INTERNAL MEDICINE

□ ORIGINAL ARTICLE □

Influence of Barometric Pressure in Patients with Migraine Headache

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Abstract

Objective Barometric pressure has been reported as a triggering and exacerbating factor in migraine headaches, although there are few reports concerning the association of weather change and migraine headache. The relationship between barometric pressure changes and migraine headaches was prospectively examined.

Methods A total of 28 migraine patients who lived within 10 km of the Utsunomiya Local Meteorological Observatory kept a headache diary throughout the year. Daily and monthly mean barometric pressure data of the Utsunomiya Local Meteorological Observatory were obtained via the homepage of the Meteorological Office.

Results The correlation between headache frequency obtained by the headache diaries for 1 year and changes in the barometric pressure during the period of 2 days before and 2 days after the headache onset were evaluated. The frequency of migraine increased when the difference in barometric pressure from the day the headache occurred to the day after was lower by more than 5 hPa, and decreased when the difference in barometric pressure from the day the headache occurred to 2 days later was higher by more than 5 hPa. Of 28 patients, weather change was associated with migraine headache development in 18 (64%) patients, 14 of which reported low barometric pressure to be a cause of headache. There was no association between the monthly mean barometric pressure and headache frequency throughout the year.

Conclusion Barometric pressure change can be one of the exacerbating factors of migraine headaches.

Key words: migraine disorders, atmospheric pressure, weather, headache diary

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Introduction

It has been reported that psychological stress (79.7%); hormonal changes in women (65.1%); fasting (57.3%); weather (53.2%); sleep disturbance (49.8%); and light, noise, perfume or odor, food, and alcohol were trigger factors and/or associated with exacerbation of migraine headaches (1). We have treated a number of patients with migraine who had such sensitivity to adverse weather that their headache attacks were triggered by cloudy weather or rain, and were preceded by the approach of a low pressure area. Although meteorological elements include weather, temperature, barometric pressure, humidity, wind and thunder, it is difficult to pinpoint one element that affects migraine headaches. In addition, there are few reports concerning the association of weather change and migraine headache. Cull (2) reported that the frequency of migraine headaches was lower when barometric pressure at 6:00 a.m. was less than 1,005 hPa than when it was more than 1,005 hPa, and when the barometric pressure within the preceding 24 hours of headache had risen more than 15 hPa. However, a fall of barometric pressure over the 24 hours preceding headache onset was not associated with the frequency of migraine headaches in that report. In contrast, recent prospective study revealed that there were correlations of subjective weather perception in migraine patients with meteological data, but after collection for multiple testing these findings were no longer significant (3). Hoffman et al found the association between weather components and the onset and severity of

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attacks in a subgroup of migraineurs (6 out of 20 migraine patients) (4).

We examined the association of barometric pressure changes and migraine headache frequency in patients with migraine with the use of a headache diary over a 1-year period and with daily and monthly barometric pressure data to clarify the effect of changes in barometric pressure following weather changes on the frequency of migraine headache attack.

Patients

The current study was designed to prospectively evaluate the link between barometric pressure changes and migraine headaches. Initially, 170 patients with migraine who visited the headache outpatient department of our hospital were asked to keep a headache diary. The diagnosis of migraine [1.1 (migraine without aura), 1.2 (migraine with aura)] was made according to "The International Classification of Headache Disorders II (ICHD- II)" diagnostic criteria. Since the Utsunomiya area in Tochigi Prefecture included mountainous areas, the effect of pressure was equalized by restricting the patients' domicile to an area within 10 km, which was narrower than the 40-km radius used in a report from Ottawa, Canada (5). We reviewed the patients' headache diaries for 1 year between April 2008 and March 2009. A total of 30 patients with migraine headache who lived within 10 km of the Utsunomiya Local Meteorological Observatory and kept a headache diary throughout the year were analyzed in this study.

Methods

All patients recorded the presence of menstruation, medication use, and their destinations when they left home in headache diaries, in addition to the characteristics of the headache and any behavior or events associated with its onset. In addition, a structured clinical interview regarding the association between headache and weather was administered at each follow-up visit. The correlation between frequency of migraine headaches and weather was evaluated using their headache diaries and medical records as well as the results of the structured clinical interview. The daily and monthly barometric pressure data of the Utsunomiya Local Meteorological Observatory were obtained via the homepage of the Meteorological Office (http://www.jma.go.jp/jma/index.html). The Utsunomiya Local Meteorological Observatory is at the center of the city of Utsunomiya at 36°32.9´N, 139°52.1´E, and 119.4 meters above sea level, with a yearly mean barometric pressure of 997.4 hPa.

For the evaluation of the correlation between mean daily barometric pressure, the barometric pressure at 6:00 a.m., and headache frequencies, the barometric pressures were divided into five groups at interval differences of 5 hPa (lower than 990 hPa; from 990 to lower than 995 hPa; from 995 to lower than 1,000 hPa; from 1,000 to lower than 1,005 hPa; and equal to or more than 1,005 hPa), using the daily mean barometric pressure and the monthly mean barometric pressure. The relationship between headache frequency and the barometric pressure at 6:00 a.m. was also examined, following a previous report (2). Changes in the barometric pressure during the period of 2 days before and 2 days after the headache onset were calculated. The barometric pressure changes were defined as the differences between the levels of the daily mean barometric pressure on the day the headache occurred (n) and 2 days before, (n-2); (n) and 1 day before, (n-1); (n) and 1 day after (n+1); and (n) and 2 days after, (n+2). For the barometric pressure changes on the day the headache occurred (n), the difference was defined as the difference between the maximum and the minimum pressures of the day, since the difference in daily mean barometric pressure could not be applied. The headache frequencies were subdivided into three groups according to the difference in the degree of barometric pressure levels:1) increase in barometric pressure difference >5 hPa, 2) the differences in barometric pressure ranging from -5 hPa to +5 hPa, 3) decrease in barometric pressure difference >5 hPa.

Headaches that occurred during menstruation and in response to psychological fear, certain foods, and the common cold were excluded. Headaches that occurred outside the 10-km range were also excluded from the analysis. The headache frequency was recorded as "2 days" even when the frequency was once but the headache occurred over 2 days, and was recorded as "1 day" even when the headache occurred twice on the same day. The frequency of headaches was calculated as described below (expressed in frequency but not in number of days).

Frequency of headache = [the number of patients with headache on a given date/(total number of patients - the number of patients who were excluded) (by reason of the above exclusion criteria)] ×100

The investigational study was approved by the institutional review board appropriate for each investigator.

Statistical analysis

Chi-square test was used for the comparison of headache frequency between the groups. All tests were two-tailed and conducted at the 0.05 significance level. Microsoft Excel was used for all statistical analyses.

Results

Among 30 migraine patients, 28 (2 men, 26 women; mean age, 38 years) were included in the final analysis; one was excluded because the occurrence of headache in that patient was biased towards a specific day of the week, and another because of pregnancy. Among the 28 patients (9 patients, migraine with aura; 19 patients, migraine without aura), three had hyperlipidemia and two had hypertension.

We designated the weather-sensitive group as the patients who answered that a weather change was associated with migraine headache development in the structured interview.

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Table 1. Clinical Features of the 28 Patients with Migraine

	n	Gender (M/F)	Disease duration (years)	Days of headache / year	Analysis days (days)	Headache frequency (%)
All subjects	28	2/26	17 ± 11	45 ± 21	310 ± 28	14.5
Weather (+)	18	2/16	18 ± 9	44 ± 17	310 ± 31	14.3
Weather (-)	10	0/10	16 ± 15	46 ± 28	310 ± 24	14.9

Weather (+), weather-sensitive group; weather (-), weather-independent groups.

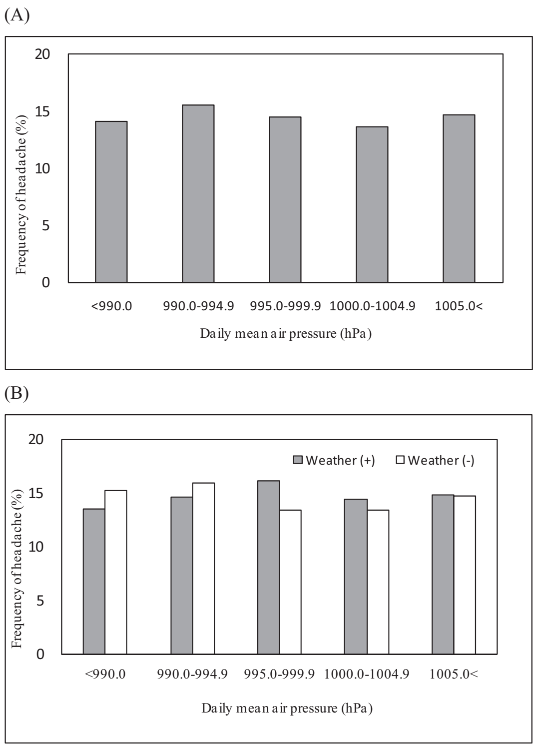

Figure 1. Daily mean barometric pressure and the association of headache frequency in total subjects (A) and in the two groups (B): weather-sensitive group, weather (+); weather-independent group, weather (-).

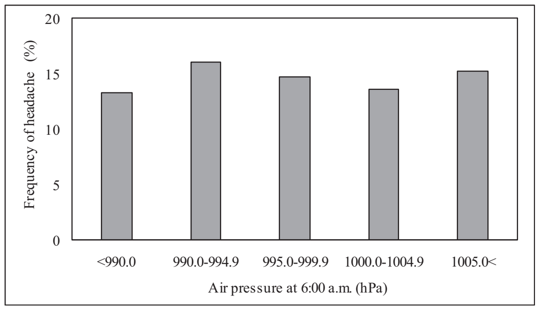

Figure 2. Daily mean barometric pressure and the association of headache frequency with barometric pressure at 6:00 a.m. in total patients.

In other words, the detailed evaluation of medical records and headache diaries in combination with available weather information revealed that of 28 patients, 18 (64%) had headaches that were associated with weather (weather-sensitive group), whereas the remaining 10 patients (36%) showed no correlation between the weather changes and headaches (the weather-independent group). There were no significant differences between the weather-sensitive group and the weather-independent group with regard to age, disease duration, and headache frequency (Table 1). In the weather-sensitive group, 14 patients (78%) reported low barometric pressure to be a cause of headache.

Daily mean barometric pressure, barometric pressure at 6:00 a.m., and headache frequency

There was no significant difference between the weather-sensitive and the weather-independent groups with regard to the relationship of daily mean barometric pressure with headache frequency (Fig. 1B). Furthermore, there was no relationship between the daily mean barometric pressure and migraine headaches (Fig. 1A). The headache frequency was 15.2% when the barometric pressure at 6:00 a.m. was equal to or greater than 1,005 hPa (56 days), whereas it was 13.3% when the barometric pressure was less than 990 hPa (23 days) (Fig. 2). These values were not significantly different from those at any other barometric pressures. In other words, there was no significant relationship between barometric pressure at 6:00 a.m. and migraine headache frequency in this study.

Change in barometric pressure

In all the subjects, the headache frequency significantly decreased (p=0.02; odds ratio, 0.78) when the barometric pressure from the day the headache occurred (n) to 2 days after (n+2) was higher by more than 5 hPa (as compared with when the barometric pressure on (n+2) ranged from -5 to 5 hPa) (Fig. 3A). In the weather-sensitive group, the frequency of headaches significantly increased (p=0.009; odds ratio, 1.27) when the difference in barometric pressure from the day the headache occurred (n) to 1 day after (n+1) was lower by more than 5 hPa (as compared with when the difference in barometric pressure on (n+1) ranged from -5 to 5 hPa) and significantly decreased (p=0.02; odds ratio, 0.84) when the difference in barometric pressure from the day the headache occurred (n) to 2 days after (n+2) was higher by more than 5 hPa (as compared with when the difference in barometric pressure on (n+2) ranged from -5 to 5 hPa) (Fig. 3B). In the case of the weather-independent group, there were no significant differences in headache frequencies at different barometric pressure ranges (Fig. 3C).

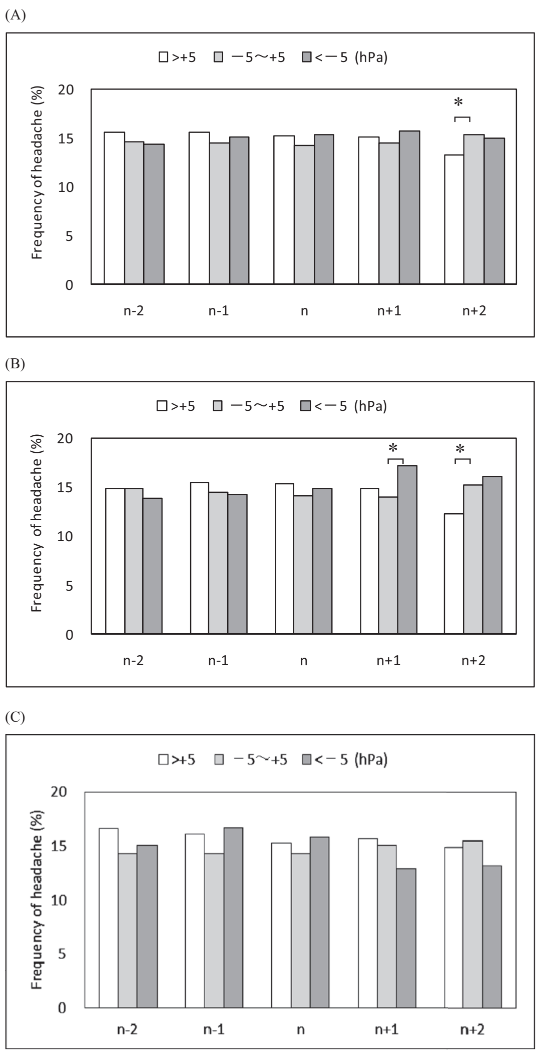

Figure 3. Change in barometric pressure and headache frequency during the period of 2 days before and 2 days after the headache onset in total subjects (A), in weather-sensitive group (B) and in weather-independent group (C).
***indicates p<0.05.**
n, the day the headache onset; n-2, 2 days before the headache onset; n-1, a day before the headache onset; n+1, a day after the headache onset; n+2, 2 days after the headache onset. > +5 hPa, increase in barometric pressure difference > 5 hPa; -5 to +5 hPa, the differences in barometric pressure ranging from -5 hPa to +5 hPa; <-5 hPa, decrease in barometric pressure difference > 5 hPa.

As an example of the increment in headache frequency associated with impending barometric depression, the headache diaries showed that 63% of the patients in the weather-sensitive group had a headache on the day before the arrival of typhoon 4 on May 19, 2008 (the fourth typhoon in that year in the area of Japan as classified by the Japanese meteorological agency), when the barometric pressure decreased by 14.1 hPa, but only 8% of the patients had a headache after the typhoon passed on 21 May 2008. The headache frequency did not increase when the differences of barometric pressure were less than 5 hPa in the cases of typhoons 2, 5, and 11.

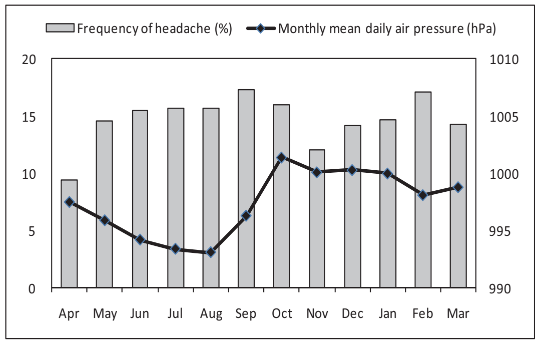

Figure 4. The relationship between monthly barometric pressure and headache frequency.

The monthly mean barometric pressure and headache frequency

In April, the headache frequency decreased (9.4%), and the monthly mean barometric pressure was 997.5 hPa. The headache frequency increased in September (17.3%) and February (17.1%), and the monthly mean barometric pressures were 996.3 and 998.1 hPa, respectively. These pressures did not differ significantly from that of April (Fig. 4). There was no association between the monthly mean barometric pressure and headache frequency. The headache frequency tended to be higher from June to August than from December to February, although the mean barometric pressure and difference in barometric pressures between the day the headache occurred and the day after that were smaller from June to August than those from December to February.

Discussion

We have shown for the first time that migraine headaches are associated with decreased barometric pressure on the following day, but are not associated with barometric pressure on the day the headache occurred. In our study, the frequency of headaches decreased when the difference in barometric pressure from the day the headache occurred to 2 days later was higher by more than 5 hPa, and increased when the difference in barometric pressure from the day the headache occurred to the following day was lower by more than 5 hPa. These results suggest that the headaches occurred during the fall in atmospheric pressure from the day of the headache to the following day. A little over 60% of patients were in this weather-sensitive group in this study, similar to the 37.5-82.5% of weather-sensitive sufferers reported by questionnaire surveys (6-8).

In an examination of 77 patients in the state of Massachusetts, the headache frequency was 32.4% in the case of low atmospheric pressure and 4% in the case of high atmospheric pressure. Importantly, it was 27.3% when the atmospheric pressure decreased and 2.5% when the atmospheric pressure increased, and was 18.1% when the atmospheric pressure was both decreased or increased (9). In the prospective study of 44 patients with migraine headaches in

Scotland, the headache frequency was lower when the atmospheric pressure at 6:00 a.m. was less than 1,005 hPa than when it was more than 1,005 hPa. In addition, a rise in pressure of more than15 hPa over the preceding 24 hours was associated with a reduction of headache, while no association of a decline in atmospheric pressure over the preceding 24 hours with headache frequency was demonstrated (2). In the present study, there was no association between the atmospheric pressure at 6:00 a.m. and the occurrence of migraine headaches on the same day. The reason for this result might be due to the differences in the mean annual atmospheric pressure among the Utsunomiya Local Meteorological Observatory, Japan, which was 997.4 hPa, in Massachusetts USA and in Scotland.

The detailed mechanism for the association of atmospheric depression and headache is unknown; however, chronic pain associated with conditions such as rheumatic disease and osteoarthritis is known to be affected by changes of weather (10, 11). When sympathetic nerves are activated by stress caused by mental strain, pain is often exacerbated; pharmaceutical treatment with a sympathetic block and surgery may be effective for treating this kind of pain. Sato (12) used a climate-controlled room and a chronic-pain rat model and determined that pain was enhanced by reduction in barometric pressure (atmospheric pressure was reduced by 27 hPa in 8 min in the climate-controlled room). A sympathetic nerve-dependent mechanism was inferred to be an important factor for pain. In addition, he showed that a barometric pressure sensor was present in the vestibular region of the inner ear using a rat model with sciatic nerve injury, which destroyed the vestibular apparatus.

Cerebral sensitivity represented by photophobia and phonophobia as described in the diagnostic criteria of "The International Classification of Headache Disorders II" might be considered as another mechanism for the association of headache frequency with the difference in barometric pressure. In severe cases, the abnormal excitability and synchronization phenomenon of the brain site associated with the sensory irritation field sensitizes the limbic cortex with the aggravation of the condition and reinforces memory and chronicity of the externally received stimulation (13). Irritation and abnormalities of the vestibular region of the inner ear are present in patients with migraine headaches. When trigeminal axons of the dural vessels are stimulated by a stress signal from sensing lowered barometric pressure, neuropeptides such as substance P and calcitonin gene-related peptide (CGRP) are secreted, leading to the development of local inflammation, a decrease in the pain threshold of the sensory nerves, dilation of blood vessels, and leakage of plasma proteins into the blood vessels. This activates platelets and 5-HT (serotonin) release, which spreads in a retrograde manner through the axon and excites the trigeminal cells, producing brainstem responses such as nausea/vomiting, and is transmitted to the thalamus and brain cortex, eventually producing pain (14). Increases in neuronal activity in rat spinal trigeminal nucleus following lowering of atmospheric pressure have been reported (15). The atmospheric pressure changes may also influence oral pain (16). Patients with migraine headaches often report dizziness as well as sound irritation (17, 18). The sensitivity of the vestibular region of the inner ear was found to be elevated during atmospheric pressure change, and the possibility of developing repeated migraine headaches leading to increased pain chronicity via reinforced memory has been suggested. Furthermore, since depressive symptoms have been associated with migraine (19), a recent observation that depression-like behavior in rats triggered by lowering barometric pressure (20) suggests a link between weather changes, migraine and depression.

There are some questionable points in the present study. In Japan, the 3-year monthly mean atmospheric pressure level from 1991 was low in the summer (from June to August) and high in the winter (from December to February). In addition, the circadian change and the daily difference in atmospheric pressure between 2 consecutive days were small in the summer and large in the other seasons (21). In Utsunomiya, from April 2008 to March 2009, similar atmospheric pressure conditions were experienced. We would have been able to definitely conclude that there was a relation between headache frequency and atmospheric pressure change if the headache frequency was higher only in the winter season, but the frequency was actually higher even in summer. It is possible that temperature and humidity, thunder, sunlight, and wind influenced headache frequency as well, although in this study those factors were could not be analyzed because of their rapid changes and fluctuations.

In patients with migraine headaches in Norway, headache attacks increased in the season of nights with the midnight sun, and sunlight (exposure amount) was thought to be associated with the frequency of headaches (22, 23). In the Canadian province of Alberta, an association between "Chinook" warm winds blowing from the west during the cold winter and migraine headache was shown (24). In the state of Massachusetts, in a study of 77 patients, an association of headache with temperature and moisture was found in 26 patients (9); however, atmospheric pressure change (a decrease) could be an independent headache exacerbation factor. Guidance for timely prophylaxis is important for patients with migraine headaches when they experience lowered barometric pressure and respond by having migraine headaches.

As a limitation, the present study included a small number of patients with female predominance and we could not evaluate the severity of headache due to daily recording using headache diary but not other questionnaires, such as Migraine Disability Assessment (25). Regarding the method used in this study, patients could predict the weather beyond the next few days by weather forecast, which may have an effect on patients' mood and thus may become a confounding factor in this study. There was no significant relationship of headache frequency with barometric pressure on the day headache occurred, even with barometric pressure at 6.00 a.m, although a significant association was found in comparison to barometric pressure on (n+1) or (n+2) day. It is therefore possible that the increased frequency of headache was attributable to the prolongation and/or worsening during the barometric pressure change rather than the increased induction of migraine attacks. A further study is warranted to determine whether headaches occur before the change in atmospheric pressure and, if so, to clarify the factors contributing to pathophysiological mechanisms in migraine. The link between a change in daily air pressure and migraine frequency, which may reveal important correlations with barometric pressure and migraine, requires further examination.

In conclusion, we have shown that atmospheric pressure changes available as digital information on-line were objectively associated with the migraine headache attacks of patients who recorded their migraine headaches in a headache diary. We may apply these observations to improve migraine headache treatment through medications such as triptans in the future by delivering barometric pressure information to patients through the public media or through handheld units such as cell phones.

The authors state that they have no Conflict of Interest (COI).

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References

1. Kelman L. The triggers or precipitants of the acute migraine attack. Cephalalgia **27**: 394-402, 2007.
2. Cull RE. Barometric pressure and other factors in migraine. Headache **21**: 102-104, 1981.
3. Zebenholzer K, Rudel E, Frantal S, et al. Migraine and weather: A prospective diary-based analysis. Cephalalgia **31**: 391-400, 2011.
4. Hoffmann J, Lo H, Neeb L, Martus P, Reuter U. Weather sensitivity in migraineurs. J Neurol **258**: 596-602, 2011.
5. Villeneuve PJ, Szyszkowicz M, Stieb D, Bourque DA. Weather and emergency room visits for migraine headaches in Ottawa, Canada. Headache **46**: 64-72, 2006.
6. Friedman DI, De Ver Dye T. Migraine and the environment. Headache **49**: 941-952, 2009.
7. Robbins L. Precipitating factors in migraine: a retrospective review of 494 patients. Headache **34**: 214-216, 1994.
8. Turner LC, Molgaard CA, Gardner CH, Rothrock JF, Stang PE. Migraine trigger factors in non-clinical Mexican-American population in San Diego county: implications for etiology. Cephalalgia **15**: 523-530, 1995.
9. Prince PB, Rapoport AM, Sheftell FD, Tepper SJ, Bigal ME. The effect of weather on headache. Headache **44**: 596-602, 2004.
10. Gorin AA, Smyth JM, Weisberg JN, et al. Rheumatoid arthritis patients show weather sensitivity in daily life, but the relationship is not clinically significant. Pain **81**: 173-177, 1999.
11. Guedj D, Weinberger A. Effect of weather conditions on rheumatic patients. Ann Rheum Dis **49**: 158-159, 1990.
12. Sato J. Possible mechanism of weather related pain. Jpn J Biometeor **40**: 219-224, 2003.
13. Rome HP Jr, Rome JD. Limbically augmented pain syndrome (LAPS): kindling, corticolimbic sensitization, and the convergence of affective and sensory symptoms in chronic pain disorders. Pain Med **1**: 7-23, 2000.
14. Moskowitz MA, Macfarlane R. Neurovascular and molecular mechanisms in migraine headaches. Cerebrovasc Brain Metab Rev **5**: 159-177, 1993.
15. Messlinger K, Funakubo M, Sato J, Mizumura K. Increases in neuronal activity in rat spinal trigeminal nucleus following changes in barometric pressure--relevance for weather-associated headaches? Headache **50**: 1449-1463, 2010.
16. Kloss-Brandstatter A, Hachl O, Leitgeb PC, et al. Epidemiologic evidence of barometric pressure changes inducing increased reporting of oral pain. Eur J Pain 2011 in press.
17. Neuhauser H, Leopold M, von Brevern M, Arnold G, Lempert T. The interrelations of migraine, vertigo, and migrainous vertigo. Neurology **56**: 436-441, 2001.
18. von Brevern M, Zeise D, Neuhauser H, Clarke AH, Lempert T. Acute migrainous vertigo: clinical and oculographic findings. Brain **128**: 365-374, 2005.
19. Victor TW, Hu X, Campbell J, White RE, Buse DC, Lipton RB. Association between migraine, anxiety and depression. Cephalalgia **30**: 567-575, 2010.
20. Mizoguchi H, Fukaya K, Mori R, Itoh M, Funakubo M, Sato J. Lowering barometric pressure aggravates depression-like behavior in rats. Behav Brain Res **218**: 190-193, 2011.
21. Yamaguchi T. Barometric changes seen from biometeorology. Jpn J Biometeor **40**: 293-302, 2004.
22. Alstadhaug KB, Salvesen R, Bekkelund SI. Seasonal variation in migraine. Cephalalgia **25**: 811-816, 2005.
23. Salvesen R, Bekkelund SI. Migraine, as compared to other headaches, is worse during midnight-sun summer than during polar night. A questionnaire study in an Arctic population. Headache **40**: 824-829, 2000.
24. Cooke LJ, Rose MS, Becker WJ. Chinook winds and migraine headache. Neurology **54**: 302-307, 2000.
25. Stewart WF, Lipton RB, Whyte J, et al. An international study to assess reliability of the Migraine Disability Assessment (MIDAS) score. Neurology **53**: 988-994, 1999.