascular risk axes.

D. Work-related fatigue score <45

Category II (Score: 1):

- Having any of the following criteria:
  A. Night shift
  B. Overtime <46 hours per month
  C. Personal burnout score between 50 and 70
  D. Work-related fatigue score between 45 and 60

Category III (Score: 2 categorized as high occupational risk [h-Oc]):

- Having any of the following criteria:
  A. Long working hours, overtime reaching 46 hours per month
  B. Personal burnout score >70
  C. Work-related fatigue score >60

2.4.3. High risk for OrAEs

Karo index values of 3 and 4 are classified as at high risk for OrAEs.

2.5. Statistical analysis

Baseline characteristics and abnormal rates were compared among workers of seven companies/factories using the analysis of variance test and the χ^2 test for continuous and categorical variables as appropriate. Kruskal-Wallis test was used for comparing median values among seven companies/factories. In addition to the crude rate ratio, logistic regression was performed to estimate the adjusted rate ratio (a-RR) for the high risk for OrAEs (h-OrAEs) among each individual company/factory, with 95% confidence intervals (CIs); age, gender and employment duration were included in the adjustment model. A $p < 0.05$ was considered statistically significant. SAS version 8.0 (SAS Institute, Cary, NC, USA) was used for all statistical analyses.

3. Results

3.1. General characteristics

The 5505 employees (2499 female and 3006 male) had an average employment duration of 8.5 years (standard deviation 6.2 years) and a mean age of 39.4 years (standard deviation 9.4 years). Table 1 summarizes the data obtained from health checkups and personal/occupational records of workers.

Table 1
Characteristics of studied employees

Variables	N = 5505 Mean ± SD/cases (abnormalities [%])/ median (IQR)
Male gender	3006 (54.6%)
Age (years)	39.4 ± 9.4
Employment duration (years)	8.5 ± 6.2
Body mass index (kg/m^2)	24.7 ± 4.6
Waist (cm)	81.1 ± 12.0
Systolic blood pressure (mmHg)	122.7 ± 16.2
Diastolic blood pressure (mmHg)	78.3 ± 11.4
Fasting blood sugar (mg/dL)	91.2 ± 22.3
Triglyceride (mg/dL)	117.1 ± 95.6
HDL cholesterol (mg/dL)	56.6 ± 13.7
Personal burnout score	27.5 ± 21.4
Work-related fatigue score	26.6 ± 20.1
Overtime per month (hours)	8.0 ± 17.5
Aged above 45 years	1293 (23.5%)
Central obesity	1747 (31.7%)
High blood pressure	2146 (39.0%)
Hyperglycemia	927 (16.8%)
Hypertriglyceridemia	1151 (20.9%)
Low HDL cholesterolemia	851 (15.5%)
Diabetes	180 (3.3%)
Hypertension	1001 (18.2%)
Metabolic syndrome	896 (16.3%)
High personal burnout score	192 (3.5%)
High work-related fatigue score	253 (4.6%)
Long working hours	412 (7.5%)
Night shift	554 (10.1%)
Cerebrocardiovascular risk score	1 (0-2)
Occupational risk score	1 (0-1)
Karo index	1 (1-2)
High cerebrocardiovascular risk score	1517 (27.6%)
High occupational risk score	683 (12.4%)
High risk for OrAEs	815 (14.8%)

HDL = high-density lipoprotein; IQR = interquartile range; OrAE = overwork-related adverse effects; SD = standard deviation.

3.2. Abnormality rates, risk scores, and karo index of each individual company/factory

3.2.1. Abnormality rates of individual risk factors

The prevalence rates of h-OrAEs for the retail stores (-A, -B), electronic part/component manufacturing factories (-A, -B), machinery/equipment manufacturing factory, and high-tech manufacturing factories (-A, -B) were 3.9%, 4.6%, 6.4%, 12.4%, 13.2%, 33.0%, and 34.2%, respectively (Table 2). According to the rates of h-OrAEs, Table 2 presents abnormality rates of individual risk factors among the total sample population. The abnormality rates of each MetS component were unfavorable for high-tech manufacturing factory workers compared with retail store workers. Similarly, the burnout scores of high-tech manufacturing factory workers were higher than those of the retail store workers.

3.2.2. Cerebrocardiovascular, occupational risk score, and karo index score

Table 2 also shows obvious differences in the prevalence rates for h-Oc and h-OrAEs between workers of retail stores and high-tech manufacturing factories (Table 2, the bottom rows). Fig. 2 plots the distribution of the Karo index values of the sample population as well as each individual company/factory. As can be seen, workers of high-tech manufacturing factories had a remarkably elevated risk for h-OrAEs than did retail store workers. The prevalence rates of the h-Cc were higher compared with those of h-Oc for the studied population, except for the high-tech manufacturing factory workers (Table 2).

3.3. Risk for h-OrAEs among worker groups

Table 3 demonstrates the a-RRs of increased risk for h-OrAEs among worker groups. After controlling for confounding factors (gender, age, duration), multivariate analysis results indicated that workers of high-tech manufacturing factory A had an 8.3-fold increased risk for h-OrAEs (95% CI, 5.2−13.0; $p < 0.05$) and those of high-tech manufacturing factory B had a 9.0-fold increased risk for h-OrAEs (95% CI, 5.9−13.7; $p < 0.05$) compared with retail store workers.

Table 2
Characteristics of study groups—employees from different companies and factories

Variable: Mean ± SD/cases (abnormalities (%))/median (IQR)	Retail store A n = 693	Retail store B n = 1059	Electronic part/component manufacturing factory A n = 342	Electronic part/component manufacturing factory B n = 1458	Machinery/equipment manufacturing factory n = 599	High-tech manufacturing factory A n = 379	High-tech manufacturing factory B n = 975	P*
Male gender	208 (30.0%)	582 (55.0%)	148 (43.3%)	779 (53.4%)	438 (73.1%)	260 (68.6%)	591 (60.6%)	<0.05
Age (years)	37.1 ± 9.0	39.3 ± 9.6	38.3 ± 7.7	36.5 ± 8.8	48.2 ± 11.2	38.7 ± 6.4	40.4 ± 6.2	<0.05
Employment duration (years)	7.7 ± 5.5	10.0 ± 6.4	7.7 ± 6.4	5.1 ± 4.7	10.±8.8	9.8 ± 5.7	11.0 ± 5.2	<0.05
Body mass index (kg/m^2)	23.9 ± 4.5	24.5 ± 4.8	24.5 ± 4.3	24.6 ± 4.8	25.6 ± 4.3	25.3 ± 4.2	25.2 ± 4.2	<0.05
Waist (cm)	77.6 ± 11.2	80.8 ± 12.1	82.0 ± 11.2	80.3 ± 12.9	85.6 ± 10.9	82.1 ± 11.4	81.±11.2	<0.05
Systolic blood pressure (mmHg)	115.2 ± 16.4	120.8 ± 17.3	120.±16.7	121.9 ± 15.1	130.±15.8	125.4 ± 13.1	126.4 ± 14.5	<0.05
Diastolic blood pressure (mmHg)	73.7 ± 11.0	77.1 ± 12.2	78.8 ± 10.8	78.3 ± 10.6	81.3 ± 11.6	80 ± 11.3	80.2 ± 10.7	<0.05
Fasting blood sugar (mg/dL)	96.0 ± 17.0	98.5 ± 20.4	92.0 ± 20.8	87.2 ± 21.8	93.3 ± 32.1	85.1 ± 11.1	86.7 ± 21.8	<0.05
Triglyceride (mg/dL)	94.1 ± 62.2	111.0 ± 110.9	113.9 ± 80.9	118.8 ± 96.2	139.5 ± 113.6	125.1 ± 87	122.1 ± 88.2	<0.05
HDL cholesterol (mg/dL)	59.9 ± 15.1	56.7 ± 14.3	57.6 ± 6.5	56.6 ± 12.4	52.2 ± 13.6	56.3 ± 14.9	56.3 ± 14.6	<0.05
Personal burnout score	25.9 ± 18.4	23.6 ± 19.0	29.7 ± 17.7	20.1 ± 23.2	30.2 ± 18.7	33.3 ± 18.4	39.0 ± 21.0	<0.05
Work-related fatigue score	25.8 ± 17.8	23.6 ± 18.6	25.8 ± 16.9	17.4 ± 21.0	31.8 ± 17.1	34.±16.4	38.1 ± 18.2	<0.05
Overtime per month (hours)	0.2 ± 0.9	2.1 ± 3.9	18.6 ± 13.5	3.2 ± 13.1	2.3 ± 8.9	27.9 ± 26.5	19.2 ± 25.0	<0.05
Aged above 45 years	132 (19.0%)	278 (26.3%)	59 (17.3%)	211 (14.5%)	345 (57.6%)	61 (16.1%)	207 (21.2%)	<0.05
Central obesity	187 (27.0%)	333 (31.4%)	135 (39.5%)	441 (30.2%)	242 (40.4%)	112 (29.6%)	297 (30.5%)	<0.05
High blood pressure	151 (21.8%)	349 (33.0%)	116 (33.9%)	541 (37.1%)	344 (57.4%)	186 (49.1%)	459 (47.1%)	<0.05
Hyperglycemia	187 (27.0%)	357 (33.7%)	43 (12.6%)	140 (9.6%)	108 (18.0%)	22 (5.8%)	70 (7.2%)	<0.05
Hypertriglyceridemia	78 (11.3%)	193 (18.2%)	58 (17.0%)	296 (20.3%)	186 (31.1%)	101 (26.6%)	239 (24.5%)	<0.05
Low HDL cholesterolemia	122 (17.6%)	170 (16.1%)	20 (5.8%)	212 (14.5%)	131 (21.9%)	52 (13.7%)	144 (14.8%)	<0.05
Diabetes	14 (2.0%)	43 (4.1%)	11 (3.2%)	43 (2.9%)	39 (6.5%)	3 (0.8%)	27 (2.8%)	<0.05
Hypertension	62 (8.9%)	161 (15.2%)	58 (17.0%)	241 (16.5%)	185 (30.9%)	76 (20.1%)	218 (22.4%)	<0.05
Metabolic syndrome	92 (13.3%)	214 (20.2%)	39 (11.4%)	194 (13.3%)	152 (25.4%)	63 (16.6%)	142 (14.6%)	<0.05
High personal burnout score	5 (0.7%)	15 (1.4%)	5 (1.5%)	49 (3.4%)	19 (3.2%)	17 (4.5%)	82 (8.4%)	<0.05
High work-related fatigue score	12 (1.7%)	26 (2.5%)	8 (2.3%)	49 (3.4%)	30 (5.0%)	27 (7.1%)	101 (10.4%)	<0.05
Long working hours	0 (0.0%)	0 (0.0%)	9 (2.6%)	45 (3.1%)	0 (0.0%)	126 (33.2%)	232 (23.8%)	<0.05
Night shift	0 (0.0%)	0 (0.0%)	0 (0.0%)	192 (13.2%)	0 (0.0%)	75 (19.8%)	287 (29.4%)	<0.05
Cerebrocardiovascular risk score	1 (0-1)	1 (0-2)	1 (0-1)	1 (0-1)	1 (1-2)	1 (0-2)	1 (0-2)	<0.05
Occupational risk score	0 (0-0)	0 (0-0)	0 (0-1)	0 (0-1)	0 (0-1)	1 (0-2)	1 (0-2)	<0.05
Karo index	1 (0-2)	1 (0-2)	1 (0-2)	1 (0-2)	2 (1-2)	2 (1-3)	2 (1-3)	<0.05
High cerebrocardiovascular risk score	129 (18.6%)	294 (27.8%)	77 (22.5%)	355 (24.4%)	268 (44.7%)	103 (27.2%)	291 (29.9%)	<0.05
High occupational risk score	16 (2.3%)	33 (3.1%)	22 (6.4%)	106 (7.3%)	35 (5.8%)	144 (38.0%)	327 (33.5%)	<0.05
High risk for OrAEs (Karo index > 2)	27 (3.9%)	49 (4.6%)	22 (6.4%)	180 (12.4%)	79 (13.2%)	125 (33.0%)	333 (34.2%)	<0.05

HDL = high-density lipoprotein; IQR = interquartile range; OrAE = overwork-related adverse effects; SD = standard deviation.
**p* values < 0.05, which were considered statistically significant. Analysis of variance was conducted for numeral variables, using Tukey's test; χ^2 test was conducted for categorical variables. Kruskal-Wallis test was used for comparisons of median values among seven companies/factories.

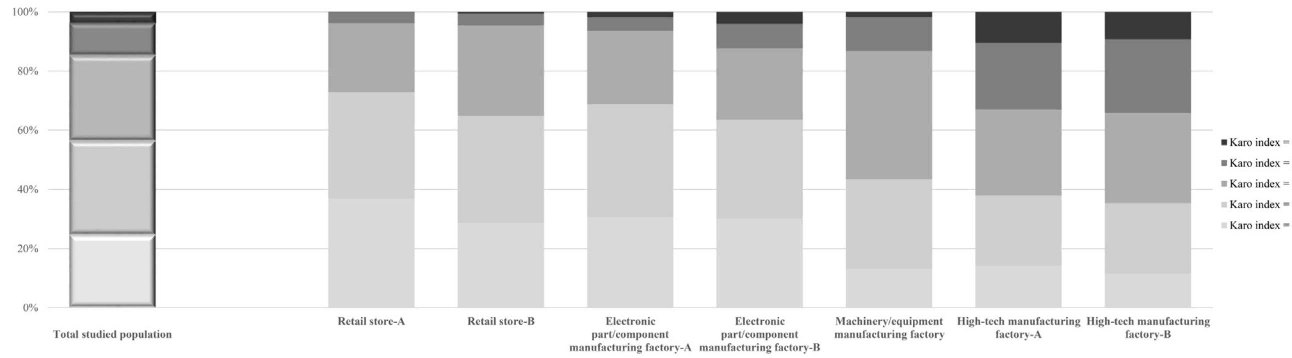

Fig. 2. The distribution of Karo index values in the total studied population and in each company.

4. Discussion

This occupational health management study is the first that incorporated legal criteria in assessing overall risk for OrAEs. Karo index, which comprises manageable components including relevant legal regulations in addition to conventional physical, psychological, occupational risk factors, can serve as a simple index summarizing the risk for OrAEs. Using Karo index, occupational health managers are able to effectively evaluate the risks for OrAEs, prioritize the high risk groups or individuals, and promote strategies for risk reduction, furtherly make positive contributions to workforce resilience.

Similar to the varied prevalence rates of stroke and ischemic heart disease among workers of different workplaces reported in other industrialized countries [27–30], disparate distributions of overwork-related risk factors and health abnormality rates were found among workplaces in the present study (Table 2, Fig. 2). Occupational health risk management plans should be customized for each different workplace.

Workers from five of the seven companies/factories in the present study had relatively larger prevalence rates of h-Cc than those of h-Oc (Table 2). Controlling cerebrocardiovascular risk should be the priority of occupational health management for middle-aged workers. MetS components are convenient and reliable risk predictors of cerebrocardiovascular diseases. Medical treatments [31] of MetS components together with lifestyle modifications [32–34] can help reduce some of the undesired consequences of overwork.

Table 3
Crude and adjusted rate ratios of h-OrAEs among employees of different workplaces

Company	Crude rate ratio	Adjusted rate ratio*	95% confidence intervals	p
Retail store A	Reference	Reference	—	—
Retail store B	1.2	0.8	0.5–1.4	0.48
Electronic part/component manufacturing factory A	1.6	1.4	0.8–2.6	0.23
Machinery/equipment manufacturing factory	3.2	2.2	1.3–3.7	<0.05
Electronic part/component manufacturing factory B	3.4	3.1	2.0–4.8	<0.05
High-tech manufacturing factory A	8.5	8.3	5.2–13.0	<0.05
High-tech manufacturing factory B	8.8	9.0	5.9–13.7	<0.05

h-OrAEs = high risk for overwork-related adverse effects.
* Adjusted for age, gender, and employment duration.

Personal burnout and work-related fatigue scores varied according to age [35], job type [35,36], experience [37], salary [38] and company size [39]. Stress management, physical activity [40], classical psychodrama method [41], reducing workload [42], increasing social support, and continuing education [43] had reported to significantly decrease personal burnout levels. Taiwan views work-related burnout syndrome as a critical health hazard in workplaces, more and more companies/factories in Taiwan have introduced assistance programs for employees [44,45], which may explain why personal and work-related burnout scores in the present study are slightly lower than those previously reported [23].

Workers of high-tech manufacturing factories recorded significantly longer overtime hours than those in other companies (Table 2) and had a higher a-RR of increased risk for h-OrAEs (Table 3) in the present study. A significant correlation between cerebrocardiovascular diseases and long working hours has been reported [46–49]; hence, the related health problems should be properly managed for workers of high-tech manufacturing factories. Furthermore, the present study used the Karo index to assess the risk of violating relevant occupational health regulations. In Taiwan, working hours are strictly limited by regulations. Employers violating such regulations shall be subject to heavy fines [14,25]. In terms of occupational exposure, managers of the business units with larger Karo index due to long working hours should pay prudent attention to the legal risk in corporate governance, in addition to the health risk of workers.

The present large-scale observational study is the first to use the Karo index to evaluate the risk for OrAEs among workers. The conclusions drawn from our observations of a stable and relatively healthy worker population may benefit employees in similar work environments. However, cross-sectional epidemiological surveys are fundamentally not as compelling as longitudinal investigations in identifying causal associations; hence, some potential limitations need to be considered. As we did not obtain the cerebrocardiovascular or mental disease endpoints data, we cannot conclude the exact correlation between Karo index and the health outcome in the present study; future studies need to confirm the statistical correlation between Karo index and the outcome of occupational health management. In addition, the present study arbitrarily used two risk axes, the precise weighting of each risk factor and the interactions among risk factors contributing to OrAEs merit further investigation and more quantitative/mathematical estimation. Still, this is an OHS survey for employees of middle- to large-sized retail and manufacturing companies; therefore, attention should be paid when applying our conclusions to the general population or other kinds of risky industries, such as transportation, construction, accommodation, food, and medical/health care. The reliability and applicability of the present indicators have to be verified in more occupation categories and for longer follow-up durations before the general real-world application.

5. Conclusion

Karo index, which covers a wide range of occupational risk factors, can be used as an assessment and a warning tool for managing the risk for OrAEs of various workplaces in Taiwan and can be applied for tracking the effectiveness of occupational health management. To reduce overwork-related health and legal risks in retail stores and manufacturing factories in Taiwan, we suggest active and prudent scontrol of cerebrocardiovascular risks and avoidance of excessive overtime hours.

Conflicts of interest

All authors have no conflicts of interest to declare.

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