Rheumatology 2003;42:955–958
doi:10.1093/rheumatology/keg264, available online at www.rheumatology.oupjournals.org
Advance Access publication 14 March 2003

Osteoarthritis pain and weather

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Objective. **To evaluate the association between weather (barometric pressure, precipitation and temperature) and pain among individuals with osteoarthritis (OA) ($n = 154$) at the following sites: neck, hand, shoulder, knee and foot.**
Methods. **This prospective study evaluated men and women, aged 49–90 yr, participating in a community-based, osteoarthritis exercise study (June 1998–January 2002). Weekly self-reported pain scores were collected using a visual analogue scale. Statistical tests, including regression and correlation analyses, were conducted. P values < 0.001 were considered significant.**
Results. **The total number of pain recordings varied by site, ranging from 2269 (feet) to 6061 (hands). The mean temperature was 23°C with a low of 0°C and a high of 36°C. Precipitation levels ranged from 0.00–21.08 cm, with a mean of 0.36 cm. Most associations explored produced non-significant findings. However, among women with hand OA, higher pain was significantly associated with days of rising barometric pressure ($P < 0.001$).**
Conclusion. **Among a population of exercisers aged 49 yr and older, overall these findings did not support the hypothesis that weather is associated with pain. While some associations were suggestive of a relationship, largely these findings indicate that weather is quite modestly, if at all, associated with pain from OA.**

KEY WORDS: Osteoarthritis, Pain, Weather.

Among individuals with arthritis, in spite of increasingly sophisticated epidemiological methods, the purported association between weather and pain largely remains an enigma. A combination of meteorological factors having an adverse effect on the pain of arthritis has been suspected [1–3]. Efforts to differentiate anecdotal suspicions from scientific evidence have led researchers to study perceived weather sensitivity in patients with arthritis, producing directly conflicting results [4, 5]. A 1997 study examining the weather–pain relationship among rheumatoid arthritis (RA) patients suggested that future studies evaluate the effects of weather on other types of arthritis [4]. Among a group of 154 radiologically confirmed osteoarthritis (OA) patients, we evaluated the hypothesis that selected weather indices have no effect on OA pain.

Materials and methods

The study exposure was a given weather condition and the study outcome was self-reported pain level. Climatological data including temperature readings in Celsius (mean, minimum and maximum), barometric pressure (mmHg) and precipitation (cm) were obtained from the US National Oceanic and Atmospheric Administration [6]. Pain was evaluated at the cervical spine, hand, shoulder, knee and foot joints. A subjective phenomenon, pain perception in one joint may contribute to pain perception in other joints. Thus, for each participant, aggregate pain scores for all joints combined were also evaluated. Data collected from the Clearwater Exercise Study (CES) were analysed. Initiated by the Arthritis Research Institute of America, Inc., the CES is a community-based study located in Clearwater, Florida investigating the efficacy of exercise among individuals with OA. The relationship that weather may share with pain was a secondary CES hypothesis. CES inclusion criteria consisted of men and women aged 40 yr or older with radiological evidence of OA, grades 2+, as defined by the Kellgren and Lawrence criteria [7]. Blinded to the current hypothesis, all CES participants were included in our study. Ranging from 49–90 yr, the mean baseline age was 72 yr, with females comprising 71% of the participants. Although the CES minimum inclusion age was 40 yr, the youngest participant was 49 yr.

Conducted from June 1998 to January 2002, follow-up times ranged from 19 to 23 months. Hand OA was defined by disease in one or more of the joint subgroups (right and left second distal interphalangeal, third proximal interphalangeal or first carpometacarpal). Diagnosis of foot OA was defined by disease at either of the first metatarsophalangeal joints. A visual analogue scale measured pain severity, where 0 = no pain and

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Submitted 26 August 2002; revised version accepted 3 January 2003.

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10 = severe pain. Prior to exercising, participants recorded their pain scores weekly. Individuals with OA at multiple sites were included in analyses for the respective sites. Owing to the sparseness of published literature regarding weather and OA pain, these data were analysed collectively and also stratified by gender.

Spearman correlation coefficients [8] assessed the relationship between pain and the continuous, absolute values of temperature, barometric pressure and precipitation. A time-series analysis explored the weather's predictive ability on pain using 1-day lagging and leading weather parameters. The average daily pain levels for all participants combined were calculated. Pain scores were analysed with weather conditions noted 1 day prior to the score (1-day lagging) and 1 day after the score (1-day leading). For the correlation analyses each point represented a date, testing the null hypothesis that the correlation between a weather index and pain was zero. Regression analyses were used to assess the individuals' relationships between pain and barometric pressure status and direction, as well as precipitation status. This statistical approach accommodated our ordinal response variable, use of repeated measurements and the ability to control for potential confounding by using the generalized estimating equation method [9].

Models testing barometric pressure direction as a predictor of pain from OA were adjusted for the absolute value of barometric pressure. PROC GENMOD in SAS [10] software was used. Power calculations for the correlation analyses indicated this study had over 80% power to detect a rho of 0.25 or higher, if one existed ($\alpha = 0.05$; two-tailed) [11]. Power analyses for the regression models with an ordinal dependent variable using repeated measures were estimated by calculating figures based upon a simpler statistical approach [11]. Calculations appropriate for a *t*-statistic noted the study had over 80% power to detect a 30% or greater difference between the groups, if one existed ($\alpha = 0.05$; two-tailed). Since multiple comparisons were made, an *a priori* alpha rejection level was set at 0.001 [12].

Results

The total number of pain recordings varied by site, ranging from 2269 (feet) to 6061 (hands). For all five sites, pain levels assumed values from 0–10, with mean scores spanning from 1.2–2.5 and corresponding standard deviations ranging from 2.1–2.7. The mean temperature was 23°C with a low of 0°C and a high of 36°C. Precipitation levels ranged from 0.00–21.08 cm, with a mean of 0.36 cm. Barometric pressure direction (rising, falling and steady) was analysed with the corresponding days' pain scores. Women demonstrated significant unadjusted associations with hand, foot and aggregate (all five sites combined) pain on days of rising barometric pressure ($P < 0.0009$, < 0.001, < 0.0001, respectively). After controlling for the influence of the absolute value of barometric pressure, only hand pain retained statistical significance with days of rising barometric pressure ($P < 0.001$). Likewise, women showed a negative association between hand ($P < 0.0009$), foot ($P < 0.0001$) and aggregate ($P < 0.0001$) pain on days of falling barometric pressure. For the three sites, however, adjusted estimates produced non-significant associations with days of falling barometric pressure ($P = 0.53$, 0.31, and 0.97, respectively). Men displayed no association with pain during days of rising nor falling barometric pressure, with adjusted P values ranging from 0.28–0.95. Among both females and males, days of steady barometric pressure revealed no significant relationship with the corresponding days' OA pain recordings.

Second, the relationship between OA pain and barometric pressure on days when the barometric pressure direction had been the same for 3 consecutive days was evaluated. For example, when the barometric pressure had been rising on Wednesday, Thursday and Friday, Friday's pain score was assessed for a relationship with barometric pressure direction. Consecutive days of rising barometric pressure indicated a significant relationship with the aggregate pain level ($P < 0.0008$). Subsequent adjustment for the barometric pressure absolute value suggested no association ($P = 0.68$). Consecutive days of falling barometric pressure indicated no predictive ability on OA pain with adjusted P values ranging from 0.43–0.99. Similarly, consecutive days of steady barometric pressure exhibited no association with pain, producing P values ranging from 0.48–0.95.

Our third approach examined the relationship between pain and a recent change in barometric pressure direction. Three-day time periods were evaluated. Aggregate pain was associated with days of falling barometric pressure that were preceded by two consecutive days of steady barometric pressure ($P < 0.001$). However, this relationship did not retain statistical significance after adjustment ($P = 0.60$). Days of rising barometric pressure preceded by 2 days of steady pressure showed no association with pain. The following patterns of barometric pressure direction were also tested, all suggesting no predictive ability for pain from OA at any of the five sites (P values ranging from 0.33–0.99): falling preceded by 2 days of rising, rising preceded by 2 days of falling and steady preceded by 2 days of rising.

Precipitation status, analysed with the corresponding days' pain scores, indicated no association as indicated by P values ranging from 0.02–0.71. Our sample data, limited by the lack of consecutive days of precipitation, focused on the effect of no precipitation. Non-significant findings were noted for the relationship between OA pain and 3 consecutive days of no rain.

Lastly, site-specific correlation analyses of aggregate mean pain scores with the weather indices produced rho values ranging from -0.07 to $+0.15$ (Table 1). Largely, no discernable patterns were noted. A significant, albeit modest, association was reflected between 1-day lagged precipitation and OA foot pain (rho = 0.15; $P < 0.001$).

Discussion

Three weather conditions were examined for an association with OA-related pain at five body sites, as well as with individuals' aggregate pain scores. Among a population of exercisers aged 49 yr and older, overall these findings did not support the hypothesis that weather is associated with pain from OA. While some associations were suggestive of a relationship, largely these findings indicate that weather is quite modestly, if at all, associated with pain level among individuals with OA.

TABLE 1. Meteorological indices' association with site-specific OA pain (Spearman correlation coefficients)

Weather index	Neck	Hand	Shoulder	Knee	Foot	Aggregate[a]
Mean temperature	0.07	0.01	0.02	0.06	0.12	0.08
Minimum temperature	0.07	0.02	0.01	0.07	0.13	0.07
Maximum temperature	0.07	0.01	0.04	0.05	0.10	0.08
Mean temperature 1-day lagging	0.05	0.00	0.02	0.06	0.11	0.07
Mean temperature 1-day leading	0.06	0.00	0.02	0.05	0.12	0.07
Barometric pressure	0.07	0.03	0.08	0.04	0.06	0.02
Barometric pressure 1-day lagging	0.05	0.04	0.02	0.06	0.01	0.04
Barometric pressure 1-day leading	0.05	0.14	0.07	0.07	0.00	0.10
Precipitation level	0.07	0.08	0.10	0.00	0.03	0.06
Precipitation level 1-day lagging	0.04	0.00	0.07	0.01	0.15*	0.00
Precipitation level 1-day leading	0.01	0.01	0.02	0.02	0.03	0.02

*P value < 0.001.
[a]Summation of the study subjects' combined five pain scores.
Each plotted point represented a date. x-axis = weather data; y-axis = patients' aggregate site-specific pain score. 1-day lagging/leading = weather index value 1 day prior/subsequent to the pain assessment.

To a large degree, these findings suggest that women experience an enhanced relationship between pain and weather compared with their male counterparts. Various approaches were used to evaluate the relationship between OA pain and weather. Numerous unadjusted relationships were highly statistically significant. For analyses testing barometric pressure direction, consideration of the absolute value of barometric pressure produced dramatically different results. After adjustment, only one test achieved statistical significance. Among women with hand OA, days of rising barometric pressure suggested higher pain levels ($P < 0.001$). Precipitation contributed little to the explanation of the weather–pain relationship. However, our ability to demonstrate this may have been restricted owing to the fewer number of days with precipitation.

Past attempts to summarize the weather's influence on pain from arthritis have generated equivocal conclusions. Results from this investigation are consistent with previously published findings [4, 13–16], yet contradictory to other published results [5, 17–23]. Although previous studies have examined populations living in cold environments [13–16, 18, 19, 24–26], several studies have assessed this relationship in warmer climates without extreme variations in temperature [17, 21, 27]. A 1995 study summarized this relationship in four US cites selected for their differing climates [27]. Chronic pain patients living in San Diego (a warm and wet climate) showed the most sensitivity to seasonal changes notwithstanding greater temperature stability than existed in the other climates studied. Studying a group of OA patients in Florida has contributed to our knowledge by examining this relationship in a warm environment.

Four factors that could have influenced our results are worthy of mention. Participants were feeling well enough to carry out their exercise routine, possibly producing overall lower pain scores. Although one related study noted the exclusion of pain data owing to an 'excess of physical activity' [17], we suggest that the associations reported within may have been underestimated based on the activity level of our study sample. We do not want to dismiss the potential influence of the exposure to exercise. However, if regular exercise diminishes the effect of weather on pain from OA, the associations reported within may have a more pronounced effect on non-exercising OA populations. Second, a potentially mitigating factor, inconsistencies in an individual's medication usage could contribute to a portion of the variation in pain level. The current study was limited by the inability to track changes in an individual's use of pain-relieving drugs. While the vast majority of related articles have not addressed medication usage, a few have mentioned this [4, 17, 26]. Third, although we experienced temperature variation during the study period, there were relatively fewer days experiencing cold weather. Approximately 19% of the dates recorded temperatures $<19°C$. This may have contributed to finding no association in the correlation analyses. Lastly, it is clear that the plethora of issues involved produces a convoluted web of factors for simultaneous consideration when examining this relationship. As with previous related studies, our inability to hold constant the multitude of extraneous factors potentially influencing this relationship could have prevented this study from finding a clear association (Table 2).

The current study hopes to augment the existing literature through the following three areas. This study reported the weather–pain relationship at five OA sites: cervical spine, hand, shoulder, knee and foot. A review of the arthritis pain–weather literature does not find site-specific reporting of results. While our findings presented no discernable patterns in the relationship by site, the hands seem to be more affected than other sites. Previous studies examining this relationship among OA patients have utilized sample sizes ranging from 24–53 patients [4, 15–17, 21]. While several similar studies have reported findings on individuals with rheumatoid arthritis, the current study reports results on a relatively larger group of individuals with OA ($n = 154$). Lastly, while the majority of related studies have been conducted in colder climates, this study adds to the body of data examining this relationship in a warmer climate.

If indeed a relationship exists, how would the elucidation of this age-old conundrum affect the quality

TABLE 2. Factors influencing the relationship between weather and pain

Pain-related:
1. Differing classifications of disease (RA, OA, fibromyalgia, gout, etc.)
2. Severity of disease
3. Geographic area of residence
4. Length of time living in geographic area
5. Length of time since disease development
6. Age of patient
7. Exposure to natural *vs* artificial climate
8. Time of day of pain assessment
9. Scales of pain measurement
10. Inconsistent pain relief usage (aspirin, NSAIDs, paracetamol, narcotics; and dosage)
11. Stress and other psychological influences
12. Hormonal changes
Weather-related:
1. Numerous weather indices (e.g. barometric pressure, temperature, wind speed, precipitation)
2. Direction (e.g. barometric pressure or temperature rising/falling)
3. Season of year
4. Wet/dry climate
5. Cold/hot climate
6. Number of days lagging or leading (e.g. 5-day lag, 1-day lead)
7. Time of day of condition assessment (e.g. morning barometric pressure, evening wind speed)
8. Permutations of weather conditions (e.g. falling barometric pressure and rising temperature)

of life for OA patients? If weather does share a relationship with OA pain, clarification of the associated weather component(s) would enhance the quality of life for millions of patients. Patberg [26] stated that manipulation of the microclimate might become a valuable addition to the treatment of OA. Past research examining this relationship employed methodological approaches that have varied widely. Future studies may want to utilize a uniform approach, reducing the likelihood of equivocal results due to design considerations. Additionally, future analyses, which could also evaluate OA stiffness as an outcome, stratified by age group, gender and site-specific OA may serve to enhance our understanding of the mechanism(s) involved in this relationship.

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