

を認識するポリクローナル抗体を利用した ELISA 法（日本ハム(株)製 ELISA キット）と、単一あるいは精製たんぱく質を認識するポリクローナル抗体を利用した ELISA 法（(株)森永生科学研究所製 ELISA キット）の 2 種類の方法が一般に用いられている。両キットとも原理はサンドイッチ ELISA 法に基づいている。表 4-5 に示すように、両検査法の特徴は互いに相補的な関係にあり、両方の検査法を用いた定量検査が最も効率的であると考えられる。両検査法は、5 つのモデル加工食品を用いた複数機関によるバリデーションにおいて前述の基準を満たすことが示されている¹⁵⁾。

現在の表示制度では、ELISA 法により食品 1g 当たり特定原材料等由来のたんぱく質を 10 μ g 以上含有することが示された場合は、微量を超える特定原材料が混入している可能性があるかと判断される。

◆◆ 3 ウェスタンブロット法

ウェスタンブロット法は、特定原材料たんぱく質をポリアクリルアミドゲル電気泳動 (SDS-PAGE) 法で分離し、PVDF 膜に転写した後、膜上で抗原抗体反応を行い、たんぱく質を検出する方法である。分子量に関する情報が得られるので、ELISA 法よりも特異的な検出が可能である。通知検査法では、卵及び牛乳についての確認試験法となっている。結果については、抗体の標的である特定のたんぱく質の分子量付近に明瞭な帯が検出されたものを陽性と判定する（卵：卵白アルブミン 50kDa, オボムコイド 38kDa, 牛乳：カゼイン 33~35kDa, β -ラクトグロブリン 18.4 kDa)。ただし、卵の場合、卵白アルブミン及びオボムコイドは、卵白の特異的なたんぱく質であり、卵黄がかなり精製された状態で含まれる加工食品には適応できないので注意する必要がある。

◆◆ 4 PCR 法

PCR 法は、標的となる DNA 上の特定の領域を PCR により増幅して、標的 DNA を非常に特異的に検出する方法である。通知検査法では、小麦、そば、落花生の場合の確認試験法となっている¹⁶⁻¹⁸⁾。小麦検知のための PCR 法では、ライ麦、オーツ麦及び大麦は検出されず、また、落花生検知のための PCR 法では、他のナッツ類や大豆は検出されない。

PCR 法は、たんぱく質測定法に比べて加工品への適用可能性が高く、最終製品の検査において有効な手段と考えられる。

2 えび・かにの検査法

えび・かにの検査法に関しては、定量検査法として 2 種の ELISA キットが既に開発されており、試験室間バリデーションも終了している。定性検査法としては PCR 法が開発されており、2008（平成 20）年度試験室間バリデーションが実施された。

◆◆ 1 定量検査法

えび・かにの主要アレルゲンは、トロポミオシンである。2005~2007（平成 17~19）年度の厚生労働科学研究では、トロポミオシンを認識する抗体を用いたサンドイッチ ELISA 法が 2 種類開発されている（日水製薬（株）製の ELISA キット（以下、A キット）¹⁹⁾、及び（株）マルハニチロ食品製の ELISA キット（以下、B キット）²⁰⁾。

甲殻類のトロポミオシンは相同性が高く、抗体による識別が困難であるため、上記 2 種の ELISA 法は、えびとかにを区別せず、甲殻類として検出するものである。A キットの場合の検討

例では、エビ類、カニ類、ヤドカリ類、オキアミ類のトロポミオシンは82~102%の交差反応性を示した。しかし、イカ類、タコ類、貝類のトロポミオシンとの反応性は低く、甲殻類に対する特異性は高い。

両キットを5種類のモデル食品を用いて10機関によるバリデーション試験に供した結果、前述の基準を満たす良好な結果が得られ、加工食品中の甲殻類たんぱく質の測定キットとして有用であることが示された²¹⁾。

◆◆ 2 定性検査法

えび・かにの確認試験法としては、えびとかにをそれぞれ特異的に検出するPCR法が開発された²²⁾。えび、かにをそれぞれ10種類以上用いた検討により、このPCR法では、えび、かにを特異的かつ高感度に検出できることが示された（えびの場合は、特異性を高めるためにPCR産物の制限酵素処理を組み合わせる）。また、ELISA法の陽性判定基準である、たんぱく質レベルで10 μ g/g相当のえび抽出物あるいはかに抽出物を含むモデル加工食品を用いた場合も、それぞれ特異的にPCR産物を検出することが可能であった。

この定性検査法については、2008（平成20）年度において試験室間バリデーションが実施された。その結果、前述の基準を満たす良好な結果が得られ、えび・かにの確認試験法として有用であることが示された。

3 まとめ

特定原材料の表示制度がスタートして8年が過ぎた。その間、検査法による監視により表示の適正化が進み、消費者の健康危害防止に効果があったと評価されている。今後も、食物アレルギーの実態に合わせて改正が行われることが考えられ、行政施策が継続される限り、検知法の開発研究が継続して遂行される必要がある。また、検査法に関しては、科学技術の進歩に伴い、簡易、安価かつ迅速な新手法を開発することが望まれている。

3 医療現場における現状と対策

1 現状（病院における食物アレルギーの対応に関する報告）

2005（平成17）年に「食物アレルギーの診療の手引き2005」が厚生労働科学研究班より発表され、小児における食物アレルギーの診断テストと栄養指導に関し、診療報酬が導入されることとなった。

そこで、病院における食物アレルギーの対応についての現状を明らかにし、その結果より課題をまとめ、今後の展望を考察することを目的として文部科学省（18300258）より助成を受け、調査を行った。

◆◆ 1 方法

調査期間は、2008（平成20）年2月1日より、同月15日であった。

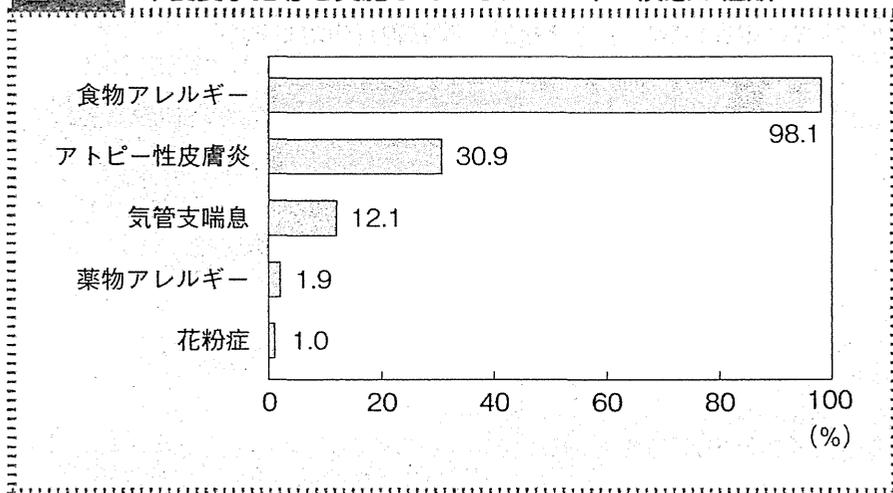
対象施設は、ホームページにより住所等の病院の情報を公開している全国47都道府県の病院施設から、栄養科が確認できた888カ所の施設にアンケート用紙を送付し、527カ所から回答を得た。

表 4-6 対象施設の概要

| 項目 | 平均±SE (標準偏差) |
|--------------------|----------------|
| 病床数 (床) | 380.2±11.0 |
| 平均在院日数 (日) | 30.8±3.0 |
| 外来患者数 (人/月) | 13,209.1±836.7 |
| 入院患者数 (人/月) | 7,004.5±404.9 |
| 常勤管理栄養士人数 (人) | 3.6±0.1 |
| 内栄養食事指導担当 (人) | 3.0±0.1 |
| 栄養食事指導件数：入院時 (人/月) | 42.4±2.1 |
| ：外来 (人/月) | 54.4±5.8 |

資料) 文部科学研究助成による研究, 2008 より

図 4-4 栄養食事指導を実施しているアレルギー疾患の種類



資料) 文部科学研究助成による研究, 2008より

アンケートの回答者は、栄養食事指導を担当している管理栄養士であった。調査内容は、医療機関の概要としては、施設の種類、診療科、給食業務形態、病床数、平均在院日数、外来及び入院患者数、管理栄養士及び栄養士の人数、栄養食事指導件数について、アレルギー及び食物アレルギーに関しては、栄養食事指導状況、指導頻度、指導形式、指導を実施しない・できない・実施数が少ない理由、入院患者に対する対応、食物アレルギー対応食専用調理場の設置状況、知識の収集方法についてであった。

◆◆◆ 2 結果

対象施設の概要を表 4-6 に示した。常勤の管理栄養士が平均 3.6 ± 0.1 人、その内栄養食事指導を担当している者は平均 3.0 ± 0.1 人であり、入院時、外来合わせて、月に 100 人程度の栄養食事指導を行っていた。

アレルギー疾患をもつ患者に対し、栄養食事指導を行っているか否かに関しては、行っている 39.5%、行っていない 60.5% であり、約 4 割の施設で栄養食事指導が行われていた。

また、栄養食事指導を行っているアレルギー疾患の種類に関しては、98.1%が食物アレルギーであった (図 4-4)。アレルギー疾患の患者に対する栄養食事指導の頻度は、「月に 1~2 人」が最も

Original Paper

Prevalence of Insomnia Among Residents of Tokyo and Osaka After the Great East Japan Earthquake: A Prospective Study

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Abstract

Background: The Great East Japan Earthquake occurred on March 11, 2011. Tokyo and Osaka, which are located 375 km and 750 km, respectively, from the epicenter, experienced tremors of 5.0 lower and 3.0 seismic intensity on the Japan Meteorological Agency scale. The Great East Japan Earthquake was the fourth largest earthquake in the world and was accompanied by a radioactive leak at a nuclear power plant and a tsunami. In the aftermath of a disaster, some affected individuals presented to mental health facilities with acute stress disorder (ASD) and/or post-traumatic stress disorder (PTSD). However, few studies have addressed mental stress problems other than ASD or PTSD among the general public immediately after a disaster. Further, the effects of such a disaster on residents living at considerable distances from the most severely affected area have not been examined.

Objective: This study aimed to prospectively analyze the effect of a major earthquake on the prevalence of insomnia among residents of Tokyo and Osaka.

Methods: A prospective online questionnaire study was conducted in Tokyo and Osaka from January 20 to April 30, 2011. An Internet-based questionnaire, intended to be completed daily for a period of 101 days, was used to collect the data. All of the study participants lived in Tokyo or Osaka and were Consumers' Co-operative Union (CO-OP) members who used an Internet-based food-ordering system. The presence or absence of insomnia was determined before and after the earthquake. These data were compared after stratification for the region and participants' age. Multivariate analyses were conducted using logistic regression and a generalized estimating equation. This study was conducted with the assistance of the Japanese CO-OP.

Results: The prevalence of insomnia among adults and minors in Tokyo and adults in Osaka increased significantly after the earthquake. No such increase was observed among minors in Osaka. The overall adjusted odds ratios for the risk of insomnia post-earthquake versus pre-earthquake were 1.998 (95% CI 1.571–2.542) for Tokyo, 1.558 (95% CI 1.106–2.196) for Osaka, and 1.842 (95% CI 1.514–2.242) for both areas combined.

Conclusions: The prevalence of insomnia increased even in regions that were at a considerable distance from the epicenter. Both adults and minors in Tokyo, where the seismic intensity was greater, experienced stress after the earthquake. In Osaka, where the earthquake impact was milder, disturbing video images may have exacerbated insomnia among adults.

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KEYWORDS

insomnia; Web-based survey; population surveillance; disaster; nuclear accidents; earthquakes

Introduction

On March 11, 2011, the Japanese islands sustained a 9.0-magnitude earthquake. Unlike previous major earthquakes in Japan [1,2], this earthquake was followed by a tsunami that devastated the affected areas [3]. More than 20,000 individuals were recorded as dead or missing. The tsunami also caused extensive damage to the Fukushima Daiichi nuclear power plant, resulting in a level 7 nuclear accident [4,5]. This induced considerable anxiety among residents living near the nuclear power plant and among people living as far away as the Tokyo metropolitan area [6]. Images of the tsunami and scenes of the nuclear accident were shown repeatedly on television and the Internet.

In the aftermath of a disaster, people may experience not only physical disorders but also acute stress disorder (ASD), which can persist for up to 4 weeks. Furthermore, chronic post-traumatic stress disorder (PTSD) is common among

individuals who have faced such situations [7]. Studies of disaster-related mental disorders typically include an assessment of the prevalence of PTSD, follow-up of patients diagnosed with ASD [8], and a comparison of the numbers of new and previous cases of PTSD in a given area. However, because these studies are usually planned after a disaster, pre-disaster prevalence must be determined retrospectively. A recollection of previous insomnia is likely to be less accurate than the prospective reporting of current symptoms of insomnia, especially during the traumatic aftermath of a disaster.

The current study made use of a daily health survey that was administered to 3128 participants in Tokyo and 1925 participants in Osaka (Table 1) from January 20 to April 30, 2011. One question on the survey specifically asked about the presence or absence of insomnia. Because the Great East Japan Earthquake occurred during the course of this survey, this was a rare opportunity to prospectively assess the impact of an earthquake on the prevalence of insomnia among residents of Tokyo and Osaka.

Table 1. Number of participants according to sex and age group.

| | Tokyo N (male/female) | Osaka N (male/female) |
|---------------------------|--------------------------|--------------------------|
| Adults (≥20 years of age) | 2073 (999/1074) | 1182 (564/618) |
| Minors (<20 years of age) | 1055 (575/480) | 743 (373/370) |

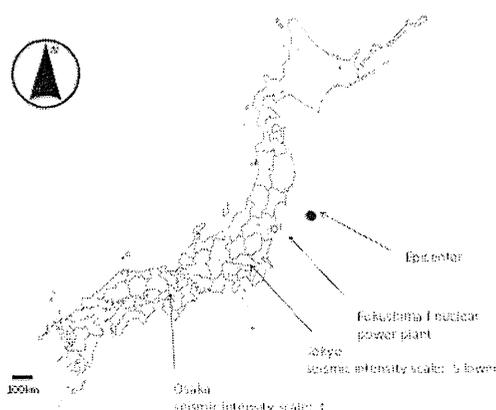
Methods

Study Period and Locations

This survey began on January 20, 2011 and continued for 101 days until April 30, 2011. The questionnaire collected data related to the individual's health status on the day of the survey, and participants were instructed to complete the survey every day for the duration of the study period. The survey was conducted via an Internet-based questionnaire among residents of the Tokyo metropolitan area and Osaka, the largest city in western Japan. Tokyo is located approximately 375 km from the epicenter of the earthquake (N 38°06' E 142°51') and approximately 200 km from the Fukushima Daiichi nuclear power plant (N 37°42' E 141°03'). The seismic intensity of the main shock in the center of Tokyo, as recorded by the Japan Meteorological Agency (JMA), was 5.0 Lower on the JMA

scale [9]. The JMA scale is comprised of 5 phases from 1 to 5. Grades 5 and 6 are further classified into 2 subcategories: upper and lower. During an earthquake with an intensity of 5.0 Lower, people may find it difficult to move around, but major destruction is generally not expected. In contrast, many people find it hard to move during earthquakes with an intensity of 5.0 Upper [9]. Shinjuku Ward, where the offices of the Tokyo Metropolitan Government are located, was subsequently hit by 10 aftershocks that continued until April 16, 2011. The seismic intensity of the aftershocks was ≥3.0, strong enough to be felt by most people inside buildings [9]. Osaka, the other area investigated in the survey, is situated 750 km from the epicenter of the earthquake. The seismic intensity of the main shock was recorded as 3.0 in the offices of the Osaka Prefectural Government. Osaka did not receive any aftershocks with a seismic intensity ≥3.0 (Figure 1).

Figure 1. Map of the locations relevant to this study.



Participants

This study was conducted with the assistance of the Japanese Consumers' Co-operative Union (CO-OP). All respondents who completed the questionnaire lived in Tokyo or Osaka and resided in households that included CO-OP members who placed food orders via the CO-OP website.

Survey Method

This study was conducted with the approval of the Ethics Committee of Nara Medical University (authorization code: 220). The general health condition of the participants, including their sleeping patterns, was investigated using an Internet-based questionnaire. The original aims of this survey were to determine the impact of biological factors, such as infectious diseases, and abiotic factors, such as climate, on the physical condition of residents during the study period. The survey method and data processing methods were described in detail in our previous study [10].

Registration Method

Respondents were recruited through a banner advertisement on the CO-OP's website. Each participant was rewarded with 500 yen (US \$1=91.15 yen on the first day of the survey) upon registration for participating in the survey. No remuneration, in the form of cash, was given for providing answers on a daily basis.

Daily Survey Method

The original research plan was to send a reminder email to all the respondents on each day of the survey that would direct them to the website where they could provide their responses. The email was distributed as planned until day 50 of the survey. The Great East Japan Earthquake occurred on day 51 of the survey. The reminder emails were discontinued, as it was decided that the participants, who were recovering from the disaster, should not be burdened. Further responses were left to the participants' discretion during a hiatus period from March 14 to April 5, 2011, when the reminders were reinstated. After the earthquake, respondents were able to submit descriptions of their physical condition by voluntarily visiting the website.

The daily survey procedure was designed to be simple. After confirming the everyday health condition of the family, participants were asked to access the survey website and answer several questions. The first question asked whether any family member was in poor health. If the participant answered "no", they were excluded from the survey. If the participant answered "yes", they were asked to answer additional "yes" or "no" questions on 19 symptoms; these questions pertained to the individual filling out the questionnaire as well as each member of his or her family [10]. The presence or absence of insomnia was prospectively investigated for 50 days before and 51 days after the Great East Japan Earthquake (including the day of the earthquake).

Statistical Analysis

In both surveyed areas, the prevalence of insomnia was calculated on a daily basis (the number of people reporting symptoms of insomnia divided by the number of responses per day) among people aged <20 years and those aged ≥ 20 years. Using a chi-square test, the presence or absence of insomnia before and after the earthquake was investigated for any correlation with region or participant age. A multivariate analysis was carried out using logistic regression analysis and a generalized estimating equation. The presence or absence of insomnia was the dependent variable. The independent variables included insomnia occurring after the earthquake, sex, age, region of each participant, the status of reminder emails (sent or not), and the incidence of pollinosis, which plagued approximately 30% of adults in those urban areas during the spring [11]. The statistical analyses were carried out using SPSS version 19.0 (IBM, Chicago, IL, USA).

Results

Response Rate

The mean (SD) daily response rate during the period when reminder emails were sent was 64.17% (5.78%) for Tokyo and 68.31% (5.18%) for Osaka. The response rate did not decline significantly over the course of the study. The response rate during the period when no reminder emails were sent (March 14 to April 5, 2011) was 24.47% (12.97%) for Tokyo and 27.82% (13.55%) for Osaka.

Daily Prevalence of Insomnia

Figures 2 and 3 illustrate the daily prevalence of insomnia in Tokyo and Osaka, respectively, according to age. The figures also indicate the dates of the main earthquake and the aftershocks with seismic intensity ≥ 3.0 . Before the earthquake, the average daily prevalence of insomnia in Tokyo was 1.05% (0.18%) for adults (age ≥ 20 years) and 0.53% (0.22%) for minors (age <20 years); after the earthquake, this value increased to 2.35% (0.65%) for adults and 1.90% (1.17%) for minors. The maximum seismic intensity of the main earthquake was 5.0 Lower in Tokyo (Figure 2).

Before the earthquake, the average daily prevalence of insomnia in Osaka was 1.25% (0.25%) for adults and 0.092% (0.14%) for minors; after the earthquake, this value increased to 1.83% (0.51%) for adults but remained approximately the same at 0.089% (0.17%) for minors. The maximum seismic intensity of the main earthquake was 3.0 in Osaka (Figure 3).

A chi-square test was conducted to analyze the data according to region and age group. There was a significant increase in the number Tokyo residents who reported symptoms of insomnia after the earthquake ($P < .001$ for both adults and minors) compared with that before the earthquake. The same findings were reported for adults in Osaka after the earthquake ($P < .001$). No significant difference was observed among minors in Osaka (Table 2). We conducted a similar chi-square test that excluded the period during which no reminder emails were sent and similar results were obtained.

Table 2. Chi-square analysis according to sex and age.

| Region | | Chi-square value | Degrees of freedom | <i>P</i> | Odds ratio | 95% CI |
|--------|--------|------------------|--------------------|----------|------------|-------------|
| Tokyo | Adults | 246.63 | 1 | <.001 | 2.107 | 1.916–2.317 |
| | Minors | 128.52 | 1 | <.001 | 2.763 | 2.301–3.319 |
| Osaka | Adults | 34.65 | 1 | <.001 | 1.438 | 1.273–1.623 |
| | Minors | 0.087 | 1 | .77 | 1.096 | 0.595–2.020 |

Figure 2. Prevalence of insomnia in Tokyo. The prevalence of insomnia increased after the earthquake for both adults and minors in Tokyo.

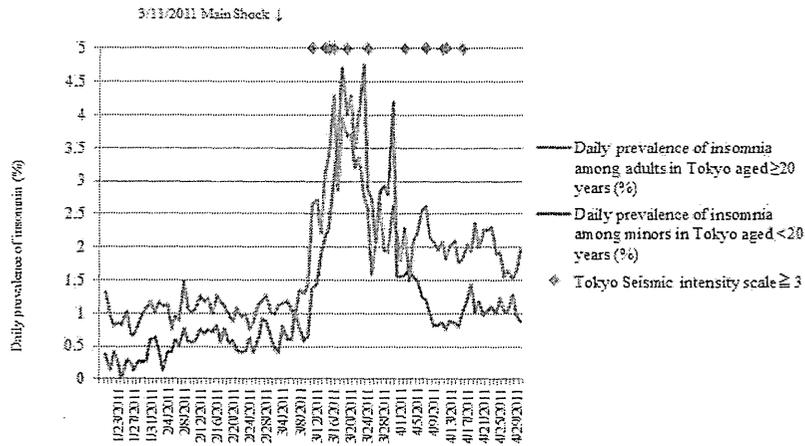
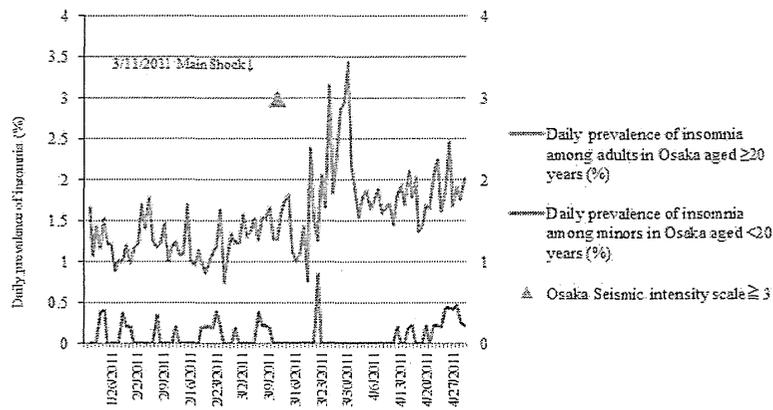


Figure 3. Prevalence of insomnia in Osaka. The prevalence of insomnia among adults increased after the earthquake. The prevalence of insomnia among minors remained approximately the same as that before the earthquake.



Analysis of Factors Associated with the Prevalence of Insomnia

Multivariate analysis was conducted to determine the odds ratios for insomnia (Table 3). The adjusted odds ratios for insomnia after versus before the earthquake were 1.998 (95% CI

1.571–2.542, $P < .001$) for Tokyo, 1.558 (95% CI 1.106–2.196, $P = .011$) for Osaka, and 1.842 (95% CI 1.514–2.242, $P < .001$) for the 2 areas combined. Table 3 presents the factors analyzed in this study and their associations with the prevalence of insomnia.

Table 3. Multivariate analysis of factors associated with the prevalence of insomnia.

| | Odds ratio | <i>P</i> | 95% CI |
|--|------------|----------|--------------|
| Predictor for sleeplessness^a | | | |
| Post-earthquake vs pre-earthquake | 1.842 | <.001 | 1.514–2.242 |
| Age ≥20 years vs age <20 years | 2.246 | .027 | 1.095–4.605 |
| Female vs male | 1.510 | .109 | 0.912–2.501 |
| Presence vs absence of pollinosis | 2.334 | .001 | 1.437–3.791 |
| Tokyo vs. Osaka | 1.404 | .187 | 0.848–2.323 |
| No reminder email vs reminder email | 1.303 | .016 | 1.050–1.617 |
| Predictor of sleeplessness | | | |
| Tokyo | | | |
| Post-earthquake vs pre-earthquake | 1.998 | <.001 | 1.571–2.542 |
| Age ≥20 years vs age <20 years | 1.378 | .421 | 0.631–3.010 |
| Female vs male | 1.670 | .903 | 0.90–3.087 |
| Presence vs absence of pollinosis | 2.437 | .005 | 1.317–4.509 |
| No reminder email vs reminder email | 1.435 | .004 | 1.121–1.838 |
| Osaka | | | |
| Post-earthquake vs pre-earthquake | 1.558 | .011 | 1.106–2.196 |
| Age ≥20 years vs age <20 years | 13.987 | <.001 | 6.408–30.530 |
| Female vs male | 1.285 | .554 | 0.554–2.983 |
| Presence vs absence of pollinosis | 2.193 | .047 | 1.012–4.751 |
| No reminder email vs reminder email | 1.005 | .983 | 0.658–1.535 |

^a values are total counts from Tokyo and Osaka

Discussion

Overall

This study examined the prevalence of insomnia among residents in areas that were at different distances from the epicenter of the Great East Japan Earthquake. This is a unique study in that it analyzes the effect of a great earthquake on the rates of insomnia and includes a pre-event baseline in the same group.

Great East Japan Earthquake and Its Impact

Major earthquakes have been common throughout the Asia-Pacific region over the past 2 decades [12,13], with more major earthquakes occurring in Japan than in any other country. In recent decades, 4 particularly large earthquakes have hit Japan, including the Great Hanshin Earthquake of 1995, which hit the Osaka region [1,2,14,15]. The Great East Japan Earthquake was the fourth largest earthquake in the world and was accompanied by 2 major events that could have occurred only in a modern society. First, the earthquake caused a radioactive leak at a nuclear power plant. Second, video images of the ensuing tsunami were recorded, and the footage was shown repeatedly on television; they were also available on the Internet. These images had a profound psychological impact on viewers. In the aftermath of a disaster, affected individuals may present to mental health facilities with ASD and/or PTSD

[16-19]. However, few studies have addressed mental stress problems other than ASD or PTSD among the general public immediately after a disaster. Although ASD and PTSD tend to draw greater research attention in studies related to a major disaster, the effects of such a disaster on residents living at considerable distances from the most severely affected area have not been examined. This study revealed an increase in the prevalence of insomnia among the general public immediately after the occurrence of a major earthquake. To our knowledge, this is the first study conducted in Japan that presents longitudinal data on the persistence of insomnia in 2 age groups.

Daily Prevalence of Insomnia in Tokyo and Osaka

The daily prevalence of insomnia increased among both adults and minors in Tokyo after the Great East Japan Earthquake. Although the daily prevalence of insomnia increased among adults in Osaka, a similar increase was not observed among minors. The adjusted odds ratios for insomnia after versus before the earthquake were 1.998 (95% CI 1.571–2.542) for Tokyo, 1.558 (95% CI 1.106–2.196) for Osaka, and 1.842 (95% CI 1.514–2.242) for the 2 areas combined. These results demonstrate an increased prevalence of insomnia among residents in regions located at considerable distances from the immediate zone of the disaster. In Tokyo, where there was no observable infrastructure damage due to the tsunami, 7 people died as a result of the initial tremor. In addition, many people in Tokyo experienced considerable psychological strain for a

prolonged period. Many commuters were stranded because of interrupted transportation services, and there was a high risk of radioactive contamination associated with the nuclear accident. The increased prevalence of insomnia among minors in Tokyo, who are generally less susceptible to stress induced by indirect sources such as media coverage, may be attributable to the effects of the aftershocks. In contrast, the seismic intensity of the main shock in Osaka was 3.0; therefore, direct feelings of fear were likely to be less common, and there was an absence of palpable aftershocks. The prevalence of insomnia among minors in Osaka following the earthquake was not increased, which can be explained by the residents' exposure to fewer direct and local effects. However, an increased number of adults in Osaka reported insomnia. This may have stemmed from exposure to information reported by the media. Other possible causes of insomnia among these adults include anxiety about their future and memories of the disaster caused by the Great Hanshin Earthquake of 1995.

Questionnaire Survey and Its Advantages

A Web-based questionnaire survey was used in the current study because more data are acquired with Internet-based epidemiological surveys than with conventional, paper-based surveys [20,21]. This method was effective in targeting general residents and enabling the acquisition of information from people with medical complaints deemed very mild to warrant a visit to a medical facility. In addition, this survey method was successful because the participants were required to respond only to simple questions regarding the presence or absence of symptoms, thus, the input burden was low. Although a meta-analysis of 68 studies [22] indicated that the normal response rate to Internet-based surveys is low (39.6%), the daily response rate for this study during the period when reminder emails were sent was 64.17% (5.78%) for Tokyo and 68.31% (5.18%) for Osaka. The survey questions were not specifically designed to detect post-disaster psychological conditions, and insomnia was only 1 of several conditions investigated. Participants' responses were limited to the presence or absence of insomnia, and there was no attempt to determine the severity

of the condition. Because insomnia was investigated as only 1 of several conditions, participants were unaware that their responses would be used in a study on post-disaster stress, even after the earthquake struck. It is possible, therefore, that the participants were less inclined to answer "yes" to the question about any experience of insomnia symptoms. This possibility is supported by the fact that the average daily prevalence of insomnia among adults before the earthquake was 1.1% in Tokyo and 1.3% in Osaka; these rates are lower than the values reported by an earlier survey on the prevalence of insomnia among Japanese adults [23].

Limitations

Immediately after the earthquake struck, an ethical decision was made to refrain from sending reminder emails. Therefore, the response rate was low during this period. However, no significant difference in the daily prevalence of insomnia correlated with the use of these reminder emails in either Tokyo or Osaka. The chi-square test results were similar between analysis including and excluding this time period. Although the reminder emails were included in the logistic regression analysis as an independent variable, the presence or absence of the reminder emails inevitably remains a limitation of this study and a potential source of bias. However, we believe that this factor had a negligible effect on the results.

Conclusions

This study examined the prevalence of insomnia among residents in areas distant from the epicenter of the Great East Japan Earthquake. In Tokyo, where the seismic intensity was higher, both adults and minors experienced increased rates of insomnia as a direct result of the earthquake and its aftershocks. Further, mental stress induced by information broadcast by the media may have influenced the prevalence of insomnia. In Osaka, where the seismic intensity was lower, only adults exhibited an increased prevalence of insomnia. Health care practitioners should be aware that individuals might experience mental stress, including insomnia, even in areas distant from those that are directly affected by a natural disaster.

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Conflicts of Interest

None declared.

References

1. Maruyama S, Kwon YS, Morimoto K. Seismic intensity and mental stress after the Great Hanshin-Awaji Earthquake. *Environ Health Prev Med* 2001 Oct;6(3):165-169 [FREE Full text] [doi: [10.1007/BF02897965](https://doi.org/10.1007/BF02897965)] [Medline: [21432256](https://pubmed.ncbi.nlm.nih.gov/21432256/)]
2. Sekizuka N, Sakai A, Aoyama K, Kohama T, Nakahama Y, Fujita S, et al. Association between the incidence of premature rupture of membranes in pregnant women and seismic intensity of the Noto Peninsula earthquake. *Environ Health Prev Med* 2010 Sep;15(5):292-298 [FREE Full text] [doi: [10.1007/s12199-010-0142-5](https://doi.org/10.1007/s12199-010-0142-5)] [Medline: [21432558](https://pubmed.ncbi.nlm.nih.gov/21432558/)]
3. Shibahara S. The 2011 Tohoku earthquake and devastating tsunami. *Tohoku J Exp Med* 2011;223(4):305-307 [FREE Full text] [Medline: [21478655](https://pubmed.ncbi.nlm.nih.gov/21478655/)]

4. Hirose K. 2011 Fukushima Dai-ichi nuclear power plant accident: summary of regional radioactive deposition monitoring results. *J Environ Radioact* 2012 Sep;111:13-17. [doi: [10.1016/j.jenvrad.2011.09.003](https://doi.org/10.1016/j.jenvrad.2011.09.003)] [Medline: [22119330](https://pubmed.ncbi.nlm.nih.gov/22119330/)]
5. Ohnishi T. The disaster at Japan's Fukushima-Daiichi nuclear power plant after the March 11, 2011 earthquake and tsunami, and the resulting spread of radioisotope contamination. *Radiat Res* 2012 Jan;177(1):1-14. [Medline: [22059981](https://pubmed.ncbi.nlm.nih.gov/22059981/)]
6. Goodwin R, Takahashi M, Sun S, Gaines SO. Modelling psychological responses to the Great East Japan earthquake and nuclear incident. *PLoS One* 2012;7(5):e37690 [FREE Full text] [doi: [10.1371/journal.pone.0037690](https://doi.org/10.1371/journal.pone.0037690)] [Medline: [22666380](https://pubmed.ncbi.nlm.nih.gov/22666380/)]
7. Bryant RA. Acute stress disorder as a predictor of posttraumatic stress disorder: a systematic review. *J Clin Psychiatry* 2011 Feb;72(2):233-239. [doi: [10.4088/JCP.09r05072blu](https://doi.org/10.4088/JCP.09r05072blu)] [Medline: [21208593](https://pubmed.ncbi.nlm.nih.gov/21208593/)]
8. Mills MA, Edmondson D, Park CL. Trauma and stress response among Hurricane Katrina evacuees. *Am J Public Health* 2007 Apr;97 Suppl 1:S116-S123. [doi: [10.2105/AJPH.2006.086678](https://doi.org/10.2105/AJPH.2006.086678)] [Medline: [17413068](https://pubmed.ncbi.nlm.nih.gov/17413068/)]
9. Japan Meteorological Agency. accessed-12-12. 2012. Tables explaining the JMA Seismic Intensity Scale URL: <http://www.jma.go.jp/jma/en/Activities/inttable.pdf> [accessed 2012-12-12] [WebCite Cache ID 6CrJ8Z3mU]
10. Sugiura H, Ohkusa Y, Akahane M, Sano T, Okabe N, Imamura T. Development of a web-based survey for monitoring daily health and its application in an epidemiological survey. *J Med Internet Res* 2011;13(3):e66 [FREE Full text] [doi: [10.2196/jmir.1872](https://doi.org/10.2196/jmir.1872)] [Medline: [21946004](https://pubmed.ncbi.nlm.nih.gov/21946004/)]
11. Kaneko Y, Motohashi Y, Nakamura H, Endo T, Eboshida A. Increasing prevalence of Japanese cedar pollinosis: a meta-regression analysis. *Int Arch Allergy Immunol* 2005 Apr;136(4):365-371. [doi: [10.1159/000084256](https://doi.org/10.1159/000084256)] [Medline: [15746556](https://pubmed.ncbi.nlm.nih.gov/15746556/)]
12. Chen CH, Tan HK, Liao LR, Chen HH, Chan CC, Cheng JJ, et al. Long-term psychological outcome of 1999 Taiwan earthquake survivors: a survey of a high-risk sample with property damage. *Compr Psychiatry* 2007 Jun;48(3):269-275. [doi: [10.1016/j.comppsy.2006.12.003](https://doi.org/10.1016/j.comppsy.2006.12.003)] [Medline: [17445522](https://pubmed.ncbi.nlm.nih.gov/17445522/)]
13. Roy N. The Asian Tsunami: PAHO disaster guidelines in action in India. *Prehosp Disaster Med* 2006 Oct;21(5):310-315. [Medline: [17297900](https://pubmed.ncbi.nlm.nih.gov/17297900/)]
14. Hyodo K, Nakamura K, Oyama M, Yamazaki O, Nakagawa I, Ishigami K, et al. Long-term suicide mortality rates decrease in men and increase in women after the Niigata-Chuetsu earthquake in Japan. *Tohoku J Exp Med* 2010 Feb;220(2):149-155 [FREE Full text] [Medline: [20139666](https://pubmed.ncbi.nlm.nih.gov/20139666/)]
15. Shinfuku N. Disaster mental health: lessons learned from the Hanshin Awaji earthquake. *World Psychiatry* 2002 Oct;1(3):158-159 [FREE Full text] [Medline: [16946841](https://pubmed.ncbi.nlm.nih.gov/16946841/)]
16. Cairo JB, Dutta S, Nawaz H, Hashmi S, Kasl S, Bellido E. The prevalence of posttraumatic stress disorder among adult earthquake survivors in Peru. *Disaster Med Public Health Prep* 2010 Mar;4(1):39-46. [Medline: [20389194](https://pubmed.ncbi.nlm.nih.gov/20389194/)]
17. Neria Y, Nandi A, Galea S. Post-traumatic stress disorder following disasters: a systematic review. *Psychol Med* 2008 Apr;38(4):467-480. [doi: [10.1017/S0033291707001353](https://doi.org/10.1017/S0033291707001353)] [Medline: [17803838](https://pubmed.ncbi.nlm.nih.gov/17803838/)]
18. Pyari TT, Kutty RV, Sarma PS. Risk factors of post-traumatic stress disorder in tsunami survivors of Kanyakumari District, Tamil Nadu, India. *Indian J Psychiatry* 2012 Jan;54(1):48-53 [FREE Full text] [doi: [10.4103/0019-5545.94645](https://doi.org/10.4103/0019-5545.94645)] [Medline: [22556437](https://pubmed.ncbi.nlm.nih.gov/22556437/)]
19. Varela E, Koustouki V, Davos CH, Eleni K. Psychological consequences among adults following the 1999 earthquake in Athens, Greece. *Disasters* 2008 Jun;32(2):280-291. [doi: [10.1111/j.1467-7717.2008.01039.x](https://doi.org/10.1111/j.1467-7717.2008.01039.x)] [Medline: [18380855](https://pubmed.ncbi.nlm.nih.gov/18380855/)]
20. Ekman A, Dickman PW, Klint A, Weiderpass E, Litton JE. Feasibility of using web-based questionnaires in large population-based epidemiological studies. *Eur J Epidemiol* 2006;21(2):103-111. [doi: [10.1007/s10654-005-6030-4](https://doi.org/10.1007/s10654-005-6030-4)] [Medline: [16518678](https://pubmed.ncbi.nlm.nih.gov/16518678/)]
21. Schleyer TK, Forrest JL. Methods for the design and administration of web-based surveys. *J Am Med Inform Assoc* 2000 Aug;7(4):416-425 [FREE Full text] [Medline: [10887169](https://pubmed.ncbi.nlm.nih.gov/10887169/)]
22. Cook C, Heath F, Thompson RL. A meta-analysis of response rates in web- or internet-based surveys. *Educ Psychol Meas* 2000 Dec;60:821-836. [doi: [10.1177/00131640021970934](https://doi.org/10.1177/00131640021970934)]
23. Kim K, Uchiyama M, Okawa M, Liu X, Ogihara R. An epidemiological study of insomnia among the Japanese general population. *Sleep* 2000 Feb 1;23(1):41-47. [Medline: [10678464](https://pubmed.ncbi.nlm.nih.gov/10678464/)]

Abbreviations

- ASD:** acute stress disorder
CO-OP: Consumers' Co-operative Union
JMA: Japan Meteorological Agency
PTSD: post-traumatic stress disorder
-

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Internet survey of the influence of environmental factors on human health: environmental epidemiologic investigation using the web-based daily questionnaire for health

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With increasing Internet coverage, the use of a web-based survey for epidemiological study is a possibility. We performed an investigation in Japan in winter 2008 using the web-based daily questionnaire for health (WDQH). The WDQH is a web-based questionnaire survey formulated to obtain information about the daily physical condition of the general public on a real-time basis, in order to study correlations between changes in physical health and changes in environmental factors. Respondents were asked whether they felt ill and had specific symptoms including fever. We analysed the environmental factors along with the health conditions obtained from the WDQH. Four factors were found to influence health: minimum temperature, hours of sunlight, median humidity and weekday or holiday. The WDQH allowed a daily health survey in the general population in real time via the Internet.

Keywords: web-based survey; environmental factor; minimum temperature; general population

Background

With the rapid progression of Internet technology, a web-based epidemiological survey was developed and implemented for use with the general public (Ekman and Litton 2007). This allowed epidemiological studies to be conducted at lower cost, with greater speed and with higher data precision compared with paper-based or face-to-face surveys on a similar scale (Bennett et al. 2007; Ekman and Litton 2007). Although early web-based surveys were found to be problematic because of population bias, this has been mitigated with the marked increase in the proportion of the population using the Internet (Ekman et al. 2006).

Web-based epidemiological studies came to be implemented for cross-sectional studies as well as for follow-up investigations (Bennett et al. 2007). To date, web-based follow-up surveys have been conducted with patients with specific diseases, but

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not with the general public. Specifically, no studies have been conducted to investigate the correlations between daily environmental changes and the daily physical condition of members of the general public. There is currently concern over human health with regard to air pollution (Huang et al. 2009) and global warming (McMichael et al. 2006). Accordingly, it would be useful to be able to determine the influence of environmental factors on the health of the general population on a daily basis. Therefore, we developed a follow-up survey system using the Internet to question citizens directly on a daily basis. We named this survey the web-based daily questionnaire for health (WDQH).

We then studied the correlations between changes in the daily physical condition of the subjects and changes in environmental factors that are considered to have an influence on health (minimum temperature, hours of sunlight, median humidity, weekday or holiday) using the WDQH.

Methods

Survey method

The WDQH is a prospective survey system designed to conduct a direct health-related questionnaire survey of individuals every day for a certain period to collect and analyse information on a real-time basis. The WDQH has already been put into operation in part, and its usefulness has been established (Sugiura et al. 2010).

Participants

Participants were persons already registered with an existing internet survey company, who noticed the request to participate in the questionnaire survey on the company website, and voluntarily decided to participate. They understood the purpose of the survey, and that it also included information on their families. In this survey, the residential area of the participants was limited to Izumo, a regional city in Japan. We only included those who understood the details of our request and agreed to cooperate in the survey. The population of Izumo is approximately 150,000, with approximately 50,000 households. The study included 702 subjects (333 males, 369 females; mean age 37.4 years; range 16–72 years) from 181 households. We collected information describing the survey participants including their residential district, age, gender, occupation, marital status, number of children and annual income. The survey was performed for 78 days from January 10, 2008 to March 28, 2008.

Questionnaire

The survey required participants to answer questions regarding subjective symptoms every day. The internet survey company sent a reminder email to each subject daily requesting completion of the questionnaire survey. The subject opened the email, accessed his/her personal password and then answered the questionnaire about himself/herself and his/her family. Respondents were asked whether they felt ill. If not, they closed the survey on that day. Those who answered in the affirmative were then asked detailed questions about whether they had any of the following symptoms: fever, coughing, diarrhoea, vomiting, rash, convulsion and others. Remuneration (approximately 60 yen/answer: US\$ 0.75; US\$1.00 = 80 yen at the time of writing) was given to the registered monitors. The survey was repeated every

day over the study period. We analysed and studied the correlations between changes in the daily physical condition of the participants and changes in environmental factors.

Environmental factors

Data describing the following 12 environmental factors are monitored and published by The Japan Meteorological Agency: mean temperature, maximum temperature, minimum temperature, hours of sunlight, cloud cover (the percentage or fraction of the sky obscured by clouds represented by an 11-point scale), median humidity, atmospheric pressure, vapour pressure, precipitation, wind direction, wind speed and weekday or holiday. Data describing these environmental factors in the survey area were collected. Mondays to Fridays were considered weekdays, while Saturdays, Sundays and public holidays were considered to be holidays.

In addition, three individual factors (sex, age and annual income) were included.

The 15 variables were first subjected to principal component analysis. As a result, five principal components were identified. The first component was temperature; the second component was hours of sunlight; the third components were sex and age; the fourth component was wind direction; and the fifth component was median humidity.

Then, the correlation coefficients of all 15 variables were examined. Eight variables (sex, age, annual income, median humidity, precipitation, wind direction, wind speed and weekday or holiday) were included because of no correlations between them. Cloud cover, vapour pressure and atmospheric pressure, which were not extracted as main components and showed strong correlations (correlation coefficient >0.5), were excluded from the variables. Mean temperature was strongly correlated with maximum temperature ($r = 0.924$) and minimum temperature ($r = 0.722$). Hence, a single variable could be selected from mean temperature, maximum temperature and minimum temperature. Minimum temperature, which was not correlated with hours of sunlight ($r = -0.097$), was selected as a variable to negate interaction with hours of sunlight, which was selected as the second component for principal component analysis. Thus, 10 variables were selected: sex, age, annual income, minimum temperature, hours of sunlight, median humidity, precipitation, wind direction, wind speed and weekday or holiday.

Additionally, the 10 selected variables were analysed using generalized estimating equations (GEE). Three variables (precipitation, wind direction and wind speed) showed no significant correlation with any independent variable (ill or healthy and details of symptoms) and were excluded from covariates by a stepwise method. The variables remaining in the final analysis included four environmental factors (minimum temperature, hours of sunlight, median humidity and weekday or holiday).

Statistical analysis

Statistical analysis was conducted using IBM SPSS 20. A p -value <0.05 was considered to indicate significance. Adjusted odds ratios and standard deviations were determined with 95% confidence intervals.

The data used in this study were answers repeatedly collected from the same subject to the same question. We selected the GEE useful for the analysis of repeated

measurements of health results. The repeated measurements included individuals and households as subject variables and days as an intra-subject variable.

Generalized estimating equations was conducted using “ill or healthy” as a dependent variable and three individual factors (sex, age and annual income) and four environmental factors (minimum temperature, hours of sunlight, median humidity and weekday and holiday) as independent variables. The GEE was also performed using presence/absence of specific symptoms (fever, coughing, diarrhoea, vomiting, rash and others) as a dependent variable, and the seven aforementioned independent variables.

Ethics and consent

This research was conducted with the approval of the Ethics Committee of Nara Medical University (Authorization code: 220).

Results

The largest age group of the enrolled subjects was between 35 and 39 years old (37 years old on average) for both males and females. The ratio of males to females of the participants was approximately 1:1. The male and female participants were similar in age distribution. Approximately, 500 completed questionnaires were received each day during the survey period, giving a daily response rate of 35% to 51% (47% on average) (Figure 1). The mean response rate was 48.7% on weekdays and 44.4% on holidays. The everyday responder rate throughout the survey period was 3.2%. Although 34.5% of persons registered to show his/her willingness to answer the survey, they did not respond. As shown in Figure 2, the proportion of respondents who reported that they felt ill during the survey period ranged from 3% to 10% on a daily basis during the survey period.

Table 1 illustrates the outcome of the questionnaire according to gender. There were more female respondents than male respondents who suffered changes in their

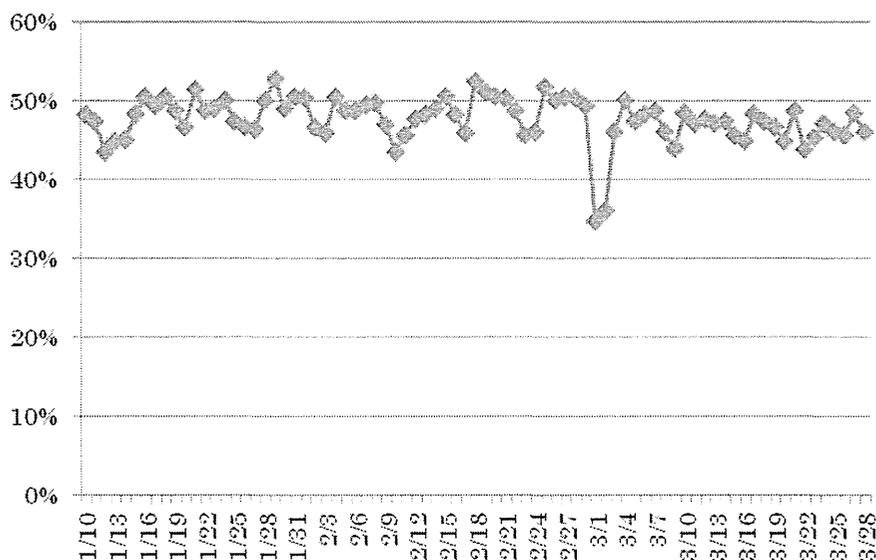


Figure 1. Daily response rate to the questionnaire.

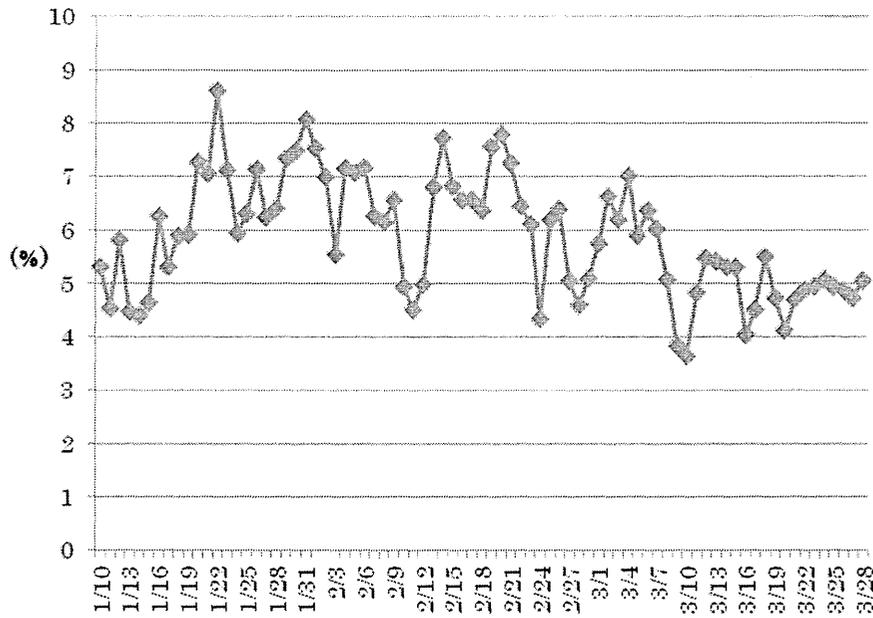


Figure 2. Proportion of respondents who answered that they were ill on specific days.

Table 1. Questionnaire outcomes.

| | Male | | Female | | Total | |
|------------|--------------------------|-------------------------|--------------------------|-------------------------|--------------------------|-------------------------|
| | Presence of symptoms (%) | Absence of symptoms (%) | Presence of symptoms (%) | Absence of symptoms (%) | Presence of symptoms (%) | Absence of symptoms (%) |
| Ill | 1746 (5.7) | 28,830 (94.3) | 2246 (6.9) | 30,274 (93.1) | 3992 (6.3) | 59,104 (93.7) |
| Fever | 247 (0.8) | 30,329 (99.2) | 249 (0.8) | 32,271 (99.2) | 496 (0.8) | 62,600 (99.2) |
| Coughing | 944 (3.1) | 29,632 (96.9) | 958 (2.9) | 31,562 (97.1) | 1902 (3) | 61,194 (97) |
| Diarrhoea | 117 (0.4) | 30,459 (99.6) | 181 (0.6) | 32,339 (99.4) | 298 (0.5) | 62,798 (99.5) |
| Vomiting | 94 (0.3) | 30,482 (99.7) | 116 (0.4) | 32,404 (99.6) | 210 (0.3) | 62,886 (99.7) |
| Rash | 28 (0.1) | 30,548 (99.9) | 34 (0.1) | 32,486 (99.9) | 62 (0.1) | 63,034 (99.9) |
| Convulsion | 19 (0.1) | 30,557 (99.9) | 2 (0) | 32,518 (100) | 21 (0) | 63,075 (100) |
| Others | 768 (2.5) | 29,808 (97.5) | 1602 (4.9) | 30,918 (95.1) | 2370 (3.8) | 60,726 (96.2) |
| Sum total | | 30,576 | | 32,520 | | 63,096 |

physical condition. Coughing accounted for the highest proportion (3%) of an individual symptom suffered by respondents during the survey period.

From principal component analysis, the first principal components were mean temperature, maximum temperature and minimum temperature. The second principal component was hours of sunlight. The third principal components were sex and age. The fourth principal component was wind direction. The fifth principal component was median humidity.

Pearson's correlation coefficients were calculated. Variables strongly correlated were as follows: mean temperature and maximum temperature ($r = 0.924$; $p < 0.001$), mean temperature and minimum temperature ($r = 0.722$; $p < 0.001$), mean temperature and atmospheric pressure ($r = -0.547$; $p < 0.001$), mean temperature and vapour pressure ($r = 0.880$; $p < 0.001$), maximum temperature

and hours of sunlight ($r = 0.566$; $p < 0.001$), maximum temperature and cloud cover ($r = -0.579$; $p < 0.001$), maximum temperature and vapour pressure ($r = 0.779$; $p < 0.001$), minimum temperature and atmospheric pressure ($r = -0.520$; $p < 0.001$), minimum temperature and vapour pressure ($r = 0.760$; $p < 0.001$), atmospheric pressure and vapour pressure ($r = -0.521$; $p < 0.001$).

Table 2 shows the results of the GEE of ill participants. The number of ill subjects was inversely proportional to individual factors (age and annual income) and environmental factors (minimum temperature and hours of sunlight). In addition, fewer people were found to be ill on holidays.

Table 3 shows the results of GEE of individual symptoms. The results revealed that the number with fever, cough, diarrhoea, vomiting and rash decreased with age. Others (unidentified complaints) decreased as annual income increased. Fever and rash decreased as the minimum temperature increased. Additionally, fever and vomiting decreased as hours of sunlight increased. On holidays, cough and others decreased and rash increased.

Discussion

In the present study, the relationship between environmental factors and health conditions, which changed on a daily basis, were analysed from health results in the daily web questionnaire survey. Case control designs, generalized linear models (GLIM), and GEE are useful for such repeated epidemiological analyses. The GEE was established by modifying GLIM, and has been found to be useful for repeated measurements and longitudinal data analysis. The GEE allows unbiased estimation and bias correction for individual confounding factors that may be generated from Internet survey results. They are commonly used in large epidemiological studies, especially multi-site cohort studies as they can handle many types of unmeasured dependence between outcomes (Nitta et al. 2010). Thus, we employed GEE for analysis of the repeated measurements of health results in our web survey to analyse the changes in environmental and health conditions.

Correlations between environmental changes and changes in daily symptoms have been reported for particular diseases (Vocks et al. 2001; Srinivasan et al. 2007; Pantavou et al. 2008). A decrease in temperature is associated with an increase in ischemic cardiac events such as angina pectoris and a rise in blood pressure, while an

Table 2. Generalized estimating equations of ill subjects.

| | Ill | | Healthy | | GEE | | | |
|---------------------|-------|--------|---------|--------|----------|--------|-----------------|-----------------|
| | Mean | SD | Mean | SD | <i>B</i> | SE | <i>p</i> -value | Exp(<i>B</i>) |
| Sex | | | | | 0.099 | 0.2440 | 0.686 | 1.104 |
| Age | 36.15 | 6.460 | 37.90 | 9.000 | -0.023 | 0.0111 | 0.035** | 0.977 |
| Annual income | 3.07 | 1.499 | 3.53 | 1.609 | -0.197 | 0.0893 | 0.027** | 0.821 |
| Minimum temperature | 5.078 | 2.8328 | 5.359 | 2.9440 | -0.029 | 0.0128 | 0.024** | 0.972 |
| Hours of sunlight | 2.873 | 3.1088 | 3.163 | 3.2276 | -0.030 | 0.0111 | 0.007** | 0.971 |
| Median humidity | 76.47 | 7.411 | 76.08 | 7.353 | 0.002 | 0.0035 | 0.563 | 1.002 |
| Weekday or holiday | | | | | 0.122 | 0.0474 | 0.010** | 1.130 |

Notes: ** $p < 0.05$; * $p < 0.1$. The table shows the mean and standard deviation (SD) based on the presence/absence of symptoms for comparison. GEE: generalized estimating equations; SE: standard error.

Table 3. Generalized estimating equations for each symptom.

| | Symptom present | | No symptom | | GEE | | | |
|---------------------|-----------------|--------|------------|--------|--------|--------|---------|--------|
| | Mean | SD | Mean | SD | B | SE | p-value | Exp(B) |
| Fever | | | | | | | | |
| Sex | | | | | 0.046 | 0.2661 | 0.862 | 1.048 |
| Age | 34.78 | 6.924 | 37.82 | 8.895 | -0.044 | 0.0110 | 0.000** | 0.957 |
| Annual income | 3.70 | 1.591 | 3.50 | 1.607 | 0.073 | 0.0637 | 0.250 | 1.076 |
| Minimum temperature | 4.655 | 2.5315 | 5.348 | 2.9407 | -0.058 | 0.0270 | 0.031** | 0.944 |
| Hours of sunlight | 2.578 | 2.8574 | 3.151 | 3.2239 | -0.076 | 0.0254 | 0.003** | 0.926 |
| Median humidity | 76.31 | 7.231 | 76.10 | 7.358 | -0.009 | 0.0088 | 0.32 | 0.991 |
| Weekday or holiday | | | | | 0.080 | 0.1347 | 0.554 | 1.083 |
| <i>Coughing</i> | | | | | | | | |
| Sex | | | | | 0.384 | 0.2593 | 0.138 | 1.469 |
| Age | 36.06 | 5.545 | 37.85 | 8.954 | -0.029 | 0.0080 | 0.000** | 0.971 |
| Annual income | 3.51 | 1.359 | 3.50 | 1.613 | -0.010 | 0.0650 | 0.882 | 0.990 |
| Minimum temperature | 5.015 | 2.8145 | 5.352 | 2.9413 | -0.042 | 0.0223 | 0.062 | 0.959 |
| Hours of sunlight | 2.772 | 3.0623 | 3.157 | 3.2254 | -0.034 | 0.0181 | 0.058 | 0.966 |
| Median humidity | 76.85 | 7.592 | 76.08 | 7.349 | 0.008 | 0.0057 | 0.145 | 1.008 |
| Weekday or holiday | | | | | 0.222 | 0.0697 | 0.001** | 1.248 |
| <i>Diarrhoea</i> | | | | | | | | |
| Sex | | | | | -0.113 | 0.3287 | 0.732 | 0.894 |
| Age | 35.49 | 6.418 | 37.81 | 8.893 | -0.030 | 0.0146 | 0.038** | 0.970 |
| Annual income | 3.55 | 1.664 | 3.50 | 1.607 | 0.026 | 0.0905 | 0.773 | 1.027 |
| Minimum temperature | 5.112 | 2.9279 | 5.344 | 2.9386 | 0.019 | 0.0369 | 0.611 | 1.019 |
| Hours of sunlight | 2.794 | 3.2217 | 3.148 | 3.2217 | -0.032 | 0.0376 | 0.396 | 0.969 |
| Median humidity | 76.55 | 7.174 | 76.10 | 7.357 | 0.002 | 0.0120 | 0.889 | 1.002 |
| Weekday or holiday | | | | | -0.156 | 0.1906 | 0.414 | 0.856 |
| <i>Vomiting</i> | | | | | | | | |
| Sex | | | | | -0.109 | 0.3291 | 0.741 | 0.897 |
| Age | 34.26 | 7.620 | 37.81 | 8.887 | -0.046 | 0.0214 | 0.032** | 0.955 |
| Annual income | 2.97 | 1.632 | 3.50 | 1.607 | -0.217 | 0.1449 | 0.134 | 0.805 |
| Minimum temperature | 4.371 | 2.5365 | 5.346 | 2.9391 | -0.051 | 0.0462 | 0.271 | 0.950 |
| Hours of sunlight | 2.050 | 2.5977 | 3.150 | 3.2228 | -0.135 | 0.0469 | 0.004** | 0.874 |
| Median humidity | 77.35 | 6.879 | 76.10 | 7.358 | 0.001 | 0.0171 | 0.933 | 1.001 |
| Weekday or holiday | | | | | -0.034 | 0.2165 | 0.874 | 0.966 |
| <i>Rash</i> | | | | | | | | |
| Sex | | | | | 1.185 | 1.0015 | 0.237 | 3.270 |
| Age | 28.43 | 3.664 | 37.81 | 8.885 | -0.199 | 0.0326 | 0.000** | 0.617 |
| Annual income | 3.69 | 1.814 | 3.50 | 1.607 | 0.053 | 0.2451 | 0.827 | 1.055 |
| Minimum temperature | 4.786 | 2.9974 | 5.344 | 2.9385 | -0.144 | 0.0643 | 0.025** | 0.866 |
| Hours of sunlight | 3.017 | 3.0967 | 3.147 | 3.2220 | -0.019 | 0.0625 | 0.762 | 0.981 |
| Median humidity | 76.12 | 7.510 | 76.10 | 7.357 | 0.004 | 0.0172 | 0.838 | 1.004 |
| Weekday or holiday | | | | | -0.483 | 0.2155 | 0.025** | 0.617 |
| <i>Others</i> | | | | | | | | |
| Sex | | | | | -0.440 | 0.3542 | 0.214 | 0.644 |
| Age | 36.55 | 6.917 | 37.84 | 8.938 | -0.002 | 0.0147 | 0.913 | 0.998 |
| Annual income | 2.43 | 1.222 | 3.53 | 1.606 | -0.654 | 0.1765 | 0.000** | 0.520 |
| Minimum temperature | 5.214 | 2.8481 | 5.347 | 2.9413 | -0.020 | 0.0150 | 0.189 | 0.981 |
| Hours of sunlight | 3.041 | 3.1820 | 3.151 | 3.2230 | -0.017 | 0.0130 | 0.198 | 0.983 |
| Median humidity | 76.08 | 7.301 | 76.10 | 7.359 | -0.003 | 0.0042 | 0.426 | 0.997 |
| Weekday or holiday | | | | | 0.147 | 0.0609 | 0.016** | 1.159 |

Notes: ** $p < 0.05$; * $p < 0.1$.