The Influence of Weather Conditions on Joint Pain in Older People with Osteoarthritis: Results from the European Project on OSteoArthritis

Erik J. Timmermans, Laura A. Schaap, Florian Herbolsheimer, Elaine M. Dennison, Stefania Maggi, Nancy L. Pedersen, Maria Victoria Castell, Michael D. Denkinger, Mark H. Edwards, Federica Limongi, Mercedes Sánchez-Martínez, Paola Siviero, Rocio Queipo, Richard Peter, Suzan van der Pas, and Dorly J.H. Deeg
for the EPOSA Research Group

ABSTRACT. ***Objective.*** This study examined whether daily weather conditions, 3-day average weather conditions, and changes in weather conditions influence joint pain in older people with osteoarthritis (OA) in 6 European countries.

Methods. Data from the population-based European Project on OSteoArthritis were used. The American College of Rheumatology classification criteria were used to diagnose OA in older people (65–85 yrs). After the baseline interview, at 6 months, and after the 12–18 months followup interview, joint pain was assessed using 2-week pain calendars. Daily values for temperature, precipitation, atmospheric pressure, relative humidity, and wind speed were obtained from local weather stations. Multilevel regression modelling was used to examine the pain-weather associations, adjusted for several confounders.

Results. The study included 810 participants with OA in the knee, hand, and/or hip. After adjustment, there were significant associations of joint pain with daily average humidity ($B = 0.004$, $p < 0.01$) and 3-day average humidity ($B = 0.004$, $p = 0.01$). A significant interaction effect was found between daily average humidity and temperature on joint pain. The effect of humidity on pain was stronger in relatively cold weather conditions. Changes in weather variables between 2 consecutive days were not significantly associated with reported joint pain.

Conclusion. The associations between pain and daily average weather conditions suggest that a causal relationship exist between joint pain and weather variables, but the associations between day-to-day weather changes and pain do not confirm causation. Knowledge about the relationship between joint pain in OA and weather may help individuals with OA, physicians, and therapists to better understand and manage fluctuations in pain. (First Release September 1 2015; J Rheumatol 2015;42:1885–92; doi:10.3899/jrheum.141594)

Key Indexing Terms:
JOINT PAIN · OLDER POPULATION · OSTEOARTHRITIS
WEATHER · WEATHER SENSITIVITY

From the Department of Epidemiology and Biostatistics, EMGO Institute for Health and Care Research, Vrije Universiteit (VU) University Medical Center; Department of Health Sciences, Faculty of Earth and Life Sciences, VU University Amsterdam, Amsterdam, the Netherlands; Institute of the History, Philosophy and Ethics of Medicine, University of Ulm; Bethesda Geriatric Clinic, University of Ulm, Ulm, Germany; Medical Research Council (MRC) Lifecourse Epidemiology Unit, University of Southampton, Southampton General Hospital, Southampton, UK; National Research Council, Institute of Neuroscience, Aging Branch, Padova, Italy; Department of Medical Epidemiology and Biostatistics, Karolinska Institutet, Stockholm, Sweden; Department of Preventive Medicine and Public Health, Unit of Primary Care and Family Medicine, Faculty of Medicine, Universidad Autonoma de Madrid, Madrid, Spain.

The Indicators for Monitoring Chronic Obstructive Pulmonary Disease and Asthma - Activity and Function in the Elderly in Ulm study (IMCA - ActiFE) was supported by the European Union (No. 2005121) and the Ministry of Science, Baden-Württemberg. The Italian cohort study is part of the National Research Council Project on Aging (PNR). The Longitudinal Aging Study Amsterdam (LASA) is financially supported by the Dutch Ministry of Health, Welfare and Sports. The Peñagrande study was partially supported by the National Fund for Health Research (Fondo de Investigaciones en Salud) of Spain (project numbers FIS PI 05/1898; FIS RETICEF RD06/0013/1013 and FIS PS09/02143). The Swedish Twin Registry is supported in part by the Swedish Ministry of Higher Education. The Hertfordshire Cohort Study is funded by the Medical Research Council of Great Britain, Arthritis Research UK, the British Heart Foundation, and the International Osteoporosis Foundation.

E.J. Timmermans, MSc, Department of Epidemiology and Biostatistics, EMGO Institute for Health and Care Research, VU University Medical Center; L.A. Schaap, PhD, Department of Health Sciences, Faculty of Earth and Life Sciences, VU University Amsterdam; F. Herbolsheimer, MSc, Institute of the History, Philosophy and Ethics of Medicine, University of Ulm; E.M. Dennison, PhD, Professor, MRC Lifecourse Epidemiology Unit, University of Southampton, Southampton General Hospital; S. Maggi, PhD, National Research Council, Institute of Neuroscience, Aging Branch; N.L. Pedersen, PhD, Professor, Department of Medical Epidemiology and Biostatistics, Karolinska Institutet; M.V. Castell, PhD, Department of Preventive Medicine and Public Health,

Personal non-commercial use only. The Journal of Rheumatology Copyright © 2015. All rights reserved.

Downloaded on April 10, 2024 from www.jrheum.org

Unit of Primary Care and Family Medicine, Faculty of Medicine, Universidad Autonoma de Madrid; M.D. Denkinger, PhD, Bethesda Geriatric Clinic, University of Ulm; M.H. Edwards, PhD, MRC Lifecourse Epidemiology Unit, University of Southampton, Southampton General Hospital; F. Limongi, PhD, National Research Council, Institute of Neuroscience, Aging Branch; M. Sánchez-Martínez, PhD, Department of Preventive Medicine and Public Health, Unit of Primary Care and Family Medicine, Faculty of Medicine, Universidad Autonoma de Madrid; P. Siviero, MSc, National Research Council, Institute of Neuroscience, Aging Branch; R. Queipo, MSc, Department of Preventive Medicine and Public Health, Unit of Primary Care and Family Medicine, Faculty of Medicine, Universidad Autonoma de Madrid; R. Peter, PhD, Professor, Institute of the History, Philosophy and Ethics of Medicine, University of Ulm; S. van der Pas, PhD, Department of Epidemiology and Biostatistics, EMGO Institute for Health and Care Research, VU University Medical Center; D.J. Deeg, PhD, Professor, Department of Epidemiology and Biostatistics, EMGO Institute for Health and Care Research, VU University Medical Center.

Address correspondence to Erik J. Timmermans, Department of Epidemiology and Biostatistics, EMGO Institute for Health and Care Research, VU University Medical Center, Boelelaan 1089A, 1081 HV Amsterdam, the Netherlands. E-mail: ej.timmermans@vumc.nl

Accepted for publication June 29, 2015.

Osteoarthritis (OA) is a process or condition affecting the joint cartilage and subchondral bone, and is frequently accompanied by pain, stiffness, and disability[1,2]. Persons with OA frequently report that weather conditions affect their pain levels. In particular, damp/rainy and cold weather conditions are perceived to affect joint pain in people with OA[3,4]. However, previous studies investigating the relationship between objective meteorological conditions and joint pain in OA have been inconclusive and contradictory[5,6]. The objective of our study is to examine whether weather conditions influence joint pain in older people with OA in 6 European countries.

Various mechanisms have been suggested to explain the effects of certain weather conditions on joint pain in OA[6,7,8]. Since tendons, muscles, bones, and scar tissues are of varied densities, differential expansions and contractions attributable to the changes in humidity and temperature may result in pain at sites of microtrauma[6,8]. Alterations of atmospheric pressure and temperature may increase stiffness in joints and make joints more sensitive to the pain of mechanical stresses. Changes in atmospheric pressure may also cause a transient disequilibrium in body pressure that may sensitize nerve endings[6,8]. Empirical evidence on these mechanisms is lacking, and large-scale epidemiological research is needed to examine whether the association between joint pain in OA and weather exists.

Previous studies have examined the relationship between joint pain in OA and meteorological conditions[5,6] such as temperature[9,10,11,12,13,14], precipitation[9,10,11,14,15], atmospheric pressure[7,9,10,11,12,13,14,16], humidity[9,11,12,13,16,17], and wind speed[9,11,15] , and show conflicting results[5,6]. Several methodological limitations are presented among the body of current evidence[5,6]. Particular problems include disclosure of the study hypothesis to participants and the small study size. Further, many studies focused on static 24-h average conditions instead of changes in the weather. Individuals with OA often report that their joint pain becomes worse during weather changes[3,6]. However, most studies focused on effects of weather conditions in the short term instead of ambient weather conditions and weather changes immediately preceding each pain report. Further, most studies were performed at single geographical sites, resulting in limited geographic and meteorological variability. An exception is a study[18] that investigated the relationship between meteorological variables and joint pain in 200 individuals with knee OA. Participants were geographically dispersed within the United States and were informed about the study hypotheses only after the data collection concluded. The findings revealed that both an increase in atmospheric pressure and a decrease in ambient temperature (the average temperature in the 3 days prior to a pain report) were associated with increased pain in OA.

Our population-based study extended previous research by including a large sample of older persons with OA in the knee, hand, and/or hip, living across 6 European countries. The association between 3-day average weather conditions and pain has never been studied in persons with OA across Europe. Our study aimed to examine whether average daily weather conditions, 3-day average weather conditions, and changes in weather conditions were associated with (day-to-day changes in) joint pain in older people with OA in 6 European countries. In addition, the effects of combinations of daily and 3-day average weather variables on joint pain in OA were examined. It was hypothesized that cold and humid weather conditions, as well as changes in atmospheric pressure, led to more pain in older people with OA.

MATERIALS AND METHODS

Design and study sample. Data from the European Project on OSteoArthritis (EPOSA) were used. The EPOSA study focused on the personal and societal burden, and its determinants of OA in older persons. A detailed description of the study design and data collection of the EPOSA study is described elsewhere[19]. Random samples were taken from existing population-based cohorts in 5 European countries (Germany, the Netherlands, Spain, Sweden, and the United Kingdom). In Italy, a new sample was drawn. A total of 2942 respondents (response rate, ranging from 64.6% to 82.2%, averaging 72.8%) were included at baseline. The age range was 65–85 years in most countries except for the United Kingdom, which had an age range of 71–79 years. All participants were interviewed by a trained researcher at home or in a clinical center using a standardized questionnaire and a clinical examination. The baseline and followup interview lasted about 90 minutes. All participants completed an informed consent. For all 6 countries, the study design and procedures were approved by the Medical Ethics committee of the respective centers.

The clinical classification criteria, developed by the American College of Rheumatology (ACR)[20], were used to determine OA. The ACR criteria for knee, hand, or hip OA were satisfied in 889 participants (31.7%) at baseline. At the end of the baseline interview (t0), all 889 participants with OA were invited to complete a pain calendar on which they were asked to score per day the level of joint pain for the following 2 weeks. In total, 784 participants (88.3%) returned the baseline pain calendar, and 750 baseline pain calendars (84.3%) were included in the analyses (e.g., these pain calendars had no missing data on all dates). Six months after the baseline

Personal non-commercial use only. The Journal of Rheumatology Copyright © 2015. All rights reserved.

Downloaded on April 10, 2024 from www.jrheum.org

interview (t1), 681 participants received a pain calendar. Of those people, 506 (74.4%) returned the pain calendar at t1. In total, 490 (72.1%) pain calendars at t1 were used in the analyses. After the 12–18 month followup interview (t2), 697 participants received a pain calendar. Of those participants, 636 (91.3%) returned the pain calendar at t2. In total, 606 pain calendars (87.0%) at t2 were used in the analyses.

Of all 889 participants with OA at baseline, 810 persons had data available on at least 2 days of the 3 pain calendars. These participants were included in the final study sample. The proportions of women and people with depression were higher in the excluded group (n = 79) compared with the included group (n = 810). Further, the excluded persons were older and received pain medication on fewer days compared with the included persons.

Measures

Dependent variable: Joint pain. After the baseline interview, 6 months later, and after the 12–18 month followup interview, participants were asked to complete a 2-week pain calendar. The pain calendars were completed by the participants in the period between December 2010 and February 2013. Per day, respondents indicated how much joint pain they experienced on an 11-point rating scale from 0 to 10 with 0 representing no pain and 10 representing the greatest pain intensity. The number of pain reports per respondent ranged from 2 to the maximum of 42. For each participant, change in pain was calculated as the difference in perceived joint pain intensity between 2 consecutive days. The number of measures on changes in joint pain ranged from 0 to a maximum of 39 across respondents.

Independent variables: Meteorological data and meteorological exposure definitions. Data-collecting weather stations provided local daily average values for temperature (°C), precipitation (mm), atmospheric pressure (hPa), relative humidity (percentages), and wind speed (m/s) for every participant for each day of their participation in the study period. The maximum distance between a weather station and a participant's residence was within 80 km. From the daily average values, 3-day average values and change values were derived for each participant. The 3-day average values consisted of the means of the daily averages over the 3-day periods before each pain report. Change in weather variables was computed as the difference in each meteorological variable between the day before each pain report and the day of the pain report itself[18].

Potential Confounders

Sociodemographic variables. Sociodemographic information was obtained on participants' age, sex, and country of residence. To account for minor sampling differences across cohort studies, the analyses are adjusted for country of residence. Participants were living in 6 European countries, including Germany, Italy, the Netherlands, Spain, Sweden, and the United Kingdom. This variable was dummy coded with Sweden as the reference category because the Swedish respondents reported, on average, the lowest joint pain intensity.

Depression. At t0 and t2, depressive symptoms were examined using the 7 four-point, Likert-scaled items of the Hospital Anxiety Depression Scale that are related to depression (HADS-D)[21]. The HADS-D has a range from 0–21. The HADS-D was used as a categorical variable with a cutoff level of 8 or more for the presence of depression (yes/no).

Medication use. Simultaneously with the pain calendars, participants were asked daily to indicate changes in medication use. This was assessed by asking participants whether they received additional pain medication because of joint pain (yes/no).

Statistical analyses. One-way ANOVA analyses and Kruskal-Wallis tests were performed to examine differences in joint pain and meteorological exposure across countries and seasons. All descriptive statistics, except sex, age, country, and the weather variables, were weighted to the European standard population in 2010. The weights were calculated per sex and per 5-year age category, using the formula:

$$W = Nexp \div Nobs$$

The Nobs was the number of persons in a specific age/sex category in the cohort, and Nexp was the number of persons in a specific age/sex category in the European standard population in 2010[22].

Multilevel regression modelling was used to examine the associations between the weather variables and (day-to-day changes in) joint pain. In these models, the joint pain intensity measures and the measures of the weather variables (level 1) were nested within 810 participants (level 2) who completed at least 2 individual pain reports of the 3 pain calendars. Participants with some missing data could remain in the analysis, thereby increasing the precision of the estimates and the power of the statistical tests[23].

A number of associations were tested: (1) whether each of the weather variables was associated with joint pain on the same day, (2) whether 3-day average weather variables were associated with joint pain on the next day, (3) whether changes in weather variables between 2 consecutive days were associated with reported pain on the second day, and (4) whether changes in weather variables between 2 consecutive days were associated with differences in pain report between these 2 days. Our study focused on the associations between joint pain and weather variables in the full sample to maximize the variation in weather variables.

All of these associations were examined in models constructed step by step. The dependent variable in each of the models was either joint pain or day-to-day changes in joint pain. Model 1 tested the univariate effects of the weather variables. Model 2 tested the effects of the weather variables, adjusted for potential confounders of sex, age, country, depression, and medication use. Subsequently, we tested pain-weather associations in Model 3, including all weather variables that reached a p value below 0.20 in Model 2 and all potential confounders. To examine the effects of the combinations of weather variables on joint pain, all possible 2-way interaction terms between weather variables were assessed separately in a fully adjusted model. The interaction effects were considered significant at a p value below 0.10[24]. For each pain-weather association, the effect size (ES) was calculated as described in Tymms[25]. ES ≤ 0.10 were considered as small, ES > 0.10 to ≤ 0.30 were considered as medium, and ES ≥ 0.50 were considered as large[26]. Statistical analyses were performed in IBM SPSS Statistics (version 20.0).

RESULTS

The characteristics of participants are presented in Table 1. At baseline, the mean age of all 810 participants with OA was 74.0 years (SD 5.0). Of the participants, 556 (68.6%) were women. Two hundred and forty participants (29.4%) had

Table 1. Characteristics of the study sample (n = 810)*. Values are n (%) unless otherwise specified.

Variables	Values
Age, yrs, mean (SD)	74.0 (5.0)
Female	556 (68.6)
Country	
Germany	84 (10.4)
Italy	167 (20.6)
The Netherlands	127 (15.7)
Spain	162 (20.0)
Sweden	158 (19.5)
United Kingdom	112 (13.8)
Depression, HADS-D score ≥ 8 at baseline and/or at 12–18 mos followup	198 (24.3)
No. days of medication use, median (IQR)	19.0 (10.0–28.0)

* Descriptive statistics are weighted, except age, sex, and country. The number of participants are nonweighted. HADS-D: Hospital Anxiety Depression Scale-Depression; IQR: interquartile range.

Personal non-commercial use only. The Journal of Rheumatology Copyright © 2015. All rights reserved.

Downloaded on April 10, 2024 from www.jrheum.org

hand OA only and 367 persons (45.0%) had knee and/or hip OA, but no hand OA. Of all 810 included participants, 203 persons (25.6%) had hand OA as well as knee and/or hip OA. In total, 25,891 (76.1%) of the possible 34,020 individual pain reports (810 × 42) were completed. Further, 23,616 (74.8%) of the possible 31,590 (810 × 39) measures on differences in joint pain between 2 consecutive days were available.

Joint pain. On 17.3% of all completed days, the participants did not experience joint pain at all (pain score 0). The participants experienced mild joint pain (pain score 1–3) and moderate to severe joint pain (pain score 4–10) on 29.6% and 53.1% of all completed days, respectively. Overall, the average joint pain intensity was 3.7 (SD 2.7, range 0–10) across countries. Significant differences in joint pain across countries and seasons were found (Table 2). Joint pain intensity was highest in Spain (mean 5.1, SD 2.9) and lowest in Sweden (2.5, SD 2.3). Overall, joint pain intensity was highest in winter (3.9, SD 2.8) and lowest in autumn (3.6, SD 2.6). However, the season in which most pain was reported differed across countries (Table 2).

Weather conditions. The distribution of the meteorological exposures in the study sample showed significant differences in daily weather conditions and 3-day average weather conditions between the 6 countries (Data supplement is available from the authors on request). No significant differences in weather changes between countries were observed (data not shown).

Average daily temperature and atmospheric pressure were highest in Spain. Further, precipitation and humidity were lowest in Spain. In Germany, daily temperature was lowest and humidity was highest. In Sweden, daily precipitation and atmospheric pressure were highest and lowest, respectively. Daily wind speed was highest in the Netherlands and lowest in Italy (Data supplement).

Joint pain intensity and daily average weather variables. After adjustment for all confounders (Table 3, Model 2), the association between joint pain and daily average humidity ($B = 0.004$, $p < 0.01$, $ES = 0.063$) was statistically significant. In a multivariable model including daily average precipitation, relative humidity, wind speed, and all confounders (Table 3, Model 3), the associations between joint pain and precipitation ($B = –0.006$, $p = 0.03$, $ES = –0.034$) and relative humidity ($B = 0.005$, $p < 0.01$, $ES = 0.068$) were significant. A significant humidity by temperature interaction effect on joint pain was found ($p = 0.01$). In the highest quartile of daily average temperature (> 16.9˚C), no significant association was found between joint pain and relative humidity ($B = 0.002$, $p = 0.44$, $ES = 0.044$), whereas the association between pain and relative humidity was statistically significant ($B = 0.006$, $p < 0.01$, $ES = 0.086$) in the lowest 3 quartiles of daily average temperature (≤ 16.9˚C; Figure 1). No associations were found between joint pain and the other daily average weather variables (Table 3, Model 2).

Joint pain intensity and 3-day average weather conditions. After adjustment for all confounders (Table 4, Model 2), the association between joint pain and 3-day average relative humidity ($B = 0.004$, $p = 0.01$, $ES = 0.054$) was significant. In a multivariable model including 3-day average atmospheric pressure, 3-day average relative humidity, and all potential confounders (Table 4, Model 3), the association between joint pain and 3-day average relative humidity was statistically significant ($B = 0.004$, $p = 0.02$, $ES = 0.052$). A significant 3-day average humidity by 3-day average temperature interaction effect on joint pain was found ($p = 0.01$). In the highest quartile of 3-day average temperature (> 16.5˚C), no significant association was found between joint pain and 3-day average humidity ($B = 0.004$, $p = 0.30$, $ES = 0.048$), whereas the association between pain and 3-day average humidity was marginally significant ($B = 0.004$, $p = 0.07$, $ES = 0.051$) in the lowest 3 quartiles of 3-day average temperature (≤ 16.5˚C). No associations were found between joint pain and the other 3-day average weather variables (Table 4). Analyses on the associations of joint pain with 1-day average weather variables and 2-day average weather conditions showed similar results.

Changes in joint pain intensity and changes in weather conditions. Changes in weather variables between 2 consecutive days were not significantly associated with reported joint pain on the second day (Table 5). Further, changes in weather variables between 2 consecutive days were not significantly associated with differences in experienced joint pain intensity between these 2 days (Table 5).

Table 2. Average joint pain in older people with osteoarthritis across countries and seasons*. Values are joint pain intensity, 0–10, mean (SD) (based on no. participants/no. pain reports).

Season	All Countries, n = 810	Germany, n = 84	Italy, n = 167	The Netherlands, n = 127	Spain, n = 162	Sweden, n = 158	United Kingdom, n = 112	p
Overall	3.7 (2.7) (810/25,891)	3.3 (2.2) (84/2882)	4.3 (2.8) (167/5203)	3.9 (2.3) (127/4165)	5.1 (2.9) (162/3900)	2.5 (2.3) (158/5893)	3.8 (2.6) (112/3848)	< 0.001
Spring	3.8 (2.7) (561/7895)	3.1 (2.1) (63/815)	4.3 (2.8) (118/1620)	4.0 (2.3) (92/1259)	5.1 (2.8) (119/1816)	2.5 (2.3) (117/1781)	3.0 (2.7) (52/604)	< 0.001
Summer	3.8 (2.7) (479/6884)	3.0 (2.1) (54/592)	4.3 (2.8) (88/1227)	4.0 (2.2) (77/1012)	4.8 (2.9) (82/966)	2.4 (2.3) (83/1188)	4.0 (2.7) (95/1899)	< 0.001
Autumn	3.6 (2.6) (442/6983)	3.7 (2.4) (61/884)	4.4 (2.8) (103/1615)	4.3 (2.5) (69/858)	4.8 (2.9) (26/314)	2.6 (2.2) (126/2576)	3.8 (2.6) (57/736)	< 0.001
Winter	3.9 (2.8) (316/4129)	3.4 (2.2) (50/591)	4.0 (3.0) (68/741)	3.4 (2.4) (59/1036)	5.5 (3.0) (62/804)	2.7 (2.5) (31/348)	4.0 (2.5) (46/609)	< 0.001

* The number of participants and pain reports are nonweighted. Descriptive statistics are weighted.

Personal non-commercial use only. The Journal of Rheumatology Copyright © 2015. All rights reserved.

Downloaded on April 10, 2024 from www.jrheum.org

Table 3. Associations between daily average weather variables and joint pain intensity in older persons with osteoarthritis.

Models	B	95% CI	p	Effect Size
Model 1				
Temperature, ˚C	–0.006	–0.010 to –0.003	< 0.001	–0.060
Precipitation, mm	–0.001	–0.003–0.003	0.98	–0.003
Atmospheric pressure, hPa	–0.002	–0.004–0.001	0.14	–0.022
Relative humidity, %	0.004	0.003–0.006	< 0.001	0.089
Wind speed, m/s	0.011	–0.004–0.027	0.15	0.025
Model 2				
Temperature, ˚C	0.002	–0.003–0.007	0.45	0.009
Precipitation, mm	–0.004	–0.009–0.002	0.18	–0.018
Atmospheric pressure, hPa	–0.003	–0.007–0.002	0.21	–0.023
Relative humidity, %	0.004	0.002–0.007	< 0.01	0.063
Wind speed, m/s	–0.020	–0.046–0.006	0.13	–0.032
Model 3				
Precipitation, mm	–0.006	–0.012 to –0.001	0.03	–0.034
Relative humidity, %	0.005	0.002–0.008	< 0.01	0.068
Wind speed, m/s	–0.012	–0.040 to –0.017	0.42	–0.027

Model 1: unadjusted model. Model 2: adjusted for sex (reference category: men), age, country (reference category: Sweden), depression (reference category: not depressed; HADS-D < 8), and medication use (reference category: no medication use). Model 3 includes all pain-weather associations that reached a p value below 0.20 in Model 2; in addition, this model includes sex (reference category: men), age, country (reference category: Sweden), depression (reference category: not depressed (HADS-D < 8), and medication use (reference category: no medication use). B: unstandardized coefficient; HADS-D: Hospital Anxiety Depression Scale-Depression.

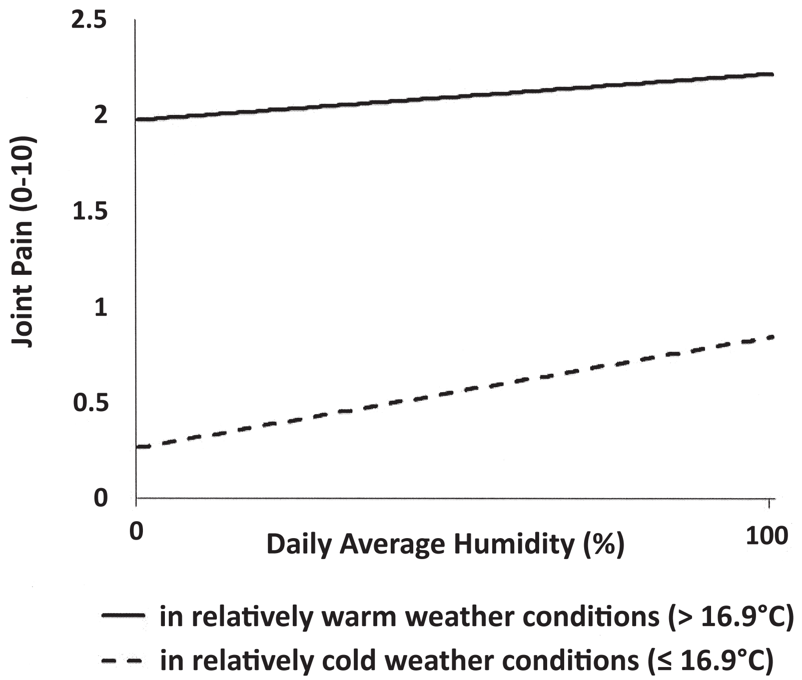

Figure 1. The association between joint pain and daily average humidity in older persons with osteoarthritis in relatively cold and warm weather conditions.

DISCUSSION

Our study showed that both daily average humidity and 3-day average humidity were positively associated with joint pain. Further, the results suggest that the effect of humidity on pain was stronger in relatively cold weather conditions. No significant associations were found between day-to-day changes in weather variables and (day-to-day changes in) joint pain.

Humidity and temperature may have an effect on the

Personal non-commercial use only. The Journal of Rheumatology Copyright © 2015. All rights reserved.

Downloaded on April 10, 2024 from www.jrheum.org

Table 4. Associations between 3-day average weather variables and joint pain intensity in older persons with osteoarthritis.

Models	B	95% CI	p	Effect Size
Model 1				
Temperature, ˚C	–0.005	–0.009 to –0.002	< 0.01	–0.051
Precipitation, mm	0.003	–0.002–0.008	0.19	0.016
Atmospheric pressure, hPa	–0.003	–0.005 to < 0.001	0.07	–0.025
Relative humidity, %	0.007	0.005–0.009	< 0.001	0.130
Wind speed, m/s	0.014	–0.007–0.034	0.18	0.028
Model 2				
Temperature, ˚C	0.003	–0.002–0.008	0.29	0.021
Precipitation, mm	–0.001	–0.009–0.007	0.81	–0.002
Atmospheric pressure, hPa	–0.005	–0.009 to –0.001	0.05	–0.034
Relative humidity, %	0.004	0.001–0.007	0.01	0.054
Wind speed, m/s	–0.015	–0.046–0.017	0.36	–0.021
Model 3				
Atmospheric pressure, hPa	–0.003	–0.008 to –0.002	0.29	0.018
Relative humidity, %	0.004	–0.001–0.007	0.02	0.052

Model 1: unadjusted model. Model 2: adjusted for sex (reference category: men), age, country (reference category: Sweden), depression (reference category: not depressed (HADS-D < 8), and medication use (reference category: no medication use). Model 3 includes all pain-weather associations that reached a p value below 0.20 in Model 2; in addition, this model includes sex (reference category: men), age, country (reference category: Sweden), depression (reference category: not depressed; HADS-D < 8,) and medication use (reference category: no medication use). B: unstandardized coefficient; HADS-D: Hospital Anxiety Depression Scale-Depression.

expansion and contraction of different tissues in the affected joint that may elicit a pain response[3,8]. Further, low temperatures may increase the viscosity of synovial fluid, thereby making joints stiffer and perhaps more sensitive to the pain of mechanical stresses[3,8]. Our study showed that, compared with warm weather conditions, the effect of relative humidity on joint pain in OA is stronger in relatively cold weather conditions. This finding supports the common belief that joint pain in older adults with OA is influenced by damp and cold weather conditions, and suggests that a causal relationship exists between joint pain and weather variables. The pain response might be intensified more in cold weather conditions because the viscosity of synovial fluid increases, which may lead to stiffer joints and more friction between tissues in the joint. The associations between joint pain and day-to-day changes in weather conditions did not confirm a causal relationship between joint pain and weather conditions. These findings suggest that there might be a momentaneous causal effect of relative humidity on joint pain that is restricted to the same day.

Our study did not replicate the findings of McAlindon, *et al*[18] that showed that day-to-day changes in atmospheric pressure were associated with joint pain. The inconsistency between results may be explained by differences in study sample. McAlindon, *et al* focused on pain-weather associations in patients with knee OA, whereas our present study focused on pain-weather associations in older persons with OA in the general population. It has been suggested that the effect of atmospheric pressure on joint pain may depend on specific joint conditions (e.g., effusions, defect of articular cartilage integrity, and presence of subchondral pseudocysts)[7,18]. Sample differences (patients vs general population) imply differences in OA severity that might explain the inconsistencies between our findings and those of McAlindon, *et al*[18].

Our findings showed that there were differences between countries in terms of joint pain intensity. Differences in sociocultural factors, such as attitudes and expressiveness, between countries could explain these differences in pain intensity[27,28,29]. In our study, the analyses were adjusted for country; however, this variable did not cover all sociocultural characteristics of a country.

To our best knowledge, our study is the first large-scale study to examine the relationship between joint pain and weather conditions in older people with OA across Europe. Another strength is the standardized assessment of OA across countries using the ACR classification criteria. Further, the participants were geographically dispersed and participated at different times, generating greater opportunity for weather exposure variability.

Some limitations of our study have to be acknowledged as well. It might be that seasonal weather patterns influence mood in older people with OA that may affect pain perception[3,6,8,30]. In our study, the associations between joint pain and weather conditions were adjusted for depression at baseline and followup. Although depression often has a chronic character[31], it would be better to adjust for emotional distress on each specific day of pain assessment.

Our study did not consider variation in weather variables in internal and external environments, or exposure time in these environments. Persons with OA may often stay inside and may often be able to regulate the

Personal non-commercial use only. The Journal of Rheumatology Copyright © 2015. All rights reserved.

Downloaded on April 10, 2024 from www.jrheum.org

Table 5. Associations of day-to-day differences in weather variables between 2 consecutive days with joint pain on the second day and day-to-day differences in joint pain intensity in older persons with osteoarthritis.

Models	B	95% CI	p	Effect Size
Joint pain on the second day				
Model 1				
Temperature, ˚C	0.003	–0.013–0.018	0.73	–0.006
Precipitation, mm	0.001	–0.004–0.005	0.76	–0.008
Atmospheric pressure, hPa	–0.002	–0.009–0.005	0.56	–0.003
Relative humidity, %	< 0.001	–0.004–0.004	0.92	–0.010
Wind speed, m/s	0.002	–0.022–0.027	0.86	0.003
Model 2				
Temperature, ˚C	–0.001	–0.017–0.015	0.91	–0.002
Precipitation, mm	–0.002	–0.007–0.002	0.29	–0.015
Atmospheric pressure, hPa	0.003	–0.004–0.009	0.44	0.012
Relative humidity, %	0.001	–0.003–0.005	0.59	0.008
Wind speed, m/s	–0.005	–0.034–0.023	0.72	–0.007
Day-to-day differences in joint pain				
Model 1				
Temperature, ˚C	0.006	–0.003–0.014	0.21	0.001
Precipitation, mm	–0.001	–0.004–0.001	0.32	–0.002
Atmospheric pressure, hPa	–0.001	–0.004–0.003	0.84	0.008
Relative humidity, %	–0.002	–0.004 to < 0.001	0.08	–0.004
Wind speed, m/s	–0.004	0.018–0.009	0.53	0.002
Model 2				
Temperature, ˚C	0.004	–0.007–0.016	0.44	0.003
Precipitation, mm	–0.002	–0.005–0.001	0.14	–0.007
Atmospheric pressure, hPa	–0.001	–0.005–0.004	0.79	0.009
Relative humidity, %	–0.002	–0.005 to < 0.001	0.08	–0.011
Wind speed, m/s	0.001	–0.008–0.002	0.90	0.001
Model 3				
Precipitation, mm	–0.001	–0.004–0.002	0.49	–0.002
Relative humidity, %	–0.003	–0.006 to < 0.001	0.08	0.015

Model 1: unadjusted model. Model 2: adjusted for sex (reference category: men), age, country (reference category: Sweden), depression (reference category: not depressed (HADS-D < 8), and medication use (reference category: no medication use). Model 3 includes all pain-weather associations that reached a p value below 0.20 in Model 2; in addition, this model includes sex (reference category: men), age, country (reference category: Sweden), depression (reference category: not depressed (HADS-D < 8), and medication use (reference category: no medication use). B: unstandardized coefficient; HADS-D: Hospital Anxiety Depression Scale-Depression.

indoor environment by using central heating. These factors may attenuate the associations between joint pain and weather variables in older people with OA. The finding that the effects of weather conditions on joint pain are small is in line with previous studies[9,18]. Small effects of weather conditions on joint pain in older people with OA may seem clinically unimportant, but are likely to make a substantial difference at a population level. It is important to pay attention to the effect of weather conditions on joint pain in older people with OA because the prevalence of OA in older people is high[32] and this large group might be impaired in their daily functioning because of weather effects on their joint pain.

Future research should take the differences between indoor and outdoor climate into account and should also consider exposure time to both environments and housing conditions[5,33,34]. Future research should also focus on hour-to-hour weather changes because this could be of more importance to pain than day-to-day changes. More research is needed to measure how weather effects on pain interfere with daily activity performance of older people with OA. Further research is also needed to examine the possible underlying physiological mechanisms on how meteorological variables influence joint structures that result in more pain. Many suggestions have been made[6,7,8], but empirical evidence is lacking.

The association between joint pain and daily average relative humidity suggests that weather conditions affect joint pain of older people with OA. The results show that the influence of daily average humidity on joint pain is stronger when the temperature is low. The associations between day-to-day weather changes and pain do not confirm causation. There might be a momentaneous causal effect of weather conditions on joint pain in OA that is restricted to the same day. Knowledge on the relationship between joint pain in OA and weather conditions may help individuals with OA, physicians, and therapists to better understand and manage fluctuations in pain.

Personal non-commercial use only. The Journal of Rheumatology Copyright © 2015. All rights reserved.

Downloaded on April 10, 2024 from www.jrheum.org

APPENDIX 1.

List of study collaborators. The European Project on OSteoArthritis (EPOSA) research group: Germany: M.D. Denkinger (Principal Investigator), R. Peter, and F. Herbolsheimer; Italy: S. Maggi (Principal Investigator), S. Zambon, F. Limongi, M. Noale and P. Siviero; the Netherlands (coordinating center): D.J.H. Deeg (Principal Investigator), S. van der Pas, L.A. Schaap, N.M. van Schoor, and E.J. Timmermans; Spain: Á. Otero (Principal Investigator), M.V. Castell, M. Sánchez-Martínez and R. Quieipo; Sweden: N.L. Pedersen (Principal Investigator) and R. Broumandi; United Kingdom: E.M. Dennison (Principal Investigator), C. Cooper, M.H. Edwards and C. Parsons.

ACKNOWLEDGMENT

We would like to thank the Royal Netherlands Meteorological Institute, the Swedish Meteorological and Hydrological Institute, and the Bavarian State Research Center for Agriculture for providing meteorological data. In addition, we would like to thank the local weather stations: Laupheim Airport (ETHL), Stuttgart Echterdingen Airport (EDDS), and Weissingen (Germany); Istrana Airport (LIPS), Sacille Meteo, Treviso-Sant' Angelo Airport (LIPH), and Vittorio Veneto (Italy); Heino, Lelystad, Schiphol, and Volkel (the Netherlands); Fermin Caballero, Avenida de la Illustration, and Madrid Airport (LEMD; Spain); Berga, Stockholm, Svanberga, and Västerhaninge (Sweden); Harpenden and Luton Airport (EGGW; UK).

REFERENCES

1. Brooks PM. Impact of osteoarthritis on individuals and society: how much disability? Social consequences and health economic implication. Curr Opin Rheumatol 2002;14:573-7.
2. Jinks C, Jordan K, Croft P. Measuring the population impact of knee pain and disability with the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Pain 2002;100:55-64.
3. Ng J, Scott D, Taneja A, Gow P, Gosai A. Weather changes and pain in rheumatology patients. APLAR J Rheumatology 2004;7:204-6.
4. Timmermans EJ, van der Pas S, Schaap LA, Sánchez-Martínez M, Zambon S, Peter R, et al. Self-perceived weather sensitivity and joint pain in older people with osteoarthritis in six European countries: results from the European Project on OSteoArthritis (EPOSA). BMC Musculoskelet Disord 2014;15:66.
5. de Figueiredo EC, Figueiredo GC, Dantas RT. Influence of meteorological elements on osteoarthritis pain: a review of the literature. Rev Bras Reumatol 2011;51:622-8.
6. Quick DC. Joint pain and weather. A critical review of the literature. Minn Med 1997;80:25-9.
7. Brennan SA, Harney T, Queally JM, O'Connor McGoona J, Gormley IC, Shannon FJ. Influence of weather variables on pain severity in end-stage osteoarthritis. Int Orthop 2012;36:643-6.
8. Jamison RN, Anderson KO, Slater MA. Weather changes and pain: perceived influence of local climate on pain complaint in chronic pain patients. Pain 1995;61:309-15.
9. Dorleijn DM, Luijsterburg PA, Burdorf A, Rozendaal RM, Verhaar J4, Bos PK, et al. Associations between weather conditions and clinical symptoms in patients with hip osteoarthritis: a 2-year cohort study. Pain 2014;155:808-13.
10. Guedj D, Weinberger A. Effect of weather conditions on rheumatic patients. Ann Rheum Dis 1990;49:158-9.
11. Sibley JT. Weather and arthritis symptoms. J Rheumatol 1985;12:707-10.
12. Strusberg I, Mendelberg RC, Serra HA, Strusberg AM. Influence of weather conditions on rheumatic pain. J Rheumatol 2002;29:335-8.
13. Vergés J, Montell E, Tomàs E, Cumelles G, Castañeda G, Marti N, et al. Weather conditions can influence rheumatic diseases. Proc West Pharmacol Soc 2004;47:134-6.
14. Wilder FV, Hall BJ, Barrett JP. Osteoarthritis pain and weather. Rheumatology 2003;42:955-8.
15. Laborde JM, Dando WA, Powers MJ. Influence of weather on osteoarthritics. Soc Sci Med 1986;23:549-54.
16. Hollander JL, Yeostros, SJ. The effect of simultaneous variations of humidity and atmospheric pressure on arthritis. BAMS 1963;44:489-94.
17. Clarke AM, Nicholl J. Does the weather affect the osteoarthritic patient? Br J Rheumatol 1991;30:477.
18. McAlindon T, Formica M, Schmid CH, Fletcher J. Changes in barometric pressure and ambient temperature influence osteoarthritis pain. Am J Med 2007;120:429-34.
19. van der Pas S, Castell MV, Cooper C, Denkinger M, Dennison EM, Edwards MH, et al. European project on osteoarthritis: design of a six-cohort study on the personal and societal burden of osteoarthritis in an older European population. BMC Musculoskelet Disord 2013;14:138.
20. Altman R. Classification of disease: osteoarthritis. Semin Arthritis Rheum 1991;20 Suppl 2:40-7.
21. Zigmond A, Snaith R. The hospital anxiety and depression scale. Acta Psychiatr Scand 1983;67:361-70.
22. Eurostat. Database, population, demography, national data, population. [Internet. Accessed July 29, 2015.] Available from: ec.europa.eu/eurostat/web/population-demography-migration-projections/population-data/database
23. Hox J. Multilevel analysis: techniques and applications (Quantitative Methodology Series), 2nd edition. New York: Routledge; 2010.
24. Aiken LS, West SG. Multiple regression: testing and interpreting interactions. Thousand Oaks: Sage Publications, Inc.; 1991.
25. Tymms P. Effect sizes in multilevel models. In: Schagen I, Elliot K, eds. But what does it mean? The use of effect sizes in educational research, 1st edition. Slough: The National Foundation for Educational Research;2004:55-66.
26. Durlak JA. How to select, calculate, and interpret effect sizes. J Pediatr Psychol 2009;34:917-28.
27. Fillingim RB. Individual differences in pain responses. Curr Rheumatol Rep 2005;7:342-7.
28. Lasch KE. Culture, pain, and culturally sensitive pain care. Pain Manag Nurs 2000;1 Suppl 1:16-22.
29. Rahim-Williams B, Riley JL 3rd, Williams AK, Fillingim RB. A quantitative review of ethnic group differences in experimental pain response: Do biology, psychology, and culture matter? Pain Med 2012;13:522-40.
30. Sulman FG. The impact of weather on human health. Rev Environ Health 1984;4:83-119.
31. Beekman AT, Geerlings SW, Deeg DJ, Smit JH, Schoevers RS, de Beurs E, et al. The natural history of late-life depression: a 6-year prospective study in the community. Arch Gen Psychiatry 2002;59:605-11.
32. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. Bull World Health Organ 2003;81:646-56.
33. Hildebrandt VH, Bongers PM, Van Dijk FJ, Kemper HC, Dul J. The influence of climatic factors on non-specific back and neck-shoulder disease. Ergonomics 2002;45:32-48.
34. Howden-Chapman P, Signal L, Crane J. Housing and health in older people: ageing in place. Soc Pol J New Zealand 1999;13:14-30.

Personal non-commercial use only. The Journal of Rheumatology Copyright © 2015. All rights reserved.

Downloaded on April 10, 2024 from www.jrheum.org