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Solar radiation and out-of-hospital cardiac arrest in Japan☆

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ABSTRACT

Background: Although several studies have estimated the effects of temperature on mortality and morbidity, little is known regarding the burden of out-of-hospital cardiac arrest (OHCA) attributable to solar radiation.

Methods: We obtained data for all cases of OHCA and meteorological data reported between 2011 and 2014 in 3 Japanese prefectures: Hokkaido, Ibaraki, and Fukuoka. We first examined the relationship between daily solar radiation and OHCA risk for each prefecture using time-varying distributed lag non-linear models and then pooled the results in a multivariate random-effects meta-analysis. The attributable fractions of OHCA were calculated for low and high solar radiation, defined as solar radiation below and above the minimum morbidity solar radiation, respectively. The minimum morbidity solar radiation was defined as the specific solar radiation associated with the lowest morbidity risk.

Results: A total of 49,892 cases of OHCA occurred during the study period. The minimum morbidity solar radiation for each prefecture was the 100th percentile (72.5 MJ/m^2) in Hokkaido, the 83rd percentile (59.7 MJ/m^2) in Ibaraki, and the 70th percentile (53.8 MJ/m^2) in Fukuoka. Overall, 20.00% (95% empirical confidence interval [eCI]: 10.97–27.04) of the OHCA cases were attributable to daily solar radiation. The attributable fraction for low solar radiation was 19.50% (95% eCI: 10.00–26.92), whereas that for high solar radiation was 0.50% (95% eCI: −0.07–1.01).

Conclusions: Low solar radiation was associated with a substantial attributable risk for OHCA. Our findings suggest that public health efforts to reduce OHCA burden should consider the solar radiation level. Large prospective studies with longitudinal collection of individual data is required to more conclusively assess the impact of solar radiation on OHCA.

1. Introduction

In recent decades, the effects of seasonal and meteorological factors on out-of-hospital cardiac arrest (OHCA) have been revealed. Sudden cardiac death and coronary heart disease events show remarkable seasonal variations with significant increases in winter(Arntz et al., 2000). Cold temperatures were found to significantly increase the risk of OHCA or sudden coronary mortality in the United States (Gerber et al., 2006), and in China, extremely hot or cold temperatures were reported to significantly increase the risk of OHCA and coronary mortality(Chen et al., 2014; Niu et al., 2016). These findings suggest that season and temperature may play important roles in the incidence of OHCA.

However, climatic factors, such as temperature and humidity, covary with sunshine even after adjusting for season (Tsai, 2015), and the underlying mechanisms leading to OHCA could differ accordingly. The atmospheric radiation budget plays an important role in determining the main characteristics of the earth's climate(Ohmura et al., 1998). In particular, surface irradiances are important to understand the climate process because the surface of the earth transforms approximately 60% of incoming solar radiation absorbed by the earth into heat, and a small change in solar radiation at the earth's surface may cause a substantial change in climate(Ohmura et al., 1998). Solar radiation reaching the earth's surface is the primary energy source for life on the earth, and variations in solar radiation greatly affect the human and terrestrial environment(Wild et al., 2005). Recent studies have also indicated that a lack of sunshine exposure may be an important environmental risk factor for cardiovascular disease morbidity and mortality(Feelisch et al., 2010; Lindqvist et al., 2016). However, little is

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known regarding the risk of OHCA in relation to solar radiation.

Most studies have evaluated the association between climatic factors and OHCA in terms of relative risk, which provides estimates of the exposure-response relationship. However, these indicators provide limited information on the excess burden due to exposure such as relative excess measures (the attributable fraction) of OHCA. The attributable fraction, which takes into account exposure risk but also the number of days on which that risk is observed, is the most useful indicator of exposure-related health burdens, and attributable risk measures the potential impact of a prevention strategy within a population(Steenland and Armstrong, 2006). Recent studies conducted in Japan, China, Hong Kong, and Canada showed that most temperature-related cardiovascular disease mortality, hospitalization, and emergency transport burden could be attributed to cold temperatures(Bai et al., 2016; Onozuka and Hagihara, 2015; Tian et al., 2016; Yang et al., 2015). However, no studies have investigated the attributable risks of OHCA due to solar radiation.

Thus, the present study used national data on OHCA cases between 2011 and 2014 in Japan to investigate the total burden of OHCA attributable to solar radiation and the relative contributions from low and high solar radiation. To the best of our knowledge, this is the first study to examine the OHCA risk attributable to solar radiation.

2. Methods

2.1. Data collection

We collected data for all OHCA cases and meteorological data reported between 2011 and 2014 in 3 prefectures of Japan: Hokkaido, Ibaraki, and Fukuoka (Table 1, Supplementary Fig. S1). These 3 prefectures were selected due to their proximity to a baseline surface radiation network (BSRN) station for the measurement of solar radiation and the availability of solar radiation data. The BSRN is managed by the Word Radiation Monitoring Center and measures surface radiative fluxes at the best possible quality with the best methods currently available and at selected sites in the major climate zones(Ohmura et al., 1998; Wild et al., 2005).

We obtained data on OHCA cases from the Fire and Disaster Management Agency of the Ministry of Internal Affairs and Communications. In Japan, municipal governments provide emergency medical services (EMSs) through approximately 800 fire stations with dispatch centers under the Fire Service Act(Kitamura et al., 2010). Because EMS providers are not allowed to terminate resuscitation in the field, all of the patients with OHCA who are treated by EMS personnel are transported to hospitals(Hagihara et al., 2012). Following the standardized Utstein-style reporting guidelines for cardiac arrest, EMS personnel summarize each case of OHCA in cooperation with the attending physicians(Hagihara et al., 2012). Reporting the registration of OHCA episodes is required under the law, which is considered to be comprehensive.

We also obtained data on the daily mean solar radiation, temperature, relative humidity, and sunshine duration from the Japan Meteorological Agency, which operates the BSRN stations in Japan. Each BSRN station was selected as a representative for each prefecture. The immediate surroundings of the BSRN station satisfy the basic conditions for climatological radiometry, and the station is free from immediate local effects, such as pollution and heat islands, local orography, such as surface tilt and an elevated horizon, and isolated atmospheric condition such as local cloud developments(Ohmura et al., 1998; Wild et al., 2005). The basic radiation measurements collected at the BSRN stations include direct solar radiation, diffuse solar radiation, and downward longwave radiation, and solar radiation was calculated as the total amount of these components. We calculated the daily 24-hour mean solar radiation, temperature, relative humidity, and sunshine duration for each station.

2.2. Ethical approval

This study was approved by the ethics committee of Kyushu University Graduate School of Medical Sciences. As this was a retrospective observational study using national registry data and because the enrolled individuals were de-identified by the Fire and Disaster Management Agency, the requirement for written informed consent was waived.

2.3. Statistical analysis

We conducted a two-stage time-series analysis using data from three Japanese prefectures to investigate the OHCA risk attributable to solar radiation. In the first stage, we first estimated prefecture-specific solar-radiation–OHCA relationships using a time-series regression model, which allowed for nonlinearity and delayed effects. In the second stage, these estimates were pooled at the multi-prefectural level with a multivariate meta-regression analysis.

In the first stage, we used a distributed lag non-linear model

Table 1
The descriptive statistics of daily out-of-hospital cardiac arrest (OHCA) cases and meteorological data in 3 Japanese prefectures from 2011 to 2014.

Prefecture	Population (2010)	Variables	Mean	SD	Percentiles				
					Min	25th	Median	75th	Max
Hokkaido	5,506,419	Daily number of OHCA cases	14.7	4.8	2	11	14	17	38
		Daily mean solar radiation (MJ/m^2)	43.5	11.3	24	34	42	52	72
		Daily mean temperature (°C)	9.4	10.0	−9.2	−0.1	9.7	18.6	28.9
		Daily mean relative humidity (%)	69.3	10.5	31	62	70	77	95
		Daily mean sunshine duration (hours)	4.9	3.9	0.0	1.2	4.4	7.8	14.1
Ibaraki	2,969,770	Number of OHCA cases	8.6	3.8	0	6	8	11	26
		Daily mean solar radiation (MJ/m^2)	49.2	10.1	27	42	49	57	75
		Daily mean temperature (°C)	14.1	8.5	−1.7	6.0	14.5	21.3	30.4
		Daily mean relative humidity (%)	72.5	13.5	32	63	75	83	98
		Daily mean sunshine duration (hours)	6.0	4.1	0.0	1.9	7.0	9.3	13.5
Fukuoka	5,071,968	Daily number of OHCA cases	10.8	4.5	0	8	10	13	32
		Daily mean solar radiation (MJ/m2)	47.4	10.6	28	39	47	56	75
		Daily mean temperature (°C)	17.3	8.2	−0.1	9.9	17.9	23.9	32.8
		Daily mean relative humidity (%)	67.6	12.6	33	58	67	76	100
		Daily mean sunshine duration (hours)	5.1	4.1	0.0	1.0	4.8	8.8	13.5

Abbreviations: MJ, megajoule; OHCA, out-of-hospital cardiac arrest; SD, standard deviation.