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REGULAR ARTICLE

The relationships of sleep duration and mental health with electrocardiographic findings: a retrospective-cohort study in Okinawa, Japan

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Abstract

Objectives Sleep disorders and psychological stress have become major concerns as health risks in modern Japanese society. Chronic sleep deprivation could lead to physical and mental exhaustion, which could affect the circulatory condition. In this study, we have investigated the effects of long-term sleep problems and mental health conditions on abnormal ECG findings from the standpoint of community health.

Methods Data were obtained from the records of community physical checkups conducted in a town in Okinawa from 1993 to 2001. Data regarding average sleep duration and the 12-item version of the general health questionnaire (GHQ) were also collected at the community physical checkups. In order to compute the odds ratio of electrocardiographic (ECG) findings according to mental health condition and sleep duration, we conducted multivariate analysis using logistic regression maneuvers.

Results There was a significant difference of average GHQ scores according to sleep duration, with shorter sleep duration ($\leq$6 h) correlating with poorer GHQ and longer sleep duration ($\geq$8 h) correlating with healthier GHQ ($p < 0.05$). In the multivariate logistic regression analysis among subjects with poorer GHQ, shorter sleep duration showed significantly high odds ratio (OR = 7.14) for abnormal ECG findings.

Conclusions The present study suggested that the mental health condition appears to impact ECG results indirectly through its strong association with sleep duration and provided ground for suggestion that mental health items to be included in community physical checkup examination items.

Keywords Sleep · Mental health · Retrospective-cohort study · Electrocardiographic findings · Circulatory condition

Introduction

Sleep disorders and excessive stress have become major concerns as health risks in modern Japanese society as well as cardiovascular diseases. Japan recorded more than 30,000 suicides per year for 9 years in a row in 2006 [1]. It is reported that one in five Japanese has some sort of sleep disorder [2].

However, mental health condition examinations are rarely done for community residents, since they are not the mandatory examination items under the Health and Medical Service Law for the Elderly (HMSLE).

Although the relationship between acute sleep deprivation and increased cardiovascular diseases has been reported in previous studies [3], there are few studies addressing the relationship among chronic sleep deprivation, mental health condition and cardiovascular diseases.

In this study, we have investigated the relationship among long-term sleep problems, mental health conditions and abnormal ECG findings from the standpoint of

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community health. Our hypothesis is that chronic sleep problems and poor mental health conditions could be a risk factor for cardiovascular diseases. We thought that those with poor mental health will develop sleep disorders, and as a result, develop more cardiovascular diseases.

Materials and methods

Study population

The Department of Preventive Medicine and Public Health, School of Medicine, Kyorin University, has conducted community physical checkups every year since 1982 in a town in Okinawa in accordance with the HMSLE. In 1995, the population of this town was 11,086 (males 5,418, females 5,568). All residents over the age of 40 who do not have the opportunity to take physical checkups provided by their employers were invited to take this community physical checkups. In addition to the physical examination items required under the HMSLE, some items are added by the department. One of the items added by the department is a mental health screening test, which was administered in 1995, 1997 and 1999.

The study population comprises 1,076 residents (aged 39–83, mean age at baseline 62.1 ± 12.9, males: 354, mean age 63.8 ± 12.0, females: 722, mean age 61.3 ± 13.3) who participated in the community physical checkups in 1993. Of the 1,076 subjects, 871 had ECG results within normal limits, 155 had ECG findings that required further examination or treatment, and 50 did not participate in the ECG examination. We also collected baseline data regarding the mental health condition and lifestyle of the subjects by interview. Previous study indicated that some long-term lifestyle patterns such as smoking or drinking are coronary risk factors [4]. Therefore, information about lifestyle, including sleep duration, smoking status and drinking habits, was obtained by trained health professionals using a lifestyle questionnaire. Four hundred and twenty-four out of 871 who had ECG within normal limits in 1993 attended the community physical checkups in 2001. Out of the 424, we had completed data from 318 subjects (mean age 62.7 ± 8.5, males: 105, mean age 64.4 ± 8.3, females: 213, mean age 61.8 ± 8.6), which formed the basis of our analysis described below.

Definitions of variables

ECG findings

ECG findings were classified into six categories, which consisted of: normal, slight abnormality, abnormality A, abnormality B, abnormality C and others, each as defined in the National Survey of Circulatory Disorders of 1990. According to Kawakubo [5], slight abnormality and abnormality A and B have cardiovascular risk, but do not automatically indicate further examination. From the standpoint of preventive medicine, we divided the above six categories into two categories of ‘no findings’ and ‘findings.’ For ‘no findings,’ we used the same classification as the National Survey of Circulatory Disorders. ‘Findings’ consisted of slight abnormality, abnormality A, abnormality B, abnormality C and others.

Sleep duration

Based on the lifestyle questionnaires collected in 1993, we categorized the sleep duration into three categories ($\leq$6, 7 and $\geq$8 h). All responses were in whole numbers or in fractions of one-half (0.5), and we rounded upward those responses that were not in whole numbers.

Mental health

Since we did not have GHQ records at the 1993 community physical checkups, we used the next available GHQ data collected from each subject after 1993 (204 subjects from 1995, 94 from 1997, 20 from 1999). To measure mental health condition, we used the 12-item version of the general health questionnaire (GHQ) [6–8]. The rating method on the 12-item version of the GHQ was 0-0-1-1 instead of the Likert scale of 0-1-2-3 [9]. The ratings were summed to a global score (range 0–12); a higher score represents more psychiatric morbidity. We categorized the GHQ results as follows: healthy, GHQ <3.0; unhealthy, GHQ $\geq$3.0. The recent studies suggest that the best cut-off point of GHQ to screen for psychiatric morbidity is 3/4 [10, 11]. However, the GHQ $\geq$4.0 was rare in our subjects and could not stand the statistical analysis; we chose 2/3 as a cutoff point.

Smoking

Based on the lifestyle questionnaire collected in 1993, we categorized smoking habit as follows: (1) never smoked or quit smoking and (2) currently smoking.

Problematic drinking

Based on the score of CAGE [12, 13], in the lifestyle questionnaires collected in 1993, we categorized problematic drinking as follows: (1) problem with drinking and (0) no problem with drinking. The impact of alcohol on human beings from a psychological and physical standpoint depends on each person’s tolerance level. Tolerance level varies from person to person, and it could also change for the same person over time as a result of repeated alcohol usage. Therefore, in this study, we decided to use the measurement for problematic drinking called 'CAGE' as opposed to quantity of alcohol intake as a risk factor for cardiovascular disease.

Items from the physical examination included age, height, weight, systolic blood pressure (SBP), diastolic blood pressure (DBP), serum total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and triglyceride (TG), which were measured through standard methods in 1993. Body mass index (BMI) was calculated by the following equation: (weight in kilograms)/(height in meters)^2.

Data analysis

We conducted statistical analysis as follows:

1. We computed the average scores of all parameters at baseline according to sleep duration. One-way analysis of variance (ANOVA) was performed for age, BMI, SBP, DBP, TC, TG, HDL-C, ECG and GHQ to test the difference among three sleep duration categories. Since our initial analysis showed that age and sleep have a significant relationship, we adjusted the age and performed the ANOVA again.
2. In order to identify the risk factors for abnormal ECG findings, we computed odds ratios (ORs) through multivariate logistic regression analysis, using ECG data collected in 2001 as the dependent variable, and age, BMI, SBP, DBP, TC, HDL-C, TG, CAGE, sleep duration, GHQ and smoking status as independent variables. As for referent categories in the calculation of OR, we used 7 h per night for sleep duration, less than 25 for BMI, less than 140 mmHg for SBP, less than 90 mmHg for DBP, less than 220 mg/dl for TC, less than 150 mg/dl for TG, more than 40 mg/dl for HDL-C, less than 3.0 for GHQ, 0 for CAGE, and 1 for smoking.
3. Lastly, we selected subjects whose GHQ was poor ($\geq$3) as well as subjects whose GHQ was healthy (<3) and computed ORs respectively similarly to the above. This analysis was performed in order to conduct comparative analysis of risk factors of abnormal ECG findings among GHQ poor scorers and better scorers. We wanted to test our hypothesis that those with poor mental health will develop sleep disorders, and as a result, develop more cardiovascular diseases.

Statistical analysis was performed by the SPSS® version 12.0J for Windows (SPSS® Inc., 2003).

Participants gave written informed consent at the time of follow-up ascertainment.

This study was approved by the ethics review committee of the School of Medicine, Kyorin University.

Results

At the time of follow-up in 1993, 128 (males 33, females 95) out of 318 subjects had abnormal ECG findings.

Table 1 shows the baseline characteristics of risk factors for abnormal ECG findings and GHQ according to sleep duration in 1993. There were significant differences among average GHQ scores by sleep, shorter sleep duration ($\leq$6) showing poorer GHQ and longer sleep duration ($\geq$8) showing the healthier GHQ ($p < 0.05$). The mean age also tended to increase as sleep duration increased ($p < 0.01$). Therefore, we re-computed the p for trend after age

Table 1 Baseline characteristics of risk factors for abnormal ECG findings and GHQ according to sleep duration in 1993

Characteristics	Sleep duration (h/day)			p for trend	Age-adjusted p for trend
	$\leq$6	7	$\geq$8		
n	91	120	107		
Age, mean	60.1 ± 7.7	63.0 ± 8.9	64.3 ± 8.5	0.002*	–
BMI, mean	24.0 ± 3.1	24.1 ± 3.4	23.6 ± 3.2	0.383	0.49
SBP, mean (mmHg)	133.4 ± 18.1	132.7 ± 15.0	132.9 ± 16.0	0.960	0.73
DBP, mean (mmHg)	79.7 ± 10.1	79.1 ± 9.9	79.0 ± 9.1	0.853	0.86
TC, mean (mg/dl)	208.9 ± 33.6	209.7 ± 31.7	203.4 ± 34.7	0.311	0.24
HDL-C, mean (mg/dl)	55.2 ± 12.6	56.3 ± 13.9	55.9 ± 13.1	0.847	0.86
TG, mean (mg/dl)	166.4 ± 111.6	172.5 ± 99.4	164.2 ± 131.0	0.858	0.84
GHQ, mean	1.85 ± 2.07	1.29 ± 1.70	1.26 ± 1.58	0.035*	0.04*

n number of subjects, *BMI* body mass index (calculated as weight in kilograms divided by the square of height in meters), *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *TC* total cholesterol, *HDL-C* high-density lipoprotein cholesterol, *TG* serum triglyceride, *GHQ* general health questionnaire

*Significant when $p < 0.05$

adjustment. The p for trend for GHQ was still significant ($p < 0.05$).

In multivariate analysis using logistic regression as shown in Table 2, we found a significant relationship ($p < 0.05$) between baseline sleep duration and abnormal ECG findings at follow-up examination in 2001. The OR of sleep duration seemed to be on the U curve, namely, shorter or longer than 7 h of sleep duration (referent category) showed higher ORs. We expected a significant relationship between GHQ and abnormal ECG findings; however, as shown in Table 2, poor GHQ scores did not indicate abnormal ECG findings. The degree of fitting of the model according to Nagelkerke R square was 7.4%.

Table 3 shows the result of multivariate logistic regression analysis for abnormal ECG findings among subjects with GHQ ≥3 and GHQ <3. In the GHQ ≥3 group, the shorter sleep duration (≤6 h) showed significantly higher risk for abnormal ECG results (OR = 7.14, $p < 0.05$). Similar to Table 2, the OR of sleep duration shows a U-shaped curve. In the GHQ <3 group, the shorter sleep duration (≤6 h) did not show significantly higher risk for abnormal ECG results (OR = 1.454, $p = 0.282$). The degree of fitting of the model according to Nagelkerke R square was 34.4%.

Discussion

In this retrospective cohort study, our hypothesis that chronic sleep problems and poor mental health conditions could be a risk factor for cardiovascular diseases was not supported. However, we found that there was a significantly different trend for mental health condition with respect to sleep duration (cf. Table 1). Further, the study suggested that shorter sleep duration could be a risk factor for abnormal ECG findings and that adequate sleep duration (7 h) was associated with less risk for abnormal ECG findings (cf. Table 2).

Our study in part supported the previous studies indicating that 7 h of sleep is the appropriate sleep duration for longevity and lower risk for coronary disease [14]. It also concurred with many previous studies that proved the association between sleep duration and physical health. One of the largest studies in this topic is by Ayas, a cohort study among 71,617 female health professionals aged 45–65. Ayas concluded that short and long self-reported sleep durations are independently associated with a modestly increased risk of coronary events. Tochikubo et al. [15] reported the relation between lack of sleep and high blood pressure. Kojima et al. [16] conducted a 12-year prospective study of residents of Shirakawago aged 20–67,

Table 2 Odds ratio of abnormal ECG findings (the results of multivariate logistic regression analysis)

Factor	*n* (ECG findings)	OR	95% CI	*p*
Age				
≤50	21 (12)	1.00	–	–
50–60	99 (40)	1.59	0.57–4.40	0.368
60–70	139 (58)	1.46	0.53–4.01	0.461
>70	59 (18)	2.66	0.87–8.09	0.083
Sex				
Male	105 (33)	1.00	–	–
Female	213 (95)	0.49	0.19–1.26	0.140
BMI				
<25	212 (87)	1.00	–	–
≥25	106 (41)	1.07	0.63–1.81	0.797
SBP				
<140	188 (80)	1.00	–	–
≥140	130 (48)	1.06	0.60–1.88	0.825
DBP				
<90	253 (103)	1.00	–	–
≥90	65 (25)	0.94	0.47–1.90	0.879
TC				
≤220	212 (85)	1.00	–	–
>220	106 (43)	0.99	0.58–1.68	0.989
HDL-C				
<40	30 (9)	1.23	0.50–3.00	0.640
≥40	288 (119)	1.00	–	–
TG				
<150	186 (82)	1.00	–	–
≥150	132 (46)	1.24	0.89–2.46	0.124
CAGE[a]				
0	227 (96)	1.00	–	–
≥1	91 (32)	0.67	0.26–1.72	0.411
Sleep (h/day)				
≤6	91 (32)	1.87	1.02–3.43	0.041*
7	107 (49)	1.00	–	–
≥8	120 (47)	1.23	0.70–2.17	0.460
GHQ				
<3	253 (100)	1.00	–	–
≥3	65 (28)	0.87	0.48–1.56	0.647
Smoking[b]				
1	284 (119)	1.00	–	–
2	34 (9)	1.75	0.74–4.11	0.196

OR odds ratio, *CI* confidence interval, *BMI* body mass index (calculated as weight in kilograms divided by the square of height in meters), *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *TC* total cholesterol, *HDL-C* high-density lipoprotein cholesterol, *TG* serum triglyceride, *GHQ* general health questionnaire

[a] CAGE, 0 no drinking problem, ≥1 drinking problem

[b] Smoking, 1 never smoke, quit smoking, 2 smoking

*Significant when $p < 0.05$

Table 3 Odds ratio of abnormal ECG findings for subjects with GHQ ≥3 and subjects with GHQ <3 (the results of multivariate logistic regression analysis)

Factor	*n* (ECG findings)	OR	95% CI	*p*
GHQ ≥ 3				
Sleep (h/day)				
≤6	23 (7)	7.14	1.24–41.12	0.028*
7	18 (11)	1.00	–	–
≥8	24 (10)	2.81	0.58–13.46	0.197
GHQ < 3				
Sleep (h/day)				
≤6	96 (37)	1.454	0.736–2.872	0.282
7	68 (25)	1.00	–	–
≥8	89 (38)	1.039	0.736–1.965	0.907

OR odds ratio, *CI* confidence interval. Factors adjusted: *BMI* body mass index (calculated as weight in kilograms divided by the square of height in meters), *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *TC* total cholesterol, *HDL-C* high-density lipoprotein cholesterol, *TG* serum triglyceride, *GHQ* general health questionnaire

CAGE, 0 no drinking problem, ≥1 drinking problem

Smoking, 1 never smoke, quit smoking, 2 smoking

*Significant when $p < 0.05$

which indicated the relation between sleep duration and mortality rate. Amagai's cohort study indicated that men sleeping less than 6 h/day and women sleeping 9 h/day or more had significantly higher risk of death than those sleeping 7–7.9 h/day [17]. Kripke et al. [18] conducted a prospective study of 1.1 million men and women regarding sleep duration and mortality, and concluded that those who slept 7 h have the longest longevity.

Many clinical studies have explained biological mechanisms between mental health condition and cardiovascular disease. For example, stress is indicated to be an important trigger of arrhythmia through sympathetic nervous activity [19]. Other studies suggested the association between myocardial infarction and stress [3]. Psychological stress can cause thrombi through the sympathetic nervous system in the short run and can lead to arteriosclerosis in the long run. The study by Tanabe indicated the association among acute fatigue, acute sleep deprivation and acute myocardial infarction [20]. There are studies that explained the association between stress-prone personality and risk of coronary heart disease [21–24]. In addition, the results of previous studies explained the positive association between mental health and cardiovascular disease [25–27].

One of the limitations of this study is the simplicity of the mental health condition test. The 12-item GHQ is a rather crude tool to measure the subtleties of the mental health condition. Since our subjects are volunteer participants whose average age is over 60, it was necessary to make the questionnaires as brief and casual as possible to increase the response rate. In future studies, more comprehensive tools, such as the Minnesota Multiphasic Personality Inventory (MMPI), Cornell Medical Index (CMI), Beck Depression Inventory (BDI-II) or State Trait Anxiety Inventory (STAI), would provide further analysis regarding which specific mental health symptoms or even personality characteristics have a stronger association with cardiovascular disease and sleep duration. One of the other limitations of this study is the demographic uniqueness of residents in Okinawa. Based on the previous epidemiological study, residents in this town in Okinawa are known for having healthier cerebral-vascular conditions than the average Japanese population, although modern lifestyles and diets have presented them with health challenges lately [28]. In order to validate the reliability of our results, a larger geographical study is expected in the future. We also recognize the limitation of our study in that we could not analyze the association of sleep duration and more details of ECG results, such as abnormal Q-QS findings, ST depression, T abnormality or arrhythmia [29]. Unfortunately, our population size was not large enough to conduct such an analysis. We used the electrocardiographic finding classification according to the National Survey of Circulatory Disorders of 1990, which includes indicators of many diseases and conditions. Therefore, we cannot say that our endpoint is a true indicator of risk for coronary heart diseases.

The strengths of our results are as follows: (1) this was an 8-year retrospective cohort study and (2) we were able to examine the interplay of sleep duration and mental health condition and how this interplay impacts the ECG findings 8 years later.

In our multivariate logistic regression analysis, the degree of fitting of the model was low for general subjects; however, it increased to 34.4% when we controlled the subjects' GHQ scores as shown in Table 3. This will give more reliability for the results in Table 3 showing that there is an association between poor mental health, shorter or longer sleep duration, and ECG findings.

Sleep deprivation is a major problem in modern society. Due to the spread of the Internet and satellite TVs, people do not seem to have enough time to rest in developed countries. Statistics show that the average sleep duration of the Japanese in 2000 was 7 h 23 min, which was 50 min shorter than 40 years ago [30]. The sleep problem may continue to grow in our society. Researching the impact of sleep on mental and physical conditions should have premium importance.

In conclusion, our findings are as follows. The mental health condition has a strong association with sleep duration, which was found to be a risk factor for abnormal ECG findings. Mental health does not appear to be directly associated with ECG; however, as shown in Table 3, mental health seems to impact ECG results indirectly through its strong association with sleep duration. The authors think that poor mental health conditions often lead to sleep disorders or insomnia, which may cause eventual cardiovascular malfunction. Although further research to clarify the effects of sleep and metal health on cardiovascular disease is necessary, measuring mental health conditions in addition to sleep duration at community physical checkups could provide us with an additional indicator for cardiovascular malfunction. Currently mental health assessment is not mandatory under the Occupational Health and Hygiene Law or any other health laws, such as the Health and Medical Service Law for the Aged and the School Public Health Law in Japan. We believe that adding mental health assessment to the examination items will contribute to better screening of high-risk individuals for circulatory disorders in the community as well as in the schools and in the workplace.

Appendix

Table 4

Table 4 The revised Minnesota Code System

ECG results classification	Minnesota code
Normal	1-0, 7-5, 9-2, 9-3, 9-4, 9-5
Slight abnormality	1-3, 2-1 ∼ 5
	3-1, 3-2, 3-3, 6-3, 6-4, 6-5
	7-3, 7-6, 8-7, 8-8, 8-9
Abnormality A	1-2, 4-3, 4-4,
	5-3 ∼ 5, 8-6
Abnormality B	4-2, 5-2, 6-2, 7-2, 7-4
	8-1, 8-2, 8-3, 8-4, 8-5
Abnormality C	1-1, 4-1, 5-1, 6-1, 7-1
	Two and more eight
Others	3-4, 6-8, 7-7, 7-8
	9-6, 9-7, 9-8

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