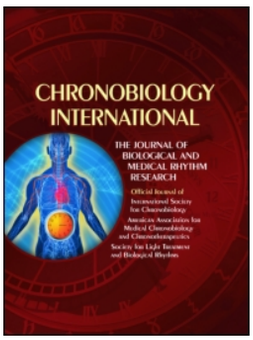

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Shift work and depressive symptoms: the mediating effect of vitamin D and sleep quality

Hwanjin Park[a], Byungsung Suh[a], and Soo-Jin Lee[b]

[a]Department of Occupational and Environmental Medicine, Kangbuk Samsung Hospital, Sungkyunkwan University School of Medicine, Seoul, Republic of Korea; [b]Department of Occupational and Environmental Medicine, College of Medicine, Hanyang University, Seoul, Republic of Korea

ABSTRACT

Shift work is associated with vitamin D level, sleep quality, and depressive symptoms. Vitamin D and sleep quality are also associated with depressive symptoms. The purpose of this study was to compare vitamin D level, sleep quality, and depressive symptoms between shift workers and daytime workers and analyze the mediating effect of vitamin D and sleep quality between shift work and depressive symptoms. Among those who participated in the Kangbuk Samsung Health Study in 2012 and 2014, 82,078 cases of full-time workers were analyzed. We evaluated their shift work, vitamin D level, sleep quality, and depressive symptoms with blood samples and questionnaires. Chi-square tests, t-tests, and path statistical analysis were performed. More depressive symptoms, lower vitamin D levels, and poorer sleep quality were associated with shift work. According to a path analysis, shift work had both a direct effect and an indirect effect on depressive symptoms, each mediated by sleep quality and vitamin D level. When a multigroup analysis was conducted for each sex, paths containing sleep quality were more significant in female shift workers than male shift workers; paths involving vitamin D did not differ between sexes. To assess depression risk in shift workers, evaluating vitamin D level and sleep quality is essential. Also, sleep problems are more prevalent in female compared to male shift workers with respect depression prevalence.

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shift work; depressive symptom; sleep quality; Vitamin D

Introduction

In the past several decades, the number of shift workers has greatly increased due to the subdivision of industrial structures and an increase in the service sector of the economy; a similar trend can also be seen in South Korea (Bae et al. 2017). With increases in the number of shift workers, the significance of the influence of shift work on health has also increased. Shift work is associated with sleep disorders (Agarwal et al., 2014); cancer (Akerstedt et al. 2015); chronic diseases such as diabetes (Gan et al. 2015); and cardiovascular diseases such as hypertension (Guo et al. 2013), stroke, and myocardial infarction (Vyas et al. 2012). Sleep issues in shift workers increase the risk of accidents (Dawson et al. 2011) and are also associated with job stress (Harma 2006) and depressive symptoms (Driesen et al. 2010). Although shift work directly disturbs the circadian rhythm and disrupts sleep, thereby leading to various health issues, shift work is considered necessary for the finely subdivided industrial structure; therefore, there is an increasing need to manage the health of shift workers (Hale et al. 1971).

Approximately 20% of required vitamin D is obtained through food; however, most vitamin D is produced endogenously by UVB exposure. Low vitamin D concentration is associated with various diseases, including autoimmune diseases, infectious diseases, osteoporosis, obesity, and diabetes (Holick 2007; Pearce and Cheetham 2010). Moreover, vitamin D deficiency is also related to cardiovascular diseases such as stroke and coronary artery disease (Wang et al. 2012) as well as various neurological diseases such as multiple sclerosis (Munger et al. 2006), Parkinson's disease (Knekt et al. 2010), and Alzheimer's disease (Littlejohns et al. 2014). Vitamin D deficiency also has known associations with cancer and respiratory disease mortality (Schottker et al. 2013), and its association with depression has

CONTACT Soo-Jin Lee sjlee@hanyang.ac.kr Department of Occupational and Environmental Medicine, College of Medicine, Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, Republic of Korea

been reported in multiple studies (Hoogendijk et al. 2008; Milaneschi et al. 2010; Pan et al. 2009).

Vitamin D receptors and activating enzymes are distributed in high concentrations in the hypothalamus and substantia nigra (Eyles et al. 2005), and damage to these areas is associated with depression (Tsopelas et al. 2011). Vitamin D receptor gene polymorphisms are associated with cognitive function disorders and depressive symptoms (Kuningas et al. 2009). Vitamin D increases the speed of neurotransmission and is also known to have antioxidative and neuroprotective effects (Buell and Dawson-Hughes 2008). Recent findings have suggested that inflammation has a key role in depression (Miller et al. 2009), and vitamin D has been found to influence depression by lowering inflammatory mediators (McCann and Ames 2008). As such, vitamin D influences neurological diseases, particularly depression, through various mechanisms.

Several studies have investigated the association between shift work and vitamin D. In a Japanese cross-sectional study conducted among indoor shift workers, no significant difference in vitamin D concentration was observed between daytime workers and rotating shift workers (Itoh et al. 2011b); an Italian cross-sectional study suggested that vitamin D concentrations were lower in shift workers than in non-shift workers (Romano et al. 2015). In a British study conducted on 45-year-old fixed shift workers, men did not have different vitamin D concentrations according to their shifts whereas women working night shifts had 8% lower vitamin D concentrations (Ward et al. 2011). Researches conducted thus far on shift work and vitamin D concentration had low sample sizes and are not consistent.

A systematic review has confirmed that shift workers have poor sleep quality (Booker et al. 2018), and vitamin D has been associated with sleep quality; in particular, when vitamin D was provided, sleep latency decreased whereas sleep efficiency and duration increased (Huang et al. 2013). The association between poor sleep quality and depressive symptoms has been found in many other groups as well (Skouteris et al. 2008, 2009).

Therefore, this study aimed to compare vitamin D concentration, sleep quality, and depressive symptoms between shift workers and non-shift workers using a large sample of medical examination data. Through pathway analysis, this study also aimed to elucidate the specific pathway through which shift work, vitamin D, and sleep quality influence depressive symptoms.

Materials and methods

Study population

The Kangbuk Samsung Health Study is a cohort of adults above 18 years of age who receive regular medical examinations every year or every two years at two hospital healthcare centers located in Seoul and Suwon. The results of annual or biennial examinations are added to the cohort. Approximately 80% are employees and their spouses at different companies that cover the cost of their examinations. The rest are those who voluntarily pay for the costs of examinations (Cho et al. 2018).

Among those who were examined at Kangbuk Samsung Hospital healthcare center and participated in the Kangbuk Samsung Health Study in 2012 and 2014, 211,269 cases of workers who worked for more than 40 hours per week were examined. Of these, 60,629 cases were missing vitamin D data; 7,784 were missing depression scale data; and shift work information was missing on 3,295 cases. All of these cases were excluded from the study, and some of these cases qualified for more than one exclusion criterion. Among the 144,210 cases remaining after exclusion, those that had changes in shift work information were excluded; subsequently, a total of 82,078 cases were analyzed. This study was approved by the Institutional Review Board at Kangbuk Samsung Hospital. Because only anonymous data without any identifiable personal information were used, prior consent was waived for the participants.

Depressive symptoms

The Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff 1977) was developed to diagnose and evaluate the severity of depressive symptoms, and its reliability has already been confirmed in multiple previous studies. This study used the Korean version of the Center for Epidemiologic Studies Depression Scale (Chon et al. 2001).

Quality of sleep

The Pittsburgh Sleep Quality Index (PSQI) (Buysse et al. 1989) is a reliable, standardized questionnaire measuring subjective sleep quality and quantitative sleep-wake parameters from the previous month. This index consists of 19 items in seven components, and the scores range between 0 and 21. Higher scores indicate a poorer sleep quality. CES-D and PSQI questionnaires are recorded on the web and the data are managed at Kangbuk Samsung health study center.

Shift work and vitamin D

Participants responded to the question, "In the past year, during which time of the day have you worked the most?" using one of the following options: "I work mostly during the day (between 6 AM and 6 PM)" and "I work during other hours." Vitamin D concentration was measured using total serum vitamin D level measured in ng/ml. Blood samples are collected from two health care centers, located in Seoul and Suwon. Subjects visited health care centers during the daytime at any season.

Statistical analysis

After comparing sex, age, vitamin D concentration, sleep quality, and depressive symptoms between shift and non-shift workers, a path model was established based on previous literature in order to explain the mediating paths between shift work and vitamin D level as well as PSQI and depressive symptoms. Subsequently, a path analysis was conducted to investigate the complex direct and indirect relationships between shift work, vitamin D concentration, sleep quality, and depressive symptoms. Next, a multigroup analysis was conducted for each sex to investigate differences between sexes. Basic statistical analyses were conducted with PASW Statistics for Windows, Version 18.0 (IBM Co., New York, USA), and the path analysis was conducted with SmartPLS 3.0.

Results

There was no significant differences in age, Vitamin D level, CES-D score and PSQI score between 82,078 cases and the excluded. Among 82,078 cases, 2,666 (3.2%) worked in shifts; and 80.8% were male and 19.2% female. The proportion of females was significantly higher in the shift workers (7.2%) than daytime workers (2.3%). The mean age of the shift workers was 35.8 years, which was significantly younger than that of the daytime workers (39.9 years). Vitamin D level was significantly higher in the daytime workers (17.02 ± 6.78) than shift workers (14.64 ± 5.99). CES-D and PSQI score were significantly higher in the shift workers (8.17 ± 8.12, 5.51 ± 2.65) than daytime workers (6.06 ± 6.62, 4.85 ± 2.20) (Table 1).

As explained in the Introduction, shift workers are known to have poorer sleep quality, and vitamin D level is known to be associated with this. Moreover, vitamin D level is also associated with sleep quality and depressive symptoms; PSQI score is related to depressive symptoms. Based on previous literature, a theoretical model was established for the analysis (Figure 1).

In SmartPLS modeling, Variance Inflation Factor value should be less than 5 for good model fit. According to the analysis, all inner VIF values were less than 5, indicating a lack of multicollinearity (Hair et al. 2014). In terms of effect size (r^2), the CES-D had a r^2 of 0.07, thereby explaining most of the variance of shift work. According to the blindfolding test, vitamin D, the CES-D, and the PSQI all had Q^2 values exceeding 0 (Sarstedt et al. 2014). Various path coefficients were significant. These findings indicated that the model had adequate predictive fit.

Shift work was significantly associated with depressive symptoms, sleep quality, and vitamin D level; its indirect effect on depressive symptoms was also significant, but its indirect effect on sleep quality was not significant. Vitamin D level and sleep quality were associated with depressive symptoms,

Table 1. General characteristics according to shift work (N = 82,078).

	Day worker (AM6~ PM6)	Shift worker	P value
Sex			<0.001
Men	64,818 (97.7)	1,538 (2.3)	
Women	14,594 (92.8)	1,128 (7.2)	
Age	39.88 ± 6.23	35.84 ± 6.31	<0.001
Total vitamin D	17.02 ± 6.78	14.64 ± 5.99	<0.001
CES-D score	6.06 ± 6.62	8.17 ± 8.12	<0.001
PSQI score	4.85 ± 2.20	5.51 ± 2.65	<0.001

Data are presented as n (%) or mean±standard deviation.
* P value by chi-square test, t-test.

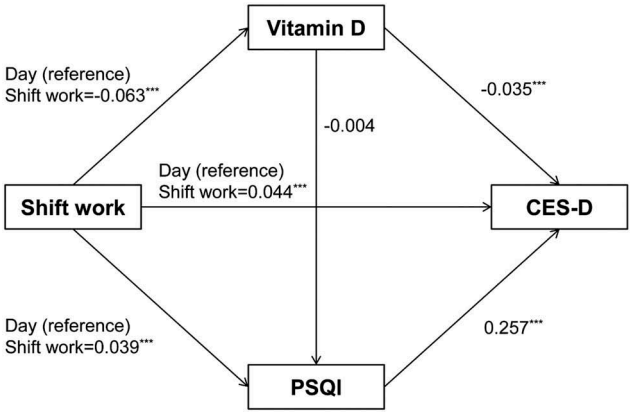

Figure 1. Results from path analyses for predicting the association CES-D score with shift work, PSQI and vitamin D (***P < 0.001).

but vitamin D level and sleep quality were not associated with each other (Table 2).

In order to assess the specific path of the indirect effect of shift work on depressive symptoms, bootstrapping was performed. Shift work was found to exert significant influences on depressive symptoms through two indirect paths. In particular, shift work increased depressive symptoms through the following paths: shift work -> sleep quality -> depressive symptoms and shift work -> vitamin D level -> depressive symptoms. The path including both vitamin D and sleep quality was not statistically significant (Table 3).

In order to investigate differences between sexes, a multigroup analysis was performed for each sex. Compared to the entire group, no significant changes in paths were observed in both females and males (Table 4).

The differences between females and males in the results of the path analysis were analyzed using the Welch-Satterthwaite test. The following paths were more significant in female shift workers than in male shift workers: shift work -> sleep quality, sleep quality -> depressive symptoms, and shift work -> depressive symptoms. The other paths involving vitamin D did not differ significantly between the sexes (Table 5).

Table 3. Specific indirect effects of shift work on CES-D score.

	β	se	T	P value
Shift work→PSQI→CES-D	0.010	0.001	8.782	<0.001
Shift work→VitD→PSQI→CES-D	0.000	0.000	1.247	0.213
Shift work→VitD→CES-D	0.002	0.000	8.992	<0.001
Shift work→VitD→PSQI	0.000	0.000	1.249	0.212

Discussion

Similar to previous research findings, this study found that shift workers have more depressive symptoms and poorer sleep quality. Vitamin D levels were significantly lower in shift workers than in daytime workers. According to a path analysis, shift work was found to have indirect and direct influences on depressive symptoms. Vitamin D and sleep quality also influenced depressive symptoms, and vitamin D did not have any direct influence on sleep quality. Whereas shift work directly influenced depressive symptoms, shift work also had indirect influences on depressive symptoms, each mediated by sleep quality and vitamin D.

Sleep issues are the most important health issue among shift workers. Shift work directly influences the normal chronobiological rhythm and decreases sleep quality (Santorek-Strumillo et al. 2012). Because shift workers work during hours that do not agree with their physiological or social circadian rhythm, these workers experience sleep difficulties (Monk 2000). Moreover, a decline in sleep quality is directly related to mortality (Akerstedt et al. 2002) and can also influence depression by decreasing the secretion of melatonin (Sallinen and Kecklund 2010). The correlation between sleep quality and depressive symptoms, which has

Table 2. Direct, indirect and total effects of Shift work, Vitamin D and PSQI on CES-D score.

	Direct effect				Indirect effects		Total effects	
	β	se	T	P value	β	P	β	P value
Shift work→PSQI	0.039	0.004	8.974	<0.001	0.001	0.212	0.040	<0.001
Shift work→Vitamin D	−0.063	0.003	19.130	<0.001			−0.063	<0.001
PSQI→CES-D	0.257	0.004	62.668	<0.001			0.257	<0.001
Vitamin D→PSQI	−0.004	0.003	1.252	0.211			−0.004	0.211
Vitamin D→CES-D	−0.035	0.003	9.967	<0.001	−0.001	0.212	−0.036	<0.001
Shift work→CES-D	0.044	0.004	10.165	<0.001	0.012	<0.001	0.056	<0.001

Table 4. Results from multi-group analysis for predicting the association CES-D score with shift work and vitamin D.

	Direct effect			Indirect effects		Total effects	
	β	T	P value	β	P value	β	P value
Female							
Shift work→PSQI	0.054	5.634	<0.001	−0.000	0.463	0.054	<0.001
Shift work→Vitamin D	−0.048	7.074	<0.001			−0.048	<0.001
PSQI→CES-D	0.242	28.853	<0.001			0.242	<0.001
Vitamin D→PSQI	0.006	0.747	0.455			0.006	0.455
Vitamin D→CES-D	−0.015	1.998	0.046	0.001	0.454	−0.014	<0.078
Shift work→CES-D	0.087	8.604	<0.001	0.014	<0.001	0.100	<0.001
Male							
Shift work→PSQI	0.029	6.234	<0.001	−0.000	0.811	0.029	<0.001
Shift work→Vitamin D	−0.038	10.252	<0.001			−0.038	<0.001
PSQI→CES-D	0.261	59.399	<0.001			0.261	<0.001
Vitamin D→PSQI	0.001	0.243	0.808			0.001	0.808
Vitamin D→CES-D	−0.014	3.647	<0.001	0.000	0.808	−0.013	0.001
Shift work→CES-D	0.009	2.281	0.023	0.008	<0.001	0.017	<0.001

Table 5. Results of Welch-Satterthwaite test for gender subgroup (Female vs Male).

	Direct effect		Indirect effects		Total effects	
	T	P value	T	P value	T	P value
Shift work→PSQI	2.381	0.017	0.601	0.548	2.363	0.018
Shift work→Vitamin D	1.289	0.197			1.289	0.197
PSQI→CES-D	2.056	0.040			2.056	0.040
Vitamin D→PSQI	0.568	0.570			0.568	0.570
Vitamin D→CES-D	0.204	0.838	0.552	0.581	0.068	0.946
Shift work→CES-D	7.181	<0.001	2.097	0.036	7.657	<0.001

already been established in a previous study (De Gennaro et al. 2004), was also found in the present study. This study found that shift work negatively influences sleep quality, thereby increasing depressive symptoms. Various measures, including melatonin, pharmacological treatment, caffeine, and naps were considered to maintain proper sleep quality in shift workers (Liira et al. 2014). However, no clear method of implementation for any of these measures has been suggested. Specific studies on such measures should be conducted in the future.

Vitamin D level was significantly lower in the shift workers than in the daytime workers. Vitamin D, which is a required liposoluble vitamin, is synthesized in the skin upon exposure to UVB; and this synthesis accounts for most of the daily requirement of vitamin D (Dusso et al. 2005). When changes in vitamin D levels because of food, vitamin D supplements, and use of sunbeds were comparatively analyzed, the use of sunbeds was found to be the factor that influenced vitamin D level the most (Brot et al. 2001). Shift work leads to less exposure to UVB compared to non-shift work, which could lead to differences in vitamin D level (Itoh et al. 2011b). Shift workers may be exposed less to sunlight outside of working hours, and this could greatly influence their vitamin D concentration.

Moreover, shift workers have a poorer diet than non-shift workers (PLoS Medicine Editors 2011), and this could lead to less vitamin D absorption from food (Itoh et al. 2011a). Shift workers tend to be more exposed to high-sugar and high-fat foods, including those sold in vending machines. Fish, egg, and dairy products, including milk and butter, are rich in vitamin D; but shift workers tend to prefer sweet foods that can be easily prepared (Wong et al. 2010). Moreover, owing to difficulties in adapting to changes in the circadian rhythm, a night shift leads to changes in dietary habits. Shift workers tend to consume snacks for sugar intake during night shifts, and this results in a decreased consumption of animal protein sources, which are important sources of vitamin D (Atkinson et al. 2008).

Many studies have investigated the correlation between vitamin D and depressive symptoms using the CES-D. Regardless of age, region, and race, low vitamin D levels are associated with depressive symptoms in healthy adults (Hoang et al. 2011), the elderly (Hoogendijk et al. 2008), and middle-aged adults (Pan et al. 2009). In particular, the association tends to be stronger in people with a past history of depression. This indicates that vitamin D levels should be closely monitored in shift workers who have a previous or current

history of depression. Vitamin D has neuroprotective effects through antioxidative actions and lowers inflammatory cytokines to suppress inflammation; these actions influence brain health and prevent depression (Hoang et al. 2011). Moreover, because low vitamin D levels may also predict the future occurrence of depression (Milaneschi et al. 2010), maintaining vitamin D levels at adequate levels in shift workers is an important factor for managing and preventing depression.

The US Institute Of Medicine recommends different age-based supplements for populations lacking vitamins (Ross et al. 2011). Although no specific guidelines or previous studies on shift workers deficient in vitamin D are available, vitamin D is certainly necessary. Further, vitamin D can help prevent depressive symptoms and cardiovascular diseases as well as breast cancer in female shift workers. A vitamin D level below 20 ng/ml is associated with the occurrence of and increased mortality from colorectal cancer, prostate cancer, and breast cancer (Holick 2007). Additionally, a Swedish cohort study and a Canadian case-control study indicated that UV exposure during adolescence decreases the occurrence of breast cancer in women (Anderson et al. 2011; Yang et al. 2011).

When a multigroup analysis was conducted for each sex to investigate differences between the sexes, the following paths were more significant in female shift workers than in male shift workers: shift work -> sleep quality, sleep quality -> depressive symptoms, and shift work -> depressive symptoms. In other words, female shift workers had more depressive symptoms than did male shift workers. In the general population, the prevalence of depression in women is known to be high (Angst et al. 2002). In non-shift worker group in this study, the CES-D score of women (10.48 ± 9.61) was significantly higher than that of men (6.47 ± 6.31). Depressive symptoms of women were consistently higher than that of men regardless of specific conditions. Although the paths involving vitamin D did not differ between sexes, the path through which shift work influences depressive symptoms through sleep quality differed between sexes. Female shift workers may have more difficulty falling asleep and more sleep issues than male shift workers (Admi et al. 2008). Moreover, because of high risk of mortality (Åkerstedt et al. 2004) and high level of fatigue (Åhsberg et al. 2000), females may also have lower shift work tolerance. Although some studies indicated no sex differences (Ansiau et al. 2008), systematic review suggested sex differences in shift work tolerance because of sleep issues (Saksvik et al. 2011). A similar finding was obtained in this study; therefore, managing sleep issues in female shift workers will assist in preventing depressive symptoms.

This study has several limitations. Because this study was conducted among East Asian individuals living at specific altitudes in the northern hemisphere, generalization of the findings to other populations is difficult. In latitudes above 40 degrees in the northern hemisphere, UVB exposure for vitamin D synthesis is thought to be insufficient between October and March (Holick 1995). Moreover, 6–8 weeks of delay are present between UVB exposure and vitamin D level changes (Lucas et al. 2005). Future studies, therefore, should consider the delay in time between seasonal changes in UVB exposure and vitamin D level. Shift work patterns were investigated not through objective data but through questions assessing shift work patterns in the past year, so individual bias may exist. This study also failed to consider individual sensitivity to shift work. The eveningness chronoype is more tolerant to shift work than the morningness chronotype (Saksvik et al. 2011). However, this study could not take these aspects into consideration. Nevertheless, more than 2,600 cases of full-time shift work were investigated; and this study also investigated the influence of shift work, vitamin D, and sleep quality on depressive symptoms in each sex.

According to a 10-year follow-up, shift work was associated with depressive symptoms as well as the occurrence of depression (Driesen et al. 2011). In this study shift work was directly associated with depressive symptoms and was found to indirectly influence depressive symptoms through sleep quality and vitamin D level. Depression is one of the most common diseases in workers and is most frequently associated with work-related illness or long-term sick leave (Henderson et al. 2005; Lexis et al. 2009). Depression also has a great social cost. Therefore, there is an urgent need to

manage depression in workers (Ustun et al. 2004). This study found that vitamin D and sleep quality partially mediate the depressive symptoms of shift workers through their respective paths. This indicates that other factors can influence the relationship between shift work and depression. In order to establish policies to manage and prevent depression in shift workers, various other related factors should be investigated.

Declaration of Interest statement

We have no conflict of interest to declare.

References

Admi H, Tzischinsky O, Epstein R, Herer P, Lavie P. 2008. Shift work in nursing: is it really a risk factor for nurses' health and patients' safety? Nurs Econ. 26:250–257.

Agarwal M, Sharma K, Jamal M. 2014. Shift work sleep disorder and complications. J Sleep Disord Ther. 3:154.

Åhsberg E, Kecklund G, Åkerstedt T, Gamberale F. 2000. Shiftwork and different dimensions of fatigue. Int J Ind Ergon. 26:457–465.

Akerstedt T, Fredlund P, Gillberg M, Jansson B. 2002. A prospective study of fatal occupational accidents – relationship to sleeping difficulties and occupational factors. J Sleep Res. 11:69–71.

Åkerstedt T, Kecklund G, Johansson S-E. 2004. Shift work and mortality. Chronobiol Int. 21:1055–1061.

Akerstedt T, Knutsson A, Narusyte J, Svedberg P, Kecklund G, Alexanderson K. 2015. Night work and breast cancer in women: a Swedish cohort study. BMJ Open. 5: e008127.

Anderson LN, Cotterchio M, Kirsh VA, Knight JA. 2011. Ultraviolet sunlight exposure during adolescence and adulthood and breast cancer risk: a population-based case-control study among Ontario women. Am J Epidemiol. 174:293–304.

Angst J, Gamma A, Gastpar M, Lépine J-P, Mendlewicz J, Tylee A. 2002. Gender differences in depression. Eur Arch Psychiatry Clin Neurosci. 252:201–209.

Ansiau D, Wild P, Niezborala M, Rouch I, Marquie JC. 2008. Effects of working conditions and sleep of the previous day on cognitive performance. Appl Ergon. 39:99–106.

Atkinson G, Fullick S, Grindey C, Maclaren D. 2008. Exercise, energy balance and the shift worker. Sports Med. 38:671–685.

Bae MJ, Song YM, Shin JY, Choi BY, Keum JH, Lee EA. 2017. The association between shift work and health behavior: findings from the Korean national health and nutrition examination survey. Korean J Fam Med. 38:86–92.

Booker LA, Magee M, Rajaratnam SMW, Sletten TL, Howard ME. 2018. Individual vulnerability to insomnia, excessive sleepiness and shift work disorder amongst healthcare shift workers. A systematic review. Sleep Med Rev. 41:220–233.

Brot C, Vestergaard P, Kolthoff N, Gram J, Hermann AP, Sorensen OH. 2001. Vitamin D status and its adequacy in healthy Danish perimenopausal women: relationships to dietary intake, sun exposure and serum parathyroid hormone. Br J Nutr. 86(Suppl 1):S97–103.

Buell JS, Dawson-Hughes B. 2008. Vitamin D and neurocognitive dysfunction: preventing "D"ecline? Mol Aspects Med. 29:415–422.

Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. 1989. The pittsburgh sleep quality index: a new instrument for psychiatric practice and research. Psychiatry Res. 28:193–213.

Cho A, Chang Y, Ahn J, Shin H, Ryu S. 2018. Cigarette smoking and thyroid cancer risk: a cohort study. Br J Cancer. 119:638–645.

Chon K, Choi S, Yang B. 2001. Integrated adaptation of CES-D in Korea. Korean J Health Psychol. 6:59–76.

Dawson D, Ian Noy Y, Harma M, Akerstedt T, Belenky G. 2011. Modelling fatigue and the use of fatigue models in work settings. Accid Anal Prev. 43:549–564.

De Gennaro L, Martina M, Curcio G, Ferrara M. 2004. The relationship between alexithymia, depression, and sleep complaints. Psychiatry Res. 128:253–258.

Driesen K, Jansen NW, Kant I, Mohren DC, van Amelsvoort LG. 2010. Depressed mood in the working population: associations with work schedules and working hours. Chronobiol Int. 27:1062–1079.

Driesen K, Jansen NW, van Amelsvoort LG, Kant I. 2011. The mutual relationship between shift work and depressive complaints–a prospective cohort study. Scand J Work Environ Health. 37:402–410.

Dusso A, Brown AJ, Slatopolsky E. 2005. Vitamin D and renal failure. In: Feldman D, Glorieux FH, Pike JW, editors. Vitamin D. San Diego, CA: Elsevier Academic Press; p. 1313–1338.

Eyles DW, Smith S, Kinobe R, Hewison M, McGrath JJ. 2005. Distribution of the vitamin D receptor and 1 alpha-hydroxylase in human brain. J Chem Neuroanat. 29:21–30.

Gan Y, Yang C, Tong X, Sun H, Cong Y, Yin X, Li L, Cao S, Dong X, Gong Y, et al. 2015. Shift work and diabetes mellitus: a meta-analysis of observational studies. Occup Environ Med. 72:72–78.

Guo Y, Liu Y, Huang X, Rong Y, He M, Wang Y, Yuan J, Wu T, Chen W. 2013. The effects of shift work on sleeping quality, hypertension and diabetes in retired workers. PLoS One. 8:e71107.

Hair JF, Black WC, Babin BJ, Anderson RE. 2014. Multivariate data analysis. Upper Saddle River (NJ): Prentice Hall.

Hale HB, Williams EW, Smith BN, Melton CE Jr. 1971. Neuroendocrine and metabolic responses to intermittent night shift work. Aerosp Med. 42:156–162.

Harma M. 2006. Workhours in relation to work stress, recovery and health. Scand J Work Environ Health. 32:502–514.
Henderson M, Glozier N, Holland Elliott K. 2005. Long term sickness absence. BMJ. 330:802–803.
Hoang MT, Defina LF, Willis BL, Leonard DS, Weiner MF, Brown ES. 2011. Association between low serum 25-hydroxyvitamin D and depression in a large sample of healthy adults: the Cooper Center longitudinal study. Mayo Clin Proc. 86:1050–1055.
Holick MF. 1995. Environmental factors that influence the cutaneous production of vitamin D. Am J Clin Nutr. 61:638S–645S.
Holick MF. 2007. Vitamin D deficiency. N Engl J Med. 357:266–281.
Hoogendijk WJ, Lips P, Dik MG, Deeg DJ, Beekman AT, Penninx BW. 2008. Depression is associated with decreased 25-hydroxyvitamin D and increased parathyroid hormone levels in older adults. Arch Gen Psychiatry. 65:508–512.
Huang W, Shah S, Long Q, Crankshaw AK, Tangpricha V. 2013. Improvement of pain, sleep, and quality of life in chronic pain patients with vitamin D supplementation. Clin J Pain. 29:341–347.
Itoh H, Mori I, Matsumoto Y, Maki S, Ogawa Y. 2011a. Vitamin D deficiency and seasonal and inter-day variation in circulating 25-hydroxyvitamin D and parathyroid hormone levels in indoor daytime workers: a longitudinal study. Ind Health. 49:475–481.
Itoh H, Weng Z, Saito H, Ogawa Y, Nakayama K, Hasegawa-Ohira M, Morimoto K, Maki S, Takahashi M. 2011b. Association between night-shift work and serum 25-hydroxyvitamin D levels in Japanese male indoor workers: a cross-sectional study. Ind Health. 49:658–662.
Knekt P, Kilkkinen A, Rissanen H, Marniemi J, Saaksjarvi K, Heliovaara M. 2010. Serum vitamin D and the risk of Parkinson disease. Arch Neurol. 67:808–811.
Kuningas M, Mooijaart SP, Jolles J, Slagboom PE, Westendorp RG, van Heemst D. 2009. VDR gene variants associate with cognitive function and depressive symptoms in old age. Neurobiol Aging. 30:466–473.
Lexis MA, Jansen NW, van Amelsvoort LG, van den Brandt PA, Kant I. 2009. Depressive complaints as a predictor of sickness absence among the working population. J Occup Environ Med. 51:887–895.
Liira J, Verbeek JH, Costa G, Driscoll TR, Sallinen M, Isotalo LK, Ruotsalainen JH. 2014. Pharmacological interventions for sleepiness and sleep disturbances caused by shift work. Cochrane Database Syst Rev. 8:CD009776.
Littlejohns TJ, Henley WE, Lang IA, Annweiler C, Beauchet O, Chaves PH, Fried L, Kestenbaum BR, Kuller LH, Langa KM, et al. 2014. Vitamin D and the risk of dementia and Alzheimer disease. Neurology. 83:920–928.
Lucas JA, Bolland MJ, Grey AB, Ames RW, Mason BH, Horne AM, Gamble GD, Reid IR. 2005. Determinants of vitamin D status in older women living in a subtropical climate. Osteoporos Int. 16:1641–1648.
McCann JC, Ames BN. 2008. Is there convincing biological or behavioral evidence linking vitamin D deficiency to brain dysfunction? FASEB J. 22:982–1001.
Milaneschi Y, Shardell M, Corsi AM, Vazzana R, Bandinelli S, Guralnik JM, Ferrucci L. 2010. Serum 25-hydroxyvitamin D and depressive symptoms in older women and men. J Clin Endocrinol Metab. 95:3225–3233.
Miller AH, Maletic V, Raison CL. 2009. Inflammation and its discontents: the role of cytokines in the pathophysiology of major depression. Biol Psychiatry. 65:732–741.
Monk TH. 2000. What can the chronobiologist do to help the shift worker? J Biol Rhythms. 15:86–94.
Munger KL, Levin LI, Hollis BW, Howard NS, Ascherio A. 2006. Serum 25-hydroxyvitamin D levels and risk of multiple sclerosis. JAMA. 296:2832–2838.
Pan A, Lu L, Franco OH, Yu Z, Li H, Lin X. 2009. Association between depressive symptoms and 25-hydroxyvitamin D in middle-aged and elderly Chinese. J Affect Disord. 118:240–243.
Pearce SH, Cheetham TD. 2010. Diagnosis and management of vitamin D deficiency. BMJ. 340:b5664.
PLoS Medicine Editors. 2011. Poor diet in shift workers: a new occupational health hazard? PLoS Med. 8:e1001152.
Radloff LS. 1977. The CES-D scale a self-report depression scale for research in the general population. Appl Psychol Meas. 1:385–401.
Romano A, Vigna L, Belluigi V, Conti DM, Barberi CE, Tomaino L, Consonni D, Riboldi L, Tirelli AS, Andersen LL. 2015. Shift work and serum 25-OH vitamin D status among factory workers in Northern Italy: cross-sectional study. Chronobiol Int. 32:842–847.
Ross AC, Taylor CL, Yaktine AL, Del Valle HB. 2011. Dietary reference intakes for calcium and vitamin D. Washington, DC: National Academies Press.
Saksvik IB, Bjorvatn B, Hetland H, Sandal GM, Pallesen S. 2011. Individual differences in tolerance to shift work–a systematic review. Sleep Med Rev. 15:221–235.
Sallinen M, Kecklund G. 2010. Shift work, sleep, and sleepiness - differences between shift schedules and systems. Scand J Work Environ Health. 36:121–133.
Santorek-Strumillo E, Zawilska JB, Misiak P, Jablonski S, Kordiak J, Brocki M. 2012. [Influence of the shift work on circadian-rhythms compare survey on health service employees and policemen]. Przegl Lek. 69:103–106.
Sarstedt M, Ringle CM, Smith D, Reams R, Hair JF Jr. 2014. Partial least squares structural equation modeling (PLS-SEM): A useful tool for family business researchers. J Fam Business Strategy. 5:105–115.
Schottker B, Haug U, Schomburg L, Kohrle J, Perna L, Muller H, Holleczek B, Brenner H. 2013. Strong associations of 25-hydroxyvitamin D concentrations with all-cause, cardiovascular, cancer, and respiratory disease mortality in a large cohort study. Am J Clin Nutr. 97:782–793.
Skouteris H, Germano C, Wertheim EH, Paxton SJ, Milgrom J. 2008. Sleep quality and depression during pregnancy: a prospective study. J Sleep Res. 17:217–220.

Skouteris H, Wertheim EH, Germano C, Paxton SJ, Milgrom J. 2009. Assessing sleep during pregnancy: a study across two time points examining the Pittsburgh sleep quality index and associations with depressive symptoms. Womens Health Issues. 19:45–51.

Tsopelas C, Stewart R, Savva GM, Brayne C, Ince P, Thomas A, Matthews FE, Medical research council cognitive F, Ageing S. 2011. Neuropathological correlates of late-life depression in older people. Br J Psychiatry. 198:109–114.

Ustun TB, Ayuso-Mateos JL, Chatterji S, Mathers C, Murray CJ. 2004. Global burden of depressive disorders in the year 2000. Br J Psychiatry. 184:386–392.

Vyas MV, Garg AX, Iansavichus AV, Costella J, Donner A, Laugsand LE, Janszky I, Mrkobrada M, Parraga G, Hackam DG. 2012. Shift work and vascular events: systematic review and meta-analysis. BMJ. 345:e4800.

Wang L, Song Y, Manson JE, Pilz S, März W, Michaëlsson K, Lundqvist A, Jassal SK, Barrett-Connor E, Zhang C. 2012. Circulating 25-hydroxy-vitamin D and risk of cardiovascular disease a meta-analysis of prospective studies. Circ Cardiovasc Qual Outcomes. 5:819–829.

Ward M, Berry DJ, Power C, Hypponen E. 2011. Working patterns and vitamin D status in mid-life: a cross-sectional study of the 1958 British birth cohort. Occup Environ Med. 68:902–907.

Wong H, Wong MC, Wong SY, Lee A. 2010. The association between shift duty and abnormal eating behavior among nurses working in a major hospital: a cross-sectional study. Int J Nurs Stud. 47:1021–1027.

Yang L, Veierod MB, Lof M, Sandin S, Adami HO, Weiderpass E. 2011. Prospective study of UV exposure and cancer incidence among Swedish women. Cancer Epidemiol Biomarkers Prev. 20:1358–1367.