Environmental Research 138 (2015) 17–21

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Fatigue and sleep under large summer temperature differences

Hisako Fujii [a], Sanae Fukuda [a,d,e,*], Daisuke Narumi [b], Tomohiko Ihara [c], Yasuyoshi Watanabe [a,d]

[a] Osaka City University, Graduate School of Medicine, Osaka 540-0051, Japan
[b] Yokohama National University, Graduate School of Environment and Information Science, Yokohama 240-8501, Japan
[c] The University of Tokyo, Graduate School of Frontier Sciences, Kashiwa, Chiba 277-8563, Japan
[d] RIKEN Center for Life Science Technologies, Kobe 650-0047, Japan
[e] Kansai University of Walfare Sciences, Department of Health Science, 3-11-1 Asahigaoka, Kashihara-shi, Osaka 582-0026, Japan

ARTICLE INFO

Article history:
Received 11 July 2014
Received in revised form
2 February 2015
Accepted 4 February 2015
Available online 13 February 2015

Keywords:
Fatigue
Sleep
Temperature differences

ABSTRACT

Background: It has been recognized that an increase in outdoor ambient temperatures has a negative impact on health, particularly fatigue and sleep quality; however, the relationship among fatigue, sleep quality, and air temperature has yet to be sufficiently elucidated.
Objectives: To examine whether fatigue and sleep quality in a healthy Japanese population were affected by rising air temperature at three time points in summer and to investigate the confounding factors for fatigue.
Methods: A total of 602 healthy volunteers in Osaka, Japan, participated in a survey that was conducted at the end of July, August, and September in 2010. The questionnaire consisted of four sections; demographic variables, accommodation status, fatigue, and sleep quality. We used the Chalder fatigue scale for assessment of fatigue, and the Japanese version of the Pittsburgh Sleep Quality Index (PSQI) for assessment of sleep quality.
Results: The fatigue score was positively correlated with the sleep quality score in the total cohort. All the questionnaires at the three time points were completed by 162 participants. There were significant differences in fatigue scores among the surveys. We stratified the subjects into two groups of good and poor sleepers using a cutoff value of the PSQI. The good sleepers did not show differences in fatigue score regardless of the change in air temperature. However, the fatigue score of poor sleepers was greater at higher air temperatures. The use of air conditioners, accommodation type, and subject's age were confounding factors for fatigue.
Conclusions: High air temperatures in summer increased fatigue in healthy volunteers, especially those with poor sleep patterns, depending on the use of air conditioners, accommodation status, and subject's age.

1. Introduction

Global warming has increased mean air temperatures around the world (IPCC-WG1, 2013). The global mean temperature will continue to rise in the future; 4.8 °C of temperature rise is predicted at most in this century if greenhouse gas emissions continue unabated (IPCC-WG1, 2013). Another warming phenomenon is urban heat island (UHI), in which a metropolitan area is warmer than a surrounding rural area. The temperature difference related to the UHI is usually larger at night than during the day, and is present during both summer and winter. In each city in Japan, a trend of the long-term temperature rise has accompanied urbanization. Both daily maximum temperature and daily minimum temperature tend to have greater increase rate as urbanization rate is large (Japan Meteorological Agency, 2013). Osaka, one of the biggest cities in Japan, is hot and humid in summer, which results in a high degree of discomfort. Between 1981 and 2010 in Osaka, the mean air temperature in August was 28.8 °C with 66% relative humidity (Japan Meteorological Agency, 1981–2010). The monthly average of long-term temperature increase rate in August in Osaka was about three times larger than that of smaller cities. The number of days of tropical nights in Osaka is increasing at a rate of 6.3 days per decade (Japan Meteorological Agency, 2008). With increasing worldwide concern about climate changes, the effects of hot weather are becoming a significant public health challenge (Hajat et al., 2010). The UHI phenomenon has also contributed to

* Corresponding author at: Kansai University Walfare Sciences, Department of Health Science, 3-11-1 Asahigaoka, Kashihara-shi, Osaka 582-0026, Japan.
E-mail addresses: hfujii@med.osaka-cu.ac.jp (H. Fujii), sfukuda@fuksi-kagk-u.ac.jp (S. Fukuda), narumi@ynu.ac.jp (D. Narumi), ihara-t@k.u-tokyo.ac.jp (T. Ihara), yywata@riken.jp (Y. Watanabe).

http://dx.doi.org/10.1016/j.envres.2015.02.006
0013-9351/

health problems (Tan et al., 2010; Tomlinson et al., 2011). One of the most direct health effects arising from warming is expected to be increased rates of mortality and morbidity associated with exposure to high ambient temperatures (Hajat et al., 2010; IPCC, 2007). Major predicted health effects of long-term climatic change include skin and eye damage from increased exposure to ultraviolet radiation, higher incidence of respiratory and cardiovascular diseases, greater incidence of vector-borne and water-borne diseases, and heat-related morbidity and mortality (Basu and Samet, 2002; Council, 2000). Rates of heat-related mortality are high in the elderly and chronically ill, particularly those with cardiovascular, respiratory, and renal diseases (Hajat et al., 2010). Thermal stress can seriously affect health and reduce tolerance to other environmental hazards (Epstein and Moran, 2006).

Poor sleep quality and fatigue are commonly associated with discomfort in a hot summer. According to a survey on global warming conducted by the Japan Meteorological Agency statistics information in 2003, the symptoms experienced in summer were “sleep disorders” in over 50% of subjects and “fatigue/not being well” in around 30%. Additionally, healthy volunteers have been reported to suffer greater fatigue at high air temperatures and humidity (Gonzalez-Hidalgo et al., 2011).

Fatigue—a subjective sense of weakness, lack of energy, and tiredness—is an important bioalarm for human health (Watanabe, 2008). Sleep disorders are common in the general population, affecting up to one-third of adults (Sohar et al., 1962; Zeitlhofer et al., 2000). The overall prevalence of insomnia during the preceding month has been found to be around 20%; this includes difficulty falling asleep, trouble keeping asleep, and early morning awakening (Doi et al., 2000a; Kim et al., 2000). Sleep quality can be regarded as an important indicator of quality of life (Hatoum et al., 1998; Yang et al., 2000; Zeitlhofer et al., 2000).

There have been few studies investigating the relationship between ambient temperature and fatigue or sleep problems. Therefore, we examined fatigue and sleep status in a healthy Japanese population during three summer months with varying ambient temperature, under the hypothesis that fatigue increases when the temperature increases. We also examined confounding factors for fatigue, such as age and gender, which affect fatigue and sleep (Doi et al., 2000a; Kumashiro and Nagae, 1984; Ohayon et al., 2004). With the advance of densification in urban areas, many people have taken measures to protect themselves from the surrounding environment to create a convenient space in which to live. As a result, the supply of housing in urban areas has increased. This phenomenon also contributes to the worsening of the heat island phenomenon. For this reason, the type of dwelling was also considered a confounding factor. Further, in prior research, non-REM sleep was decreased (Haskell et al., 1981), awakening increased, and the quality of sleep decreased under conditions of high temperature and humidity (Okamoto-Mizuno et al., 1999). Air conditioning during sleep was also analyzed as a confounding factor. Similarly, we set air conditioning use during the day as a confounding factor.

2. Methods

2.1. Participants

Healthy adults over 20 years old in Osaka Prefecture, who are mainly the members of the “Association of Osaka Clinical Trial Volunteers” operated by the Center for Drug and Food Clinical Evaluation, Osaka City University Hospital, were recruited for this study from June to September 2010. Exclusion criteria were as follows: (1) shift workers; (2) those with sleep problems for more than 1 month; (3) working every weekend; (4) a past history of surgery; (5) pregnancy; (6) having disorders, such as diabetes mellitus, kidney disorders, psychiatric disorders, cancer, liver disorders, heart disease, respiratory disorders, stroke, connective tissue disease, rheumatism, or sleep disorders; (7) taking sleeping medicine or psychotropic drugs; (8) students; and (9) having difficulties in social life or work because of fatigue. Prior to enrollment, it was confirmed by phone using trained staff that each participant met all criteria.

2.2. Questionnaire

The questionnaire collected descriptive information on sociodemographic characteristics, such as gender, age, area of residence, type of accommodation, occupation, working hours, main location of everyday activities, fatigue and sleep quality, and use of air conditioner during the daytime and nighttime before the survey.

Fatigue was assessed by the Chalder fatigue scale (Chalder et al., 1993) and sleep quality was assessed by the Japanese version of the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989; Doi et al., 1998). The Chalder fatigue scale was developed to measure two constructs, physical fatigue and mental fatigue (Chalder et al., 1993), and is an appropriate and useful measure of fatigue-related symptomatology and disability within a general population of individuals with varying levels of fatigue (Taylor and Torres, 2000). The scale elicits four-point Likert scale ratings (always, sometimes, rarely, or never) across 14 simple and unambiguous items with scores from 0 to 40. Higher score indicated higher fatigue. The PSQI is a 19-item survey designed to comprehensively measure the complex phenomenon of sleep across seven constructs: subjective sleep quality; sleep latency (the time from lying down for sleep to the start of actual sleep); sleep duration; habitual sleep efficiency (the proportion of actual sleep to time spent in bed); sleep disturbance; use of sleeping medication; and daytime dysfunction. Construct-specific scores are calculated and weighted on a 0–3 Likert scale and then aggregated into a PSQI score that has a range of 0–21. Poor sleepers were defined by PSQI scores ≥ 5 (Doi et al., 2000b).

Questionnaires were mailed to subjects at the end of July, August, and September in 2010 to be answered on the fourth Tuesday of each month. To match the condition of responses at home between evenings to bedtime, we asked all subjects to answer all questions so as to accurately recall the seven days from the date of response. A reminder e-mail was sent to each subject enrolled in the study 1 day prior to the assigned date of completion of each questionnaire. We obtained data on daily maximum and minimum air temperatures from the Japan Meteorological Agency for specified days concordant with the survey. The study was approved by the ethics committee of Osaka City University Graduate School of Medicine.

2.3. Statistical analysis

Continuous data are expressed using mean $\pm$ standard deviation. Nominal data such as gender are presented as percentages. The two-tailed *t*-test, bivariate correlation analysis, and repeated-measures analysis of variance (ANOVA) were used to assess statistical significance for comparison of participants at the three times of the survey. In the two-tailed *t*-test and bivariate correlation analysis, the average values were calculated for subjects surveyed more than once out of three times to present a more precise value for each individual. Multivariate models were then developed, including type of accommodation, air conditioner use in daytime or nighttime, age, and gender (the categories of each parameter are shown in Table 3). Dependent variables were fatigue score and sleep score. We excluded incomplete data in each analysis.