

## EXTENDED REPORT

## Weather and the pain in fibromyalgia: are they related?

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**Objectives:** To examine the association between fibromyalgic pain and weather to determine the nature of their interrelationship.

**Methods:** The daily pain ratings of 55 female patients previously diagnosed with fibromyalgia were recorded on visual analogue scales (VAS) over 28 days. These ratings were then related to the official weather parameters and a composite weather variable using time series methodology. Effect sizes  $r$  were calculated from the  $t$  values and  $df$ .

**Results:** A composite weather variable did not significantly predict changes in pain, either the same day ( $t=-1.15$ ,  $df=1483$ ,  $p=0.25$ ) or on the next day ( $t=-1.55$ ,  $df=1483$ ,  $p=0.12$ )—that is, the weather was not a factor for changes in the subjective pain of FM. Patients' pain did not predict weather change in this sample, and neither same day ( $t=-0.69$ ,  $df=1483$ ,  $p<0.49$ ) nor previous day pain ( $t=-1.31$ ,  $df=1483$ ,  $p<0.19$ ) predicted weather changes. A post hoc exploratory analysis showed that those with  $<10$  years of fibromyalgia experienced significantly greater weather sensitivity to pain ( $t=-2.73$ ,  $df=389$ ,  $p<0.006$ ) than those with longer illness.

**Conclusion:** A statistically significant relationship between fibromyalgic pain and the weather was not found in this sample, although it is possible that a group of patients with less chronic fibromyalgia might be weather sensitive.

Patients with fibromyalgia (FM) often report that weather conditions influence their pain.<sup>1,2</sup> In fact, weather sensitivity is a minor criterion for the diagnosis of FM.<sup>3</sup> In a critical review of published reports, however, Quick found only three studies that related the pain in fibromyalgia to weather.<sup>4</sup> Guedj and Weinberger found that barometric pressure affected fibromyalgic pain positively,<sup>5</sup> while de Blécourt *et al* and Hagglund *et al* found no associations.<sup>6,7</sup>

It has been doubted that patients with rheumatism can predict the weather from their pain, although patients have reported this and the claim has been scientifically studied since the 19th century.<sup>8–11</sup> Studies have found increased pain in arthritic conditions that have been associated with living in a poor climate.<sup>12,13</sup> Correlations of rheumatoid arthritic pain (RA) with temperature and relative humidity have also been found.<sup>14,15</sup> McGorry *et al* found a relationship between low back pain and temperature.<sup>16</sup> Positive correlations have been found between relative humidity and pain in osteoarthritis (OA) and RA, humidity and stiffness in RA and cloudiness, humidity and pain in RA.<sup>9,10,15,17</sup> Gorin *et al* found positive associations between pain in RA and cold, overcast days and also following days with high barometric pressure.<sup>18</sup> Pain also increased with changes in the relative humidity from one day to the next in this study, which had a daily, diary design with time series statistics. Negative correlations between temperature and pain in RA have also been noted.<sup>9,10</sup> None the less, several other studies have found no associations between the weather and rheumatic pain.<sup>8,19–21</sup>

In sum, the studies in this field have produced contradictory results and some have even been counterintuitive.<sup>5,14,15</sup> It appears that the subjective experience of weather sensitivity is often greater than it has been possible to demonstrate objectively. Gorin *et al*, therefore, suggested that future research should examine concurrent psychological factors.<sup>18</sup> Aikman noted a large discrepancy between the objective pain measures in patients with RA and OA and their subjective sensitivity to the weather.<sup>9</sup> Hagglund *et al* reported that most patients with fibromyalgia believe that weather affects their symptoms, and noted a strong relationship between patients' weather beliefs and self reported pain scores.<sup>7</sup>

The aim of this study was to evaluate the relationship between the daily weather and pain variations in patients with FM. We focused upon the commonly used weather parameters (barometric pressure, cloudiness, wind speed, relative humidity, temperature, and sunlight).<sup>9</sup>

However, as these variables are intercorrelated, we thought that a stronger and more consistent relationship between FM pain and a composite or overall weather variable was likely. Others have also combined the individual weather parameters for the same reason.<sup>10,20</sup> We expected less strong relationships between fibromyalgic pain and the individual weather parameters, but chose to examine them as well in order to allow for easier comparison with some of the previously published studies.<sup>10</sup>

We chose time series methodology as a response to the suggestions of previous authors, who have noted the need for a more dynamic and directional study of the pain/weather relationship.<sup>9,10,14,18</sup> Time series analysis allows the study of the effect of fluctuations in the weather on pain and vice versa. We used weather changes to predict variations in the same and next day pain. We also examined whether fibromyalgic pain could predict the weather the next day.

## PATIENTS AND METHODS

## Patients

Sixty one female patients previously diagnosed with fibromyalgia were recruited from the Norwegian Association of Fibromyalgia (NAF) for participation in the study. The ethics committee of NAF approved the study before its start and a signed consent to participate was then obtained from all participants. Specialists in either internal medicine or rheumatology had previously diagnosed all of the participants as having fibromyalgia.<sup>22</sup> The patients were initially contacted by

**Abbreviations:** ATQ-30, automatic negative thoughts; BDI, depression; FM, fibromyalgia; MCMI, Millon Clinical Multiaxial Inventory; NAF, Norwegian Association of Fibromyalgia; OA, osteoarthritis; RA, rheumatoid arthritis; STAI-T, trait anxiety; VAS, visual analogue scale

telephone from a list, provided by the local group of patients with fibromyalgia, of those willing to participate. The participants were told that the intention of the study was to analyse the daily fluctuations of their pain. They were not informed that their pain fluctuations would be related to objective weather measurements. Six had to be excluded from the study because of missing pain recordings. A total of 55 women with a mean age of 45.7 (SD 10, range 21–68 years), living in an urban area (Trondheim, Norway), with 11 years (SD 3.1) of formal education and mean disease duration of 15.57 years (SD 9.11, range 3–45 years) completed the study.

## Assessments

### Pain

Each subject rated her pain daily on a 100 mm visual analogue scale (VAS) extending from no pain (0) to very severe pain (100). A VAS has been shown to be a reliable pain measure.<sup>23</sup> This was initially done as an outpatient and recorded after instructions given by a doctor. Subsequently, pain was registered at home in a personal diary at 2 00 pm each day for 28 days.

### Psychological parameters

The participants scored their trait anxiety (STAI-T), automatic negative thoughts (ATQ-30), and depression (BDI) as well as the personality characteristics of anxiousness and dysthymia, derived from the Millon Clinical Multiaxial Inventory (MCMI),<sup>24–27</sup> These instruments are frequently used and considered to be reliable and well accepted measures of these constructs.

### Weather parameters

The National Institute of Meteorology provided the meteorological data, which were measured daily at 2 00 pm: barometric pressure (hectopascal or millibar), cloudiness ranged from 0 (clear)–9 (fog), sunlight (hours of observed sunlight), wind speed (wind velocity in knots), humidity (relative humidity in percentages), and temperature (centigrade). Participants entered the study over several months (March to June).

### Weather variable (factor analysis)

Principal component analysis was used to create a composite weather variable, weather, from the five highly correlated weather parameters ( $r$  range from 0.45 to 0.79) barometric pressure, cloudiness, sunlight, humidity, and temperature. Wind speed was neither correlated with the other weather parameters nor with the pain ratings and was not included in the factor analysis. Thus, the weather variable was the first principal component of the factor analysis of the other five weather parameters, in which increasing values indicated better weather. The total variance explained by the first principal component was 61% (Kaiser-Meyer-Olkin=0.73, Barlett  $\chi^2=4180.8$ ,  $df=10$ ,  $p<0.0001$ ).

## Statistical analysis

### Time series analysis

We examined the relationship between pain and the weather on the previous day, present day, and next day using time series methodology as both the daily pain ratings and the daily weather measurements are short time series. The two series had no other time dependencies (the autocorrelation and partial autocorrelation coefficients of the two AutoRegressive Integrated Moving Average (ARIMA) filtered series were not significant). The adjusted series were then cross correlated in order to look for significant relationships between them.<sup>28</sup>

The SAS Procedure Mixed was used to quantify the relationships between the pain and weather parameters.<sup>29</sup> This procedure calculates the effect of the predictor (weather) across the individual dependent time series (pain) and reports an overall significance across the entire sample. It also allows

the time dependencies between the serial (daily) observations to be taken into account. It was necessary to drop the first observation in each series as we examined the effects of previous day predictor (lagged weather variable) upon the next day's dependent variable (pain).

The program calculates the  $t$  values from the ratio of the regression parameter estimate to its standard error. We also examined the relationship of pain to the single weather parameters: barometric pressure, sunlight, temperature, humidity, and cloudiness, using the same procedure as above. As these variables are moderately highly correlated, the significance levels were adjusted using a Bonferroni correction for each class of predictor (previous day weather parameter, same day, and previous day pain rating). The individual weather parameters were examined only in order to ease comparisons with previously published work.

### Post hoc exploratory analyses

In order to look for factors which might contribute to greater weather sensitivity, we explored post hoc the effects of the duration of the disorder, age, education level, the personality characteristics of anxiousness and dysthymia, as well as the initial levels of negative thoughts, anxiety, and depression upon the relationships between FM pain and the weather.

We also explored post hoc the relationship between the weather and pain on the two days with the greatest rate of weather change during the study (barometric pressure changed 17.7 hPa/24 h). Paired  $t$  tests were used. The purpose was to see if severe weather change was more associated with pain than the more usual daily fluctuations in the weather.

Further details of the analyses are available on request from the first author.

## RESULTS

### Pain and the weather

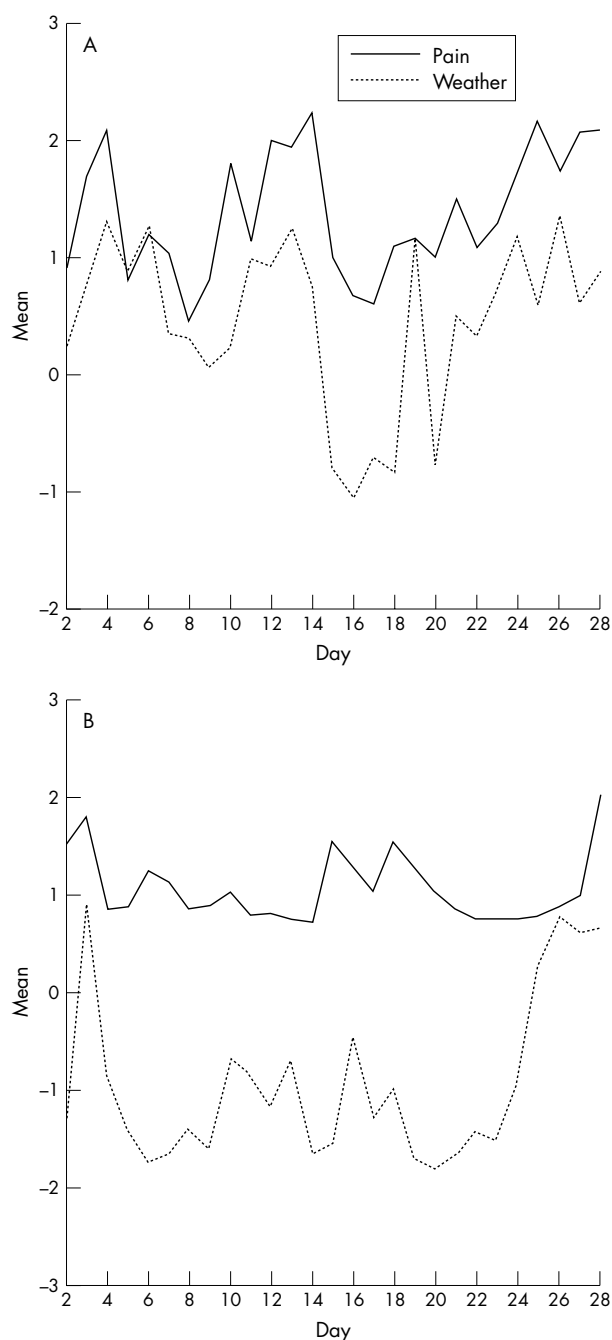
The individual patient's daily pain ratings and the composite daily weather variable were recorded on a graph on the same axis. This was carried out on a random selection of patients in the study. It showed considerable intra- and interindividual variation in the daily pain ratings, a moderate variation of the weather variable, and no obvious visual relationship between them.

There was no overall trend over time in the pain ratings (Pearson's  $r=0.03$ ,  $p>0.3$ ,  $n=1485$ ) or in the weather variable (Pearson's  $r=-0.01$ ,  $p>0.6$ ,  $n=1485$ ), although pain and weather were slightly correlated ( $r=-0.142$ ,  $p<0.001$ ,  $n=1485$ ) during the four week study period. The cross correlation analysis of the adjusted pain and weather series (time effects had been removed) showed that changes in the weather probably preceded increases in pain by one day (ratio of the cross correlation coefficient to its standard error=0.053/0.026=2 indicating possible significance at  $p<0.05$ ). No other lags appeared significant when the ratio of the cross correlation and the standard error were examined.

The main weather measure, the composite weather variable, did not significantly predict changes in pain, either same day ( $t=-1.15$ ,  $df=1483$ ,  $p=0.25$ ) or on the next day ( $t=-1.55$ ,  $df=1483$ ,  $p=0.12$ )—that is, in general, the weather was not a factor in changes of the subjective pain in FM in this sample.

Furthermore, neither did same day ( $t=-0.69$ ,  $df=1483$ ,  $p<0.49$ ) nor previous day pain ( $t=-1.31$ ,  $df=1483$ ,  $p<0.19$ ) predict the weather—that is, patient pain does not appear to predict weather change in this sample.

Using the same approach we examined the relationship of pain to the single weather parameters: barometric pressure, sunlight, temperature, humidity, and cloud cover, in order to allow comparison with previous published work. No single weather parameter approached significance in predicting FM pain (all the adjusted values were  $p>0.2$ ). Likewise, FM pain



**Figure 1** (A) Case 25: Pain (VAS/30) diary vs weather (inverse value) for 28 days. The pain and weather variables are modulated for educational/visual reasons (pain variable is divided by 30 and weather variable is inverse). FM duration is six years. (B) Case 41: pain (VAS/30) v weather (inverse value). FM duration is 30 years.

did not predict changes in any single weather parameter (all the adjusted values were  $p > 0.2$ ).

#### Post hoc exploratory analyses

The duration of FM (mean 15.6, SD 9.5, range 3–45 years) was divided into thirds (<10, 10–20, and >30 years) and the three groups were compared. There were significant interaction effects between the duration of the illness and the effect of the weather upon FM pain ( $F [2.1479] = 4.12$ ,  $p < 0.02$ ). Only the subgroup with <10 years of fibromyalgia experienced increased weather sensitivity in their next day pain ( $t = -2.73$ ,  $df = 1479$ ,  $p = 0.006$ ) when compared with those with the greatest duration of FM. There was no evidence that age, edu-

cation level, initial trait anxiety (STAI-T), initial negative thoughts (ATQ-30), initial depression (BDI) or the personality traits of anxiousness and dysthymia (MCMI) had any effect upon weather sensitivity (the interaction effects with the weather did not significantly predict changes in pain).

We examined the effects of the two days with the greatest weather changes in order to determine if extreme weather changes had greater effects upon pain in fibromyalgia. Those days with great weather change (day 116 v day 117 of the year and day 144 v day 145), did not show a significant relationship between the marked weather change and pain ( $t = 0.995$ ,  $p > 0.05$ ,  $df = 17$ ;  $t = 0.997$ ,  $p > 0.05$ ,  $df = 12$ ). The entire sample was not taking part in the study on these days. Figure 1 shows our results.

#### DISCUSSION

This study did not show that the weather influences fibromyalgic pain, either on the same or the next day. Pain did not predict weather changes on either the same or the next day. None the less, weather and FM pain were slightly, but statistically significantly, correlated.

The study could have detected even very small relationships between the weather and variations in fibromyalgic pain (effect sizes, Pearson's  $r$ , as small as 0.06 could have been detected, based on sample size and calculations from the  $t$  values that we found here).<sup>30</sup> Our finding of only small correlations and no directional effects is consistent with the contradictory findings of earlier studies.<sup>5 9 10 13–17</sup> That is, the findings are of a correlational nature and do not appear to be of a causal, or directional, nature.

Our main findings are in relation to the composite weather variable we created out of five of the meteorological measurements. However, since others have reported the relationships between pain and individual meteorological measures, the relationship between pain and the individual weather parameters are also reported here to enable comparison.<sup>5 9 10 13–16 18</sup> However, none of the single weather parameters had any significant directional relationship with the FM pain.

It has been suggested that not only weather but also the rate and degree of weather change, is related to fibromyalgic pain.<sup>13</sup> Therefore we checked the two days with the greatest rate of weather change in the study. There were no significant pain changes during these days. Thus, our weather/pain findings do not appear to result from a dilution of a pain/weather relationship on those days with rapid weather changes by other days with only minimal weather changes.

The finding that those with FM for less than 10 years had significantly greater weather sensitivity for pain is interesting. It also raises the possibility that a sample of patients with less chronic FM might be weather sensitive. Why patients with FM might be more sensitive to weather changes earlier in their illness than later is uncertain.

There are several possible explanations for our findings. The most likely is that there is no association between fibromyalgic pain and weather. Similarly, the contradictory findings in studies of RA and weather have led to the conclusion that there is no or very modest association between them.<sup>14 15 18</sup>

The discrepancies between our findings and common belief may have several causes. One may be the time at which we measured pain and the weather variable. FM pain was measured at 2 00 pm, which is the period of the day with fewest FM symptoms. It might have been better to assess pain in the morning and later in the afternoon, times associated with greater pain. Another possibility is that patients may tend to attribute their pain to the weather because of its prominence.<sup>31</sup> Alternatively, there may also be a tendency to a confirmatory bias stemming from anecdotal beliefs about pain and weather.<sup>10 31</sup>

Weather sensitivity has been associated with the personality characteristics of the patient.<sup>7</sup> Personality as a factor in FM

pain is uncertain, although high levels of neuroticism are often associated with symptoms of depression and anxiety. Anxiety and depression are associated with the reporting of greater subjective pain.<sup>32,33</sup> High subjective pain sensitivity and low thresholds for pain perceptions are common features in patients with FM.<sup>33</sup> However, we did not find any influence of the initial levels of anxiety and depression or the corresponding personality traits on the relationship between FM pain and the weather.

Thus, the anecdotal beliefs about a directional relationship between FM pain and the weather do not find support in our study. The effect size calculations show that if relationships did exist and we did not detect them, they are probably of little clinical relevance.<sup>30</sup>

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