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NIGHT-SHIFT WORK AND RISK OF COMPROMISED VISUAL ACUITY AMONG THE WORKERS IN AN ELECTRONICS MANUFACTURING COMPANY

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Abstract
Objectives: To evaluate the association between night-shift work exposure and visual health, this cross-sectional study utilized visual acuity, a surrogate measure for visual function, as a parameter, and performed an analysis comparing visual acuity between daytime and nighttime employees in an electronics manufacturing company. **Material and Methods:** Data of personal histories, occupational records, physical examinations and blood tests was obtained from the electronic health records of workers. The total of 8280 workers including 3098 women and 5182 men, wearing their own daily used eyeglasses, were included in the final analysis. The mean age of the sample population was 34.7 years old (standard deviation = 5.4 years). All workers were divided into 3 work categories – consistent daytime worker (CDW), day-shift worker (DSW) and night-shift worker (NSW). The check-up results of glasses-corrected visual acuity (c-VA) were utilized to classify individuals as good (≥ 1.2, both eyes) and inadequate (< 0.8, the better eye) c-VA. **Results:** Consistent daytime workers had the highest rate of good c-VA (42.5% vs. 25.1% DSW and 21.1% NSW, p = 0.047). Night-shift workers had the highest rate of inadequate c-VA (CDW, DSW and NSW: 2.6%, 6.2%, and 7.6%, p = 0.03) among all employees. After controlling for covariates, NSW were found at an increased risk for inadequate c-VA (adjusted odds ratio (OR_a) = 2.7, 95% confidence interval (CI): 2.0–3.6, vs. CDW), and less likely to have good c-VA (OR_a = 0.4, 95% CI: 0.4–0.5, vs. CDW). **Conclusions:** Night-shift work is moderately associated with compromised visual acuity of employees in this electronics manufacturing company. Int J Occup Med Environ Health 2018;31(1):71–79

Key words:
Aging, Occupational health, Visual acuity, Electronics manufacturing industry, Health check-ups, Night-shift work

INTRODUCTION

Controlling the entry of light, eye plays an essential role in regulating circadian rhythm of the human body [1]. Similar to other organs in the human body [2], diurnal rhythms such as intraocular pressure fluctuations exist in human eyes [3]. Night jobs are associated with visual fatigue [4,5] and the diurnal inconsistency of intraocular pressure was found amongst night-shift workers [6]. Furthermore, shift work and disturbed sleep were already proposed as the risk factors for retinopathy [7,8]. Theoretically, a normal diurnal

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rhythm is important to the health of human eyes, however, visual functions among night-shift workers, whose diurnal rhythms differ from those of daytime workers, have rarely been investigated on a large scale.

In Taiwan, night-shift work is legislated as a health hazard in workplaces [9] and periodic health evaluations are compulsory to all employees [10]. This health data including visual acuity, a surrogate measure for visual function, provides a splendid basis for observational research to assess the associations with night work exposure on visual health among workers.

To evaluate the association between visual health and night-shift work, an unavoidable occupational exposure in the modern workplace, we conducted a large scale workplace-based survey to assess the differences of visual acuities between nighttime and daytime workers.

MATERIAL AND METHODS

Study populations

Employees in one electronics manufacturing company received periodic health check-ups to monitor general health conditions. The compulsory health check-up was performed in November 2013 by one qualified health check-up institution [10] in North Taiwan. The corrected visual acuity (c-VA), occupational, personal and health records of a total of 8280 workers including 3098 women and 5182 men, wearing their own daily used eyeglasses, were included in the final analysis.

Study design and data collection

This cross-sectional study analyzed secondary data obtained from existing health check-up records of employees. The Ethical Committee for Human Research at En Chu Kong Hospital, New Taipei City, Taiwan, approved the study protocol used in this work (ECKIRB1040501). The En Chu Kong Hospital Institutional Review Board waived the requirement for informed consents from the participants due to the retrospective and anonymous nature of this analysis.

Demographic and biological measurements

Health check-ups were performed in accordance with the standard procedures [10]. Anthropometric data of the physical examination records included measurements of waist circumferences and blood pressure. Waist circumferences were measured midway between the lowest rib and the superior border of the iliac crest. Sitting blood pressure was measured on the dominant arm using digital automatic sphygmomanometers. Participants were placed in a reclining position, and venous blood from an antecubital vein of the arm was taken for subsequent tests.

After at least an overnight 8 h fast, analyses of fasting glucose, triglyceride and high-density lipoprotein (HDL) cholesterol were conducted by autoanalyzers. Blood specimens were centrifuged immediately and shipped frozen in dry ice to the central clinical laboratory. Participants wore their own daily used eyeglasses during eye examination; visual acuity was obtained by well-trained and experienced nurses using table-top visual acuity instruments [11].

Definitions

Exposure

All workers were divided into 3 categories – consistent daytime workers (CDW), fixed 12 h day-shift workers (DSW) and fixed 12 h night-shift workers (NSW). Consistent daytime workers worked in offices from 8:00 a.m. to 5:00 p.m. Shift work schedules on the 24 h production line were divided according to a fixed 4-team/2-shift plan. Daytime shifts begin at 7:30 a.m. and nighttime shifts at 7:30 p.m. Each shift involved 2 work days followed by 2 rest days. Shift workers did their job in cleanrooms where the environment was controlled to eliminate all dust and kept within consistent as well as narrow limits of humidity (55±5%), and consistent lighting level beyond 1000 lux.

Workers needed to wear specific caps, clothes, masks, and shoes. They were required to pass through an air shower gate when entering the cleanroom. Workers were assigned

to work either fixed 12 h day-shifts or fixed 12 h night-shifts at the beginning of employment.

Outcomes

In this study, the glasses-corrected visual acuity (c-VA) of both eyes > 1.2 [12] was defined as a good c-VA. The c-VA of the better eye < 0.8 was defined as an inadequate c-VA [9,13] and c-VA of the better eye < 0.6 was defined as a low c-VA [13].

Covariates

According to metabolic syndrome (MetS) criteria, abnormalities of health check-up results were marked if the subjects had any of the following risk determinants [14]:

- central obesity – waist circumference ≥ 90 cm in men and ≥ 80 cm in women;
- elevated blood pressure – systolic blood pressure (SBP) ≥ 130 mm Hg or diastolic blood pressure (DBP) ≥ 85 mm Hg;
- hyperglycemia – fasting sugar ≥ 100 mg/dl;
- hypertriglyceridemia – triglycerides ≥ 150 mg/dl;
- hypo-HDL cholesterolemia – HDL < 40 mg/dl in men and < 50 mg/dl in women.

Data of duration of employment was obtained from administrative records and high educational attainment was defined as bachelor's degree or above.

Statistical Analysis

Baseline characteristics and abnormal rates among CDW, DSW and NSW were compared using the ANOVA test and the Chi^2 test for continual and categorical variables as appropriate. Multivariate logistic regression was employed to estimate the adjusted odds ratio (OR_a) and 95% confidence intervals (CI) of risk factors were used for evaluating good c-VA and inadequate c-VA, under adjustments for gender, age, each MetS component and occupational factors. A p-value < 0.05 was considered statistically significant.

RESULTS

As shown in the Table 1, the mean age for this sample population was 34.7 years old (standard deviation (SD) = 5.4 years), the mean value of c-VA was 1.1 (SD = 0.3) for right eye and 1.1 (SD = 0.2) for left eye. The overall prevalence rates of inadequate, low and good c-VAs were 4.8%, 1.6% and 32.2%, respectively.

Table 1. Characteristics of study groups – employees with varied work schedules in an electronics manufacturing company

Variable	Study groups				p[a]
	total	CDW	DSW	NSW	
Respondents [n (%)]	8 280 (100.0)	3 884 (46.9)	2 517 (30.4)	1 879 (22.7)	< 0.01
male [n (%)]	5 182 (62.6)	2 745 (70.7)	1 219 (48.4)	1 218 (64.8)	< 0.01
female [n (%)]	3 098 (37.4)	1 139 (29.3)	1 298 (51.6)	661 (35.2)	< 0.01
Age [years] (M±SD)	34.7±5.4	35.1±5.3	34.6±5.5	34.0±5.4	< 0.01
Seniority [years] (M±SD)	6.9±4.3	7.1±4.2	7.1±4.3	6.0±4.3	< 0.01
Waist [cm] (M±SD)	81.1±11.3	81.9±10.5	79.5±11.6	81.7±12.0	< 0.01
Blood pressure [mm Hg] (M±SD)					
systolic	122.1±14.5	122.1±14.5	120.7±14.6	124.1±14.0	< 0.01
diastolic	76.0±11.0	77.2±10.5	74.1±11.3	75.9±11.4	< 0.01
Fasting blood sugar [mg/dl] (M±SD)	87.2±17.7	82.1±13.0	91.4±17.8	92.3±22.3	< 0.01
Triglyceride [mg/dl] (M±SD)	119.8±97.4	117.5±95.6	119.5±101.1	125.3±95.7	0.02

Table 1. Characteristics of study groups – employees with varied work schedules in an electronics manufacturing company – cont.

Variable	Study groups				p[a]
	total	CDW	DSW	NSW	
HDL cholesterol [mg/dl] (M±SD)	56.5±13.9	57.6±14.4	56.3±13.8	54.6±12.8	< 0.01
Corrected visual acuity					
left (M±SD)	1.07±0.25	1.12±0.24	1.02±0.24	1.01±0.25	< 0.01
right (M±SD)	1.05±0.26	1.11±0.25	1.00±0.25	0.99±0.25	< 0.01
Hyperglycemia [n (%)]	1 351 (16.3)	216 (5.6)	619 (24.6)	516 (27.5)	< 0.01
Hypertriglyceridemia [n (%)]	1 886 (22.8)	855 (22.0)	548 (21.8)	483 (25.7)	< 0.01
Hypo-HDL cholesterol [n (%)]	1 100 (13.3)	382 (9.8)	439 (17.4)	279 (14.8)	< 0.01
Elevated blood pressure [n (%)]	2 886 (34.9)	1 354 (34.9)	776 (30.8)	756 (40.2)	< 0.01
Central obesity [n (%)]	2 351 (28.4)	1 043 (26.9)	725 (28.8)	583 (31.0)	< 0.01
Metabolic syndrome [n (%)]	1 166 (14.1)	413 (10.6)	392 (15.6)	361 (19.2)	< 0.01
Visual acuity [n (%)]					
good	2 676 (32.3)	1 649 (42.5)	631 (25.1)	396 (21.1)	< 0.01
inadequate	398 (4.8)	100 (2.6)	155 (6.2)	143 (7.6)	< 0.01
low	135 (1.6)	34 (0.9)	50 (2.0)	51 (2.7)	< 0.01
Highest educational level ≥ bachelor's degree	4 934 (59.6)	3 469 (89.3)	844 (33.5)	621 (33.0)	< 0.01

M – mean; SD – standard deviation.
HDL – high density lipoprotein.
Hyperglycemia – fasting glucose ≥ 100 mg/dl.
Hypertriglyceridemia – triglyceride ≥ 150 mg/dl.
Hypo-HDL cholesterol = HDL < 50 in female or < 40 in male.
Elevated blood pressure – systolic blood pressure (SBP) ≥ 130 mm Hg or diastolic pressure (DBP) ≥ 85 mm Hg.
Central obesity – waist circumference ≥ 80 cm in female or ≥ 90 cm in male.
CDW – consistent daytime workers (8 h/day); DSW – day-shift workers (12 h/day); NSW – night-shift workers (12 h/night).
[a] ANOVA was conducted for numeral variables, using Tukey's test, Chi^2 test was conducted for categorical variables among groups of work schedules.

The distribution rates of CDW, DSW and NSW were 46.9%, 30.4% and 22.7%, respectively. The Table 1 also shows the personal, occupational data, metabolic health risk factors and c-VA among the 3 subgroups. As it can be seen, CDW had significantly more favorable c-VA measurements and a higher rate of good c-VA than the shift workers did (CDW, DSW and NSW: 42.5%, 25.1% and 21.1%, respectively, p = 0.047). Night-shift workers had a significantly higher rate of inadequate c-VA (CDW, DSW and NSW: 2.6%, 6.2%, and 7.6%, respectively, p = 0.03), and a significantly higher rate of low c-VA than the daytime workers did (CDW, DSW and NSW: 0.9%, 2% and 2.7%, respectively, p = 0.03).

Although NSW were the youngest among all 3 subgroups, they had significantly higher rates for metabolic abnormalities than the daytime workers (CDW and DSW) did. Differences of corrected visual acuities between workers with varied work schedules are demonstrated in the Table 2. The CDW significantly had the best measures of c-VA among 3 subgroups.

The decreasing trends of c-VA with increasing age for both daytime and nighttime workers can be seen in the

Table 2. Differences of corrected visual acuities amongst employees with varied work schedules in an electronics manufacturing company

Variable	Corrected visual acuity	
	left side	right side
M	1.07	1.05
RMSE	0.24	0.25
df	2.00	2.00
Sum of squares	25.08	28.77
MS	12.54	14.38
F	212.98	227.86
p	< 0.01	< 0.01
CDW vs. DSW [MD (95% CI)]	0.10 (0.09–0.12)	0.12 (0.1–0.13)
CDW vs. NSW [MD (95% CI)]	0.12 (0.1–0.13)	0.12 (0.1–0.14)
DSW vs. NSW [MD (95% CI)]	0.01 (–0.01–0.03)	0.004 (–0.01–0.02)

M – mean; RMSE – root mean square error; df – degrees of freedom; MS – mean square; MD – mean difference; CI – confidence interval. CDW – consistent daytime workers (8 h/day); DSW – day-shift workers (12 h/day); NSW – night-shift workers (12 h/night).

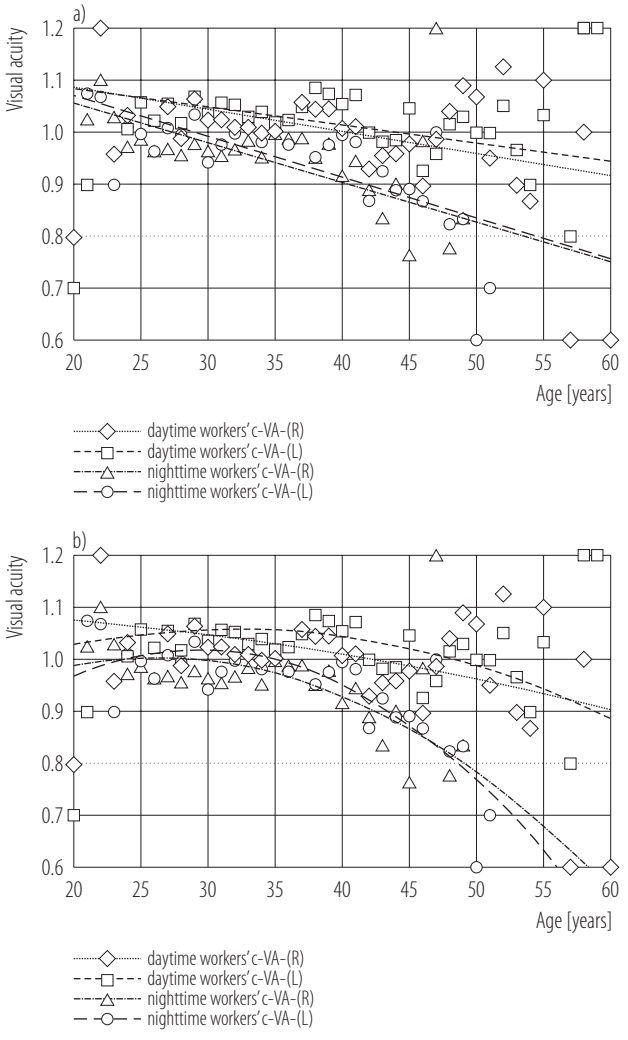
Figure 1. Particularly, in line with the aging process, the downward trends revealed that nighttime workers reached the inadequate (better eye c-VA < 0.8) or low visual acuity (better eye c-VA < 0.6) sooner than daytime workers did.

In the multivariate analysis, after adjusting for potential confounding variables, NSW were found to have a significantly unfavorable c-VA (Table 3). Night-shift workers had the OR_a = 2.7, 95% CI: 2.0–3.6, vs. CDW for

Table 3. Multivariate analysis for adjusted odds ratio of decreased visual acuity among employees with varied work schedules in an electronics manufacturing company

Variable	Visual acuity					
	inadequate		low		good	
	OR_a (95% CI)	p	OR_a (95% CI)	p	OR_a (95% CI)	p
Female vs. male gender	1.3 (1.1–1.7)	0.01	1.3 (0.9–1.9)	0.15	0.7 (0.6–0.8)	< 0.01
DSW vs. CDW	2.0 (1.5–2.7)	< 0.01	1.7 (1.02–2.9)	0.04	0.6 (0.5–0.6)	< 0.01
NSW vs. CDW	2.7 (2.0–3.6)	< 0.01	2.6 (1.5–4.4)	< 0.01	0.4 (0.4–0.5)	< 0.01
Age [years]	1.1 (1.05–1.1)	< 0.01	1.1 (1.02–1.1)	< 0.01	0.98 (0.971–0.995)	< 0.01
Seniority [years]	0.97 (0.9–0.99)	0.02	1.0 (0.95–1.1)	0.94	1.0 (1.004–1.03)	0.02
Central obesity vs. normal	1.1 (0.8–1.4)	0.57	1.4 (0.96–2.1)	0.08	1.0 (0.9–1.1)	0.65
Hyperglycemia vs. normal	1.4 (1.1–1.8)	< 0.01	1.7 (1.2–2.5)	0.01	0.6 (0.5–0.7)	< 0.01
Elevated blood pressure vs. normal	0.8 (0.7–1.1)	0.15	0.7 (0.5–1.0)	0.07	1.0 (0.9–1.1)	0.82
Hypo-HDL cholesterol vs. normal	1.2 (0.9–1.6)	0.19	1.0 (0.7–1.7)	0.87	0.9 (0.7–1.01)	0.07
Hypertriglyceridemia vs. normal	1.1 (0.8–1.4)	0.53	1.1 (0.7–1.7)	0.70	0.9 (0.8–0.99)	0.04
High educational level vs. < bachelor degree	0.9 (0.7–1.1)	0.32	0.8 (0.5–1.3)	0.43	1.1 (0.9–1.2)	0.29

OR_a – adjusted odds ratio for age, gender, education, job types, duration of work and metabolic components.
Other abbreviations as in Table 1 and 2.



Daytime workers – consistent daytime workers (CDW, 8 h/day) and day-shift workers (DSW, 12 h/day).
Nighttime workers – night-shift workers (NSW, 12 h/night).
c-VA – corrected visual acuity; R – right side; L – left side.

Fig. 1. Trends of visual acuity distributions: a) linear and b) quadratic – according to age of employees with varied work schedules in an electronics manufacturing company

inadequate c-VA; OR_a = 2.6, 95% CI: 1.5–4.4, vs. CDW for low c-VA; and OR_a = 0.4, 95% CI: 0.4–0.5, vs. CDW for good c-VA. Besides, analysis results also showed that DSW (OR_a = 2, 95% CI: 2.0–3.6, vs. CDW), elevated blood sugar (OR_a = 1.4, 95% CI: 1.1–1.8) and female gender (OR_a = 1.3, 95% CI: 1.1–1.7) were independently associated with inadequate c-VA. Similarly, DSW (OR_a = 1.7, 95% CI: 1.02–2.9, vs. CDW) and elevated blood sugar (OR_a = 1.7, 95% CI: 1.2–2.5) were independently associated with low c-VA.

Finally, NSW (OR_a = 0.4, 95% CI: 0.4–0.5 vs. CDW), DSW (OR_a = 0.6, 95% CI: 0.5–0.6 vs. CDW), hyperglycemia (OR_a = 0.6, 95% CI: 0.5–0.7), female gender (OR_a = 0.7, 95% CI: 0.6–0.8) and hypertriglyceridemia (OR_a = 0.9, 95% CI: 0.8–0.99) were the inverse factor for workers possessing a good c-VA.

For all the shift workers in the head to head analysis, comparing between with and without nighttime work exposure (Table 4), significantly unfavorable c-VA was found among NSW, who had the OR_a = 1.3, 95% CI: 1.01–1.7, vs. DSW for inadequate c-VA, the OR_a = 1.5, 95% CI: 1.002–2.3, vs. DSW for low c-VA; and the OR_a = 0.8, 95% CI: 0.7–0.9, vs. DSW for good c-VA.

Table 4. Head to head multivariate analysis of visual acuity among employees with different work schedules (NSW vs. DSW) in an electronics manufacturing company

Visual acuity	OR_a (95% CI)	p
Inadequate	1.3 (1.010–1.7)	0.040
Low	1.5 (1.002–2.3)	0.048
Good	0.8 (0.700–0.9)	< 0.010

NSW – night-shift workers (12 h/night); DSW – day-shift workers (12 h/day).
Abbreviations as in Table 2 and 3.

DISCUSSION

To the best of our knowledge, this is the first large scale study illustrating that night workers have significantly lower visual acuity as compared to the daytime employees (CDW and DSW). Findings from this worker population could contribute to health policy development in similar workplaces. Additionally in this study, aging, elevated blood sugar and female gender were also found to be associated with inferior visual acuities. In terms of workplace health promotion and work fitness [15], visual health protection for the susceptible workers are desirable [16].

In this study, night-shift workers had significantly inferior c-VAs compared with the daytime workers. The workers exposed to night-shift work were also markedly less likely to process good visual acuity (Tables 1, 3 and 4). Symptomatically, dry eyes syndrome and visual fatigue, as reported in the research of night jobs, disturbed sleep and cleanroom [4,5,17], are associated with reduced visual function [18].

Shift workers, especially those working long hours, should be provided with appropriate resting periods to help recover from eye fatigue. Biopathologically, low visual acuity is highly correlated with adverse retina health condition [19], which may be affected by shift-works [7,8]. Since chronic circadian rhythm disruption may induce inflammatory reactions, a probable biological explanation for the reduced visual acuity of nighttime workers might be the inflammatory lesions on retina [20,21]. Melatonin, a circadian rhythm hormone, was shown to improve visual function via anti-inflammatory effects [22]. It will be interesting to test whether anti-inflammatory supplements may improve visual health among nighttime workers.

The prevalence of hyperglycemia in this young middle-aged worker population was 16.3% (Table 1); and high blood sugar is found to be associated with an increased risk of poor visual acuity among workers (Table 3). Hyperglycemia is a predisposing factor for retinal damage [23], successful control of hyperglycemia may slow down progression of retinopathy and improve visual acuity [24]. Considering visual health, blood sugar monitoring and control ought to be an important item in a workplace health promotion project.

This study found that with the increasing age, nighttime workers reached the outcome of inadequate or low visual acuity sooner than daytime workers (CDW and DSW) did (Figure 1). Although NSW were the youngest among all 3 subgroups, they did not have the better visual acuity (Table 1–4). A sharp decline in visual acuity of the nighttime workers aged over 40–45 years old was consistent with previous findings from observations of shift workers in many health aspects [25]. Age-specific decline in visual acuity had been confirmed [26,27] and circadian disruption accelerating the aging process was highly plausible [28,29]. In terms of occupational health and safety [4], visual function decline should be an important concern for the aging nighttime workforce.

Regarding the gender-related differences, these findings are similar to those of previous large-scale studies [30,31], showing that women employees have higher rates of decreased visual acuity than men employees do. Meanwhile, the relationship between sex hormone changes and visual function variations had been reported in healthy individuals [32]. Thus, individualized strategies in the visual health protection for both genders might be required in the future.

The main goal of large scale workplace health surveillance is usually for screening rather than for definite diagnosis. Hence, some potential limitations of our analysis need to be considered. Firstly, the precise diagnosis of visual deficiencies requires further evaluation from ophthalmologists. Secondly, these screening results did not necessarily represent the best-spectacle corrected visual acuity of workers, caution should be taken when applying our conclusions to the general population. Eye lens and fundus conditions, visual accommodation, intraocular pressure and other contributing factors should be also evaluated longitudinally in future investigations of nighttime workers. Certainly, more precise researches for mechanisms, interactions of each risk factor that influencing the visual acuity of night-shift workers must be conducted in the future.

CONCLUSIONS

Nighttime work is moderately associated with compromised visual acuity among the employees of this large electronics manufacturing company. Since atypical schedules are common in modern workplaces, we suggest that, when arranging long-term atypical work schedules, the employers and managers should evaluate and promote the visual health of nighttime workers.

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