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The influence of weather conditions on outdoor physical activity among older people with and without osteoarthritis in six European countries

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Abstract

Objectives—Older adults with osteoarthritis (OA) often report that their disease symptoms are exacerbated by weather conditions. This study examines the association between outdoor physical activity (PA) and weather conditions in older adults from six European countries and assesses whether outdoor PA and weather conditions are more strongly associated in older persons with OA than in those without the condition.

Methods—The American College of Rheumatology classification criteria were used to diagnose OA. Outdoor PA was assessed using the LASA Physical Activity Questionnaire. Data on weather parameters were obtained from weather stations.

Results—Of the 2,439 participants (65–85 years), 29.6% had OA in knee, hand and/or hip. Participants with OA spent fewer minutes in PA than participants without OA (Median=42.9, IQR=20.0–83.1 versus Median=51.4, IQR=23.6–98.6; $p<0.01$). In the full sample, temperature ($B=1.52$; $p<0.001$) and relative humidity ($B=-0.77$; $p<0.001$) were associated with PA. Temperature was more strongly associated with PA in participants without OA ($B=1.98$; $p<0.001$) than in those with the condition ($B=0.48$; $p=0.47$).

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Conclusions—Weather conditions are associated with outdoor PA in older adults in the general population. Outdoor PA and weather conditions were more strongly associated in older adults without OA than in their counterparts with OA.

Introduction

Physical activity (PA) helps older people with osteoarthritis (OA) to reduce pain and improve functioning [1,2]. Despite the potential health benefits of PA, the majority of people with OA do not engage sufficiently in physical activities [3–5]. Environmental factors, such as weather conditions, are known to influence PA of healthy people. Only few studies have explored these factors in older people with OA, even though older people with OA often report that their disease symptoms are exacerbated by the weather [6–8]. More insight into the relationship between PA and weather conditions in older people with OA in the general population is particularly valuable for determining during what meteorological conditions PA interventions should be modified to maintain a sufficient compliance [9]. Knowledge on the relationship between PA and environmental factors, such as weather conditions, could be used in the prevention of mobility limitations and management of pain, which are both very relevant in older people and to an even greater extent to older people suffering from OA [10].

Two recent studies focused on the association between objectively measured PA and weather conditions in people with knee OA [8,11]. A study by Robbins et al. showed that warmer weather was associated with both greater frequency of daily PA and increased time engaging in moderate and vigorous PA of people with knee OA [8]. Feinglass et al. found that light or heavy rain, and cold ($<-7^{\circ}\text{C}$) or hot ($>24^{\circ}\text{C}$) temperature were negatively associated with PA [11]. Caution should be taken, however, when interpreting the results of Feinglass et al. In this study, the participants received interventions aimed at increasing PA [11]. As a consequence, the participants in this study may have been more physically active than the general population of people with knee OA. This may have biased the relationship between PA and weather conditions in people with knee OA.

In the studies of Feinglass et al. and Robbins et al., no distinction was made between indoor and outdoor PA [8,11]. The characteristics of housing, use of air conditioning and exposure time to the actual weather conditions were not taken into account, which may have diminished the effects of weather conditions on PA in their study. Previous research addressed the influence of weather conditions on the type, participation rate, frequency and duration of physical active leisure engagement in the general population [12]. To our knowledge, research on the influence of weather conditions on PA in specific outdoor activities by older people with OA in the general population does not exist. The most important outdoor activities for older people are walking, cycling, and gardening [13]. Participation in each of these activities may be influenced differently by weather conditions [14].

This study aims to examine the association of outdoor PA with weather conditions in older adults and to assess whether outdoor PA and weather conditions are more strongly associated in older persons with OA than in those without the condition. The current study

extends previous research by examining the relationship between outdoor PA and weather conditions in a large-scale population-based study, including older people without OA as well as older people with knee, hand and/or hip OA from six European countries. This study focuses on the relationship between PA and various objectively measured weather parameters, including outdoor temperature, precipitation, atmospheric pressure, relative humidity and wind speed. In addition, this study focuses explicitly on the association between weather conditions and outdoor activities, including walking, cycling and gardening.

Methods

Design and study sample

Baseline data from the European Project on OsteoArthritis (EPOSA) were used. The EPOSA study focuses 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, but to summarize, random samples were taken from existing population-based cohorts in five European countries (Germany, the Netherlands, Spain, Sweden and the United Kingdom (UK)) [15]. In Italy, a new sample was drawn. A total of 2,942 respondents (response rate, ranging from 64.6% to 82.2%, averaging 72.8%) were included. The age-range was between 65-85 years in most countries except for the UK, which had an age-range of 71-80 years. All participants were interviewed by a trained researcher at home or in a clinical center, using a standardized questionnaire and a clinical exam. The interview lasted about one and a half hours. All participants completed an informed consent. For all six countries, the study design and procedures were approved by the Medical Ethics committee of the respective centers.

Individuals with cognitive impairments (Mini-Mental State Examination score ≤ 23) were excluded from the analyses [16]. Moreover, those who had missing data on outdoor PA and/or the presence of OA were necessarily omitted from the analyses. In total, 2,439 (82.9%) were included in the current study. The excluded participants ($n=503$) were older, lower educated and had more chronic diseases and functional limitations than the included participants. Furthermore, the proportion of women was higher in the excluded group than in the included group.

Measures

Dependent variable

Outdoor physical activity: Physical activity was measured using the LASA Physical Activity Questionnaire (LAPAQ), an instrument validated against diaries and pedometer measurements in older persons [13]. The LAPAQ was completed by the participants in the period between December 2010 and December 2011. The LAPAQ covers frequency and duration of different activities during the previous two weeks. Activities covered in the LAPAQ include walking outside, cycling, gardening, light and heavy household work and a maximum of two sports. In order to calculate average daily outdoor PA in minutes, the frequency and duration of walking, cycling and gardening were multiplied and divided by 14

days. Sport activities were not included in this outdoor PA measure, because certain sports could be performed indoors as well as outdoors.

Independent variables

Weather data: Data-provid weather stations provided local daily (24-hour) average values for temperature (in degrees Celsius (°C)), precipitation (in millimeters (mm)), barometric pressure (in hectopascals (hPa)), relative humidity (in percentages), and wind speed (in meters per second (m/s)) for the location of all participants, for each of the fourteen days before the completion of the LAPAQ. The maximum distance between a weather station and a participants' residence was within 80 kilometres. For each participant, averages of the weather parameters in the two-week period for which they reported their outdoor PA were calculated. The two-week averages of each weather parameter were calculated by dividing the sum of all daily (24-hour) weather parameter values by 14 days.

Potential confounders—We considered the following potential confounders: age, sex (0=men, 1=women), educational level (0=lower educated than secondary education, 1=secondary education or a higher level), number of chronic diseases, Body Mass Index (BMI), anxiety, depression, mastery, PA pattern, and functional limitations.

Number of chronic conditions was measured through self-reported presence of the following chronic diseases or symptoms that lasted for at least three months or diseases for which the participant had been treated or monitored by a physician: chronic non-specific lung disease, cardiovascular diseases, peripheral artery diseases, stroke, diabetes, cancer, and osteoporosis. The number of chronic diseases other than OA was categorized into 0, 1, 2 or more chronic diseases.

Body Mass Index (BMI) was calculated as weight in kilograms (kg) divided by height in squared meters (m). Weight was measured to the nearest 0.1 kg using a calibrated scale. Height was measured to the nearest 0.001 m using a stadiometer.

Emotional distress is associated with inclement weather conditions and physical inactivity in older adults [17,18]. To account for the effects of emotional distress on outdoor PA, analyses were adjusted for anxiety and depression. Anxiety and depressive symptoms were examined by the Hospital Anxiety Depression Scales (HADS) [19]. The HADS is a self-report questionnaire comprising 14 four-point Likert scaled items, 7 for anxiety (HADS-A) and 7 for depression (HADS-D). Both scales have a range from 0 to 21. A higher score on the HADS-A and HADS-D indicates greater anxiety and depression respectively. HADS-A and HADS-D were used as categorical variables with cut-off level of 8 or more for presence of anxiety and depression [19].

Mastery is the extent to which individuals consider themselves to be in control of events and ongoing situations. Mastery is a psychological resource when coping with stressful life events [20]. Mastery was measured by means of an abbreviated 6-item version of the Pearlin Mastery Scale [20]. The questionnaire consists of six statements such as "I can do almost everything, if I want to." and "I have little control about things that happen to me." Original response categories range from 0=strongly disagree to 4=strongly agree. Response

categories of individual items were rescaled in a way that higher scores represent a higher sense of mastery. The summed items range from 0 to 24, with higher scores indicating a higher sense of mastery.

The LAPAQ also assessed whether the PA pattern of the participants was normal as compared to the rest of the past year [13]. If participants answered 'no' then they were asked for what reason. Physical activity pattern was categorized into "activity pattern was normal as compared to the rest of the past year", "activity pattern was not normal as compared to the rest of the past year because of weather conditions" and "activity pattern was not normal as compared to the rest of the past year because another reason than weather conditions". The categories were dummy coded and the first category ("activity pattern was normal as compared to the rest of the past year") was used as reference category.

To assess the severity of OA, functional limitations were assessed by the physical function subscales of the Australian/Canadian Osteoarthritis Hand Index (AUSCAN) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) [21,22]. The AUSCAN physical function subscale contains nine items concerning degree of difficulty with hand function experienced in the previous 48 hours. The WOMAC physical function subscale contains seventeen items relating to difficulty with knee and/or hip function experienced in the previous 48 hours. The AUSCAN and WOMAC responses were scaled on a five-point Likert scale ranging from none (0) to extreme difficulty (4). For both the AUSCAN and WOMAC, missing values were imputed according to the user manual, and subscale scores were normalized resulting in subscale scores ranging from 0 (no difficulties) to 100 (extreme difficulties).^{21,22} Because of the high number of persons scoring 0 on the AUSCAN and WOMAC physical function subscale, and the highly skewed distribution of these variables, these variables were dichotomized: quartiles 1-3 (0) versus quartile 4 (people having most difficulties (1)). This dichotomization corresponds to earlier studies [23,24].

Potential effect modifiers

Osteoarthritis: Algorithms for clinical OA of the hip, knee and hand were developed based on the American College of Rheumatology (ACR) classification criteria and were based on both self-report and physical examination [25]. The diagnosis of hip OA was present in case of: pain in the hip as evaluated by the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain subscale score (cut-off score=3, range=0-20), plus all of: pain associated with hip internal rotation in at least one side; morning stiffness lasting more than 60 minutes as evaluated by the WOMAC stiffness subscale (score from 'mild' to 'extreme'; and over 50 years of age [22]. The diagnosis of knee OA was present in the case of: pain in the knee as evaluated by the WOMAC pain subscale score (cut-off score=3, range=0-20), plus any 3 of: over 50 years of age; morning stiffness lasting more than 30 minutes as evaluated by the WOMAC stiffness subscale (score from 'mild' to 'extreme'); crepitus on active motion in at least one side; bony tenderness in at least one side; bony enlargement in at least one side; no palpable warmth of synovium in both knees [22]. The diagnosis of hand OA was present in case of: pain, aching or stiffness of the hand as evaluated by the Australian /Canadian Osteoarthritis Hand Index (AUSCAN) pain (cut-off score=3, range=0-20) and stiffness (score 'mild' to extreme') subscale, plus any 2 of: hard

tissue enlargement of 2 or more of the 2nd and 3rd distal interphalangeal (DIPs), 2nd and 3rd proximal interphalangeal (PIPs), 1st carpometacarpal (CMC) joints of at least one hand; hard tissue enlargement of 2 or more DIPs of at least one hand; deformity of at least 1 of the 2nd and 3rd DIPs, 2nd and 3rd PIPs, 1st CMC joints of at least one hand [21]. Swelling of the metacarpophalangeal joints, which is also included in the ACR classification criteria as a control to exclude rheumatic arthritis, was only measured in the UK and Germany. Osteoarthritis was defined as present when the participant had clinical OA in hip, knee and/or hand.

Country of residence: Weather conditions and levels of outdoor PA may differ across countries. Therefore, it was examined whether country of residence modifies the relationship between weather conditions and outdoor PA. Participants were living in six European countries, including Germany, Italy, Netherlands, Spain, Sweden and the UK.

Statistical analyses—Differences in characteristics between older people with and without OA were examined using independent t-tests for continuous data and chi-square tests for categorical data. For skewed continuous variables, differences between older adults with and without OA were tested using a Mann-Whitney U test. Kruskal-Wallis tests were performed to examine differences in PA measures and meteorological exposure across countries. In addition, linearity between outdoor PA and individual weather parameters were assessed. All descriptive statistics, except age, sex and country, were weighted to the European standard population in 2010. The weights were calculated per sex and per five-year age category, using the formula: $W = N_{\text{exp}} / N_{\text{obs}}$, with the N_{obs} being the number of persons in a specific age/sex category in the cohort, and N_{exp} being the number of persons in a specific age/sex category in the European standard population in 2010 [26].

Linear regression analyses were used to examine cross-sectional associations of total outdoor PA with each of the weather parameters. Furthermore, linear regression analyses were used to examine whether the weather parameters were associated with daily PA in each of the three outdoor activities. To examine whether OA modified the relationship between outdoor PA and weather parameters, the interaction effects between OA and each individual weather parameter were assessed in fully adjusted models. Furthermore, country of residence was assessed for potential effect modification by examining interaction effects between country and each individual weather parameter on total outdoor PA in fully adjusted models. In these analyses, country was analysed in dummies with Sweden as reference category, because the Swedish participants reported, on average, to be physically less active in the outdoor environment. The interaction effects were considered as significant at a p-value below 0.10 [27]. If an interaction term was significant, group-specific associations between outdoor PA and weather parameters were calculated as described in Figueiras and colleagues [28]. In case the interaction effect was not significant, a pooled analysis (also adjusted for OA and/or country) was performed.

All associations between PA and individual weather parameters were examined in models constructed step by step. Model 1 tested the effects of the weather parameters on outdoor PA, adjusted for the covariates age and sex. Model 2 tested the effects of each individual weather parameter on outdoor PA, additionally adjusted for the covariates educational level,

number of chronic diseases, BMI, anxiety, depression, mastery, PA pattern, and functional limitations. In all models, the p-value was set to 0.05. Statistical analyses were performed in IBM SPSS Statistics (version 20.0).

Results

The mean age of the 2,439 participants was 73.8 (SD=5.0) years. Of all participants, 1,235 (50.6%) were female. Seven hundred and three persons (29.6%) fulfilled the ACR classification criteria for knee, hand, and/or hip OA. The characteristics of the participants with and without OA are presented in Table 1.

Outdoor physical activity

In the full sample, participants spent 47.1 minutes (Interquartile range (IQR)=21.4-93.2) per day doing outdoor PA. The time spent on outdoor PA significantly differed across countries (Table 2). In the full sample, the participants with OA spent significantly less time in outdoor PA than those without OA (Median=42.9, IQR=20.0-83.1 versus Median=51.4, IQR=23.6-98.6; $p<0.01$) (Table 3). Total time spent on walking, cycling and gardening, however, did not differ significantly between both groups (Table 3).

Weather conditions

The distribution of the meteorological exposures in the study sample showed significant differences in daily weather conditions between the six countries (Table 4). Average daily temperature was highest in Spain and lowest in the Netherlands. Daily precipitation was highest in Sweden and lowest in the Netherlands. Atmospheric pressure was highest in the Netherlands and lowest in Sweden. Relative humidity was lowest in Spain and highest in Sweden. Wind speed was highest and lowest in the Netherlands and Italy respectively.

Total outdoor physical activity and weather conditions

After adjustment for all confounders, the association of total outdoor PA with temperature ($B=1.52$; $p<0.001$) was statistically significant in the full sample (Table 5; Model 2). For example, this means that daily outdoor PA increases with 1.52 minutes when the temperature increases with 1.0 °C.

After adjustment for all confounders, also a statistically significant association between outdoor PA and relative humidity ($B=-0.77$; $p<0.001$) was observed in the full sample (Table 5; Model 2). The association between total outdoor PA and relative humidity differed across countries. Relative humidity was negatively associated with total outdoor PA in all countries, except in Spain (Germany: $B=-1.12$; $p=0.10$, Italy: $B=-2.82$; $p<0.001$, the Netherlands: $B=-2.16$; $p<0.001$; Spain: $B=0.19$; $p=0.70$; Sweden: $B=-0.43$; $p=0.49$, and UK: $B=-0.92$; $p=0.48$). In Italy and the Netherlands, the negative association of total outdoor PA with relative humidity was stronger and statistically significant.

A significant OA by temperature interaction effect ($p=0.05$) on total outdoor PA was found in the full sample. The association between total outdoor PA and temperature was stronger in

older adults without OA ($B=1.98$; $p<0.001$) than in those with OA ($B=0.48$; $p=0.47$) (Figure 1).

Outdoor walking and weather conditions

After adjustment for all confounders, the association between outdoor walking and relative humidity ($B=-0.34$; $p=0.02$) was statistically significant in the full sample. A significant OA by humidity interaction effect ($p=0.08$) on outdoor walking was observed. The association of outdoor walking with relative humidity was stronger in older adults without OA ($B=-0.46$; $p=0.01$) than in those with the condition ($B=-0.03$; $p=0.88$) (Figure 2).

Cycling and weather conditions

There were no statistically significant associations between cycling and weather parameters. The associations between cycling and weather parameters did not differ between older people with and without OA.

Gardening and weather conditions

After adjustment for all confounders, the associations between gardening in minutes per day and temperature ($B=1.23$; $p=0.02$), precipitation ($B=-2.31$; $p=0.03$) and relative humidity ($B=-1.07$; $p<0.01$) were statistically significant in the full sample. The associations between gardening and weather parameters did not differ between older people with and without OA.

Discussion

This study examined the association of outdoor PA with weather conditions in a large sample of older people with and without OA in six European countries, focusing on specific outdoor activities. The results showed that higher temperatures were associated with increased outdoor PA, and that increased humidity levels were associated with decreased outdoor PA. Temperature was more strongly associated with outdoor PA in older people without OA than in those with OA. Furthermore, it was found that with increased humidity levels, older people without OA spent less time walking outdoors than those with the condition.

Our findings provide evidence that weather conditions are associated with outdoor PA in older people. The finding that warmer temperatures were associated with increased PA in older people was in line with previous studies [29–33]. Our finding that outdoor PA in older people decreased with an increase in relative humidity was also in line with previous research [33]. Increased humidity makes it more difficult to cool down in warm weather conditions [34]. Older people may decrease their outdoor PA in humid weather conditions, because of their increased frailty and reduced ability to thermoregulate [35]. The present study showed that the association between outdoor PA and relative humidity was not similar across countries. Only in Spain, a positive association between outdoor PA and relative humidity was observed. In comparison to the participants in the other countries, Spanish participants were, on average, exposed to low humidity levels. Although the association between outdoor PA and relative humidity was not significant in Spain, more humid conditions may facilitate outdoor PA in this country. To our knowledge, there is no

explanation for the stronger negative associations between outdoor PA and relative humidity in Italy and the Netherlands. Contrary to other studies, our study did not show significant associations of total outdoor PA with precipitation, atmospheric pressure and wind speed [14,36].

Our findings did not confirm that outdoor PA was more strongly associated with weather conditions in older people with OA than in those without OA. Older people with OA frequently report that their disease symptoms, such as stiffness and joint pain, are influenced by weather conditions [6–8]. Several physiological mechanisms have been suggested to account for an increase in stiffness and joint pain, which could affect outdoor PA in older people with OA. For example, it has been suggested that humidity and temperature have an effect on the expansion and contraction of different tissues in the affected joint, which may elicit a pain response [7,37,38]. In addition, lower temperature may increase the viscosity of synovial fluid, thereby making joints stiffer and perhaps more sensitive to the pain of mechanical stresses [37,38]. Furthermore, it has been proposed that high atmospheric pressure leads to extrusion of synovial fluid through articular defects, which also may lead to more stiffness and joint pain [39]. A recent study by Dorleijn et al. showed that barometric pressure and relative humidity influence perceived OA symptoms, such as pain and disability [40]. Dorleijn and colleagues found that the contribution of these weather parameters to the severity of OA symptoms was not clinically relevant [40]. Although older people with OA often report that their disease symptoms are influenced by weather conditions and the potential mechanisms are well described in literature, the results of this study showed that temperature was more strongly associated with total outdoor PA in older people without OA than in those with OA [7,37,38]. Furthermore, it was found that relative humidity was more strongly associated with outdoor walking in older adults without OA than in those with the condition. A possible explanation could be that older people without OA might be better able to adapt their behaviour to the environment and they might be better able or more willing to perform outdoor activities in favourable weather conditions [41].

Outdoor PA in older people with OA may also be affected by aspects of the social and built environment that were not considered in the current study [10,41]. Older people with OA might have a smaller social network than their counterparts without OA [42]. Older people with OA who receive less encouragement of others might be less motivated to spend time in outdoor PA despite favourable weather conditions [10]. Furthermore, older people with OA may perceive the built environment (e.g., the presence and condition of sidewalks, bike paths and rest places) more as a barrier for outdoor PA than older people without OA [39]. As a consequence, older people with OA might be less likely to spend time in outdoor PA despite favourable weather conditions.

To our best knowledge, this is the first large-scale population-based study that examines whether the relationships between PA and objective weather conditions are different between older people with and without OA in Europe. Previous research on the relationship between PA and weather conditions in people with OA did not make a distinction between indoor and outdoor PA and mainly focused on the influence of temperature and precipitation on PA [8,11]. This study explicitly examined the associations between outdoor PA and a variety of objectively measured weather parameters, including temperature, precipitation, atmospheric

pressure, relative humidity and wind speed. Another strength of this study is that the diagnosis of OA was standardized across all countries by using the ACR classification criteria [25].

Some limitations of this study have to be acknowledged as well. First, although we had data available on a range of confounding factors, we lacked more detailed information on duration of disease and disease control with treatment, which might have affected outdoor physical activity. Individuals who have OA for a longer period and those who do not receive treatments may be less physically active. Second, total outdoor PA in minutes per day was calculated as the average daily time spent on walking, cycling and gardening in the previous two weeks. Although outdoor PA could include other activities, this measure does include the most important outdoor activities in older persons [13]. Third, the average weather parameters were objectively measured for each day in the present study, whereas outdoor PA in minutes per day was assessed retrospectively by self-reports using the LAPAQ. The LAPAQ assesses daily average PA in minutes per day based on the frequency and duration of PA in the previous two weeks and does not provide detailed information about PA on specific days [13]. Fourth, although we excluded individuals with cognitive impairments, participants might have had difficulties to compare their PA pattern over the last two weeks with their PA pattern over the last year, which may have caused recall bias in the PA pattern variable. Finally, the use of a self-reported measure of PA might have caused a social desirability bias. Alternatively, it would be better to assess outdoor PA on a day-to-day basis by using objective PA measures, such as accelerometers.

In this study, outdoor PA was not measured over time, covering subsequent different weather conditions. However, outdoor PA was assessed during different seasons across participants, resulting in meteorological variety. Longitudinal studies are needed to examine the effects of daily average weather conditions on daily PA of older people with and without OA over a longer time period. In addition, future research should focus on indoor as well as outdoor PA simultaneously and should account for differences in weather parameters between the indoor and outdoor environment. Furthermore, the use of objective measures of PA, such as accelerometers, would not only give further insight in the quantity of PA, but also into the intensity of PA. Future research is also needed to examine whether PA of older adults with OA are more strongly influenced by other environmental factors than weather conditions, such as proximity of facilities in the neighbourhood environment and presence and condition of sidewalks.

In conclusion, our results showed potentially important relationships between weather conditions and outdoor PA in older people in the general population. The findings showed that increased temperature facilitates outdoor PA in older people. Furthermore, this study identified increased relative humidity as a barrier to outdoor PA in older adults. Outdoor PA and weather conditions were more strongly associated in older adults without OA than in their counterparts with OA. This was particularly true for temperature and relative humidity. The latter condition was observed to affect outdoor walking in particular. The current findings suggest that weather conditions should be taken into consideration when designing and interpreting the results of interventions aimed at increasing PA of older people in the general population.

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Figure 1. Associations between total outdoor physical activity in minutes per day and weather parameters in older people with and without osteoarthritis.^{a-c}

^a Abbreviation: °C: Degrees Celsius; hPa: Hectopascals; mm: Millimetres; m/s: Meters per second; OA=Osteoarthritis.

^b Error bars represent 95%-confidence intervals. Asterisk: p-value<0.05; ns: not significant.

^c The associations are adjusted for age, sex (reference category: men), country (reference category: Sweden), educational level (reference category: not better educated than secondary education), Body Mass Index, number of chronic diseases (reference category: no chronic diseases), anxiety (reference category: not anxious), depression (reference category: not depressed), mastery, physical activity pattern (reference category: normal physical activity pattern), and functional limitations (reference category: quartiles 1-3).

Figure 2. Associations between outdoor walking in minutes per day and weather parameters in older people with and without osteoarthritis.^{a-c}
^a Abbreviation: °C: Degrees Celsius; hPa: Hectopascals; mm: Millimetres; m/s: Meters per second; OA=Osteoarthritis.
^b Error bars represent 95%-confidence intervals. Asterisk: p-value<0.05; †: 0.05 p<0.10; ns: not significant.
^cThe associations are adjusted for age, sex (reference category: men), country (reference category: Sweden), educational level (reference category: not better educated than secondary education), Body Mass Index, number of chronic diseases (reference category: no chronic diseases), anxiety (reference category: not anxious), depression (reference category: not depressed), mastery, physical activity pattern (reference category: normal physical activity pattern), and functional limitations (reference category: quartiles 1-3).

Table 1
Characteristics of the study sample stratified for osteoarthritis.^{a,b}

	Participants with OA (n=703)		Participants without OA (n=1,736)		p-value
	n		n		
Age in years (Mean (SD))	703	73.9 (4.9)	1,736	73.6 (5.0)	0.21
Sex (female) (n (%))	703	479 (68.1)	1,736	756 (43.5)	<0.001
Educational level (secondary education) (n (%))	702	366 (51.5)	1,734	1,084 (61.6)	<0.001
Country of residence (n (%))	703		1,736		<0.001
Germany		84 (11.9)		307 (17.7)	
Italy		129 (18.3)		193 (11.1)	
the Netherlands		118 (16.8)		384 (22.1)	
Spain		135 (19.2)		290 (16.7)	
Sweden		130 (18.5)		271 (15.6)	
United Kingdom		107 (15.3)		291 (16.8)	
Chronic diseases (n (%))	697		1,728		
0		222 (32.7)		699 (41.6)	
1		250 (35.2)		649 (36.6)	
2		225 (32.0)		380 (21.8)	
Body Mass Index in kg/m ² (Mean (SD))	692	28.4 (4.8)	1,703	27.1 (4.0)	<0.001
Anxiety (HADS-A 8) (n (%))	685	209 (31.2)	1,689	220 (13.2)	<0.001
Depression (HADS-D 8) (n (%))	686	141 (16.7)	1,690	142 (7.2)	<0.001
6-Item Pearlin Mastery score (0-24) (Mean (SD))	678	16.3 (4.7)	1,651	17.6 (4.1)	<0.001
Physical activity pattern (n (%))	689		1,694		<0.001
Normal PA pattern		492 (70.5)		1,286 (75.1)	
Abnormal PA pattern because of weather conditions		25 (3.8)		77 (4.6)	
Abnormal PA pattern because of another reason than weather conditions		172 (25.7)		331 (20.3)	
AUSCAN functional limitations (4 th quartile) (n (%))	702	413 (59.1)	1,735	249 (15.3)	<0.001
WOMAC functional limitations (4 th quartile) (n (%))	702	424 (60.7)	1,734	181 (10.8)	<0.001

^aDescriptive statistics are weighted (except age, sex and country), n is non-weighted.

^bAbbreviations: AUSCAN= Australian/Canadian Osteoarthritis Hand Index; HADS-A= Hospital Anxiety Depression Scales - Anxiety; HADS-D=Hospital Anxiety Depression Scales – Depression; IQR= Interquartile range; n= Number; OA= Osteoarthritis; PA= Physical activity; SD= Standard deviation; WOMAC= Western Ontario and McMaster Universities Osteoarthritis Index.

Table 2
Outdoor physical activity in minutes per day stratified for country.^{a,b}

	Full sample (n=2,439)	Germany (n=391)	Italy (n=322)	the Netherlands (n=502)	Spain (n=425)	Sweden (n=401)	United Kingdom (n=398)	p-value
Outdoor physical activity								
Total outdoor PA in minutes/day (Median (IQR))	47.1 (21.4-93.2)	77.6 (38.8-128.6)	61.2 (25.7-139.4)	31.1 (15.0-61.2)	45.0 (25.7-83.6)	30.0 (15.0-60.0)	68.6 (34.3-140.0)	<0.001
Walked in past two weeks (yes) (n (%))	2,205 (90.0)	352 (90.3)	242 (75.0)	455 (90.6)	422 (99.2)	346 (86.5)	388 (97.4)	<0.001
Walking in minutes/day (Median (IQR))	25.7 (11.4-60.0)	30.9 (17.1-60.0)	25.7 (8.6-53.7)	15.0 (7.1-30.0)	45.0 (25.7-60.0)	20.0 (8.8-30.0)	25.7 (12.9-60.0)	<0.001
Cycled in past two weeks (yes) (n (%))	657 (26.9)	186 (47.0)	136 (42.8)	292 (57.3)	6 (1.4)	9 (2.3)	28 (6.5)	<0.001
Cycling in minutes/day (Median (IQR))	12.9 (5.4-25.7)	17.1 (8.6-35.9)	8.6 (3.6-20.0)	10.7 (5.6-21.4)	1.0 (0.1-18.4)	25.5 (18.9-51.4)	4.8 (2.9-14.9)	<0.001
Gardened in past two weeks (yes) (n (%))	1,309 (52.2)	247 (61.7)	253 (78.6)	194 (37.4)	54 (13.2)	212 (52.8)	349 (87.1)	<0.001
Gardening in minutes/day (Median (IQR))	32.1 (12.9-77.1)	42.9 (21.4-90.0)	51.4 (17.1-120.0)	17.1 (6.4-38.6)	25.2 (12.9-34.3)	25.7 (8.6-60.0)	38.6 (16.9-90.0)	<0.001

^a Descriptive statistics of the full sample are weighted. The n is non-weighted.

^b Abbreviations: IQR= Interquartile range; n= Number; PA= Physical activity.

Table 3
Outdoor physical activity in minutes per day stratified for osteoarthritis.^a

	Participants with OA (n=703)		Participants without OA (n=1,736)		p-value
	n		n		
Outdoor physical activity					
Total outdoor PA in minutes/day (Median (IQR))	703	42.9 (20.0-83.1)	1,736	51.4 (23.6-98.6)	<0.01
Walking in minutes/day (Median (IQR))	616	25.7 (10.7-45.0)	1,589	28.6 (11.4-60.0)	0.28
Cycling in minutes/day (Median (IQR))	165	12.9 (5.7-29.8)	492	11.4 (5.4-25.7)	0.29
Gardening in minutes/day (Median (IQR))	356	32.1 (12.9-64.3)	953	32.1 (12.9-85.7)	0.36

^a Abbreviations: IQR= Interquartile range; n= Number; OA=Osteoarthritis; PA= Physical activity.

Table 4

Distribution of meteorological exposure in the study sample.^a

Weather parameters	Full sample	Germany	Italy	the Netherlands	Spain	Sweden	United Kingdom	p-value
Temperature (in °C) (Mean (SD))	12.0 (5.3)	13.1 (4.5)	13.8 (6.5)	7.6 (4.6)	14.4 (5.4)	10.4 (4.1)	14.1 (2.3)	<0.001
Precipitation (in mm) (Median (IQR))	1.6 (0.6-2.9)	1.7 (1.0-2.8)	2.2 (0.7-6.1)	0.9 (0.4-1.8)	1.9 (0.9-3.6)	2.6 (1.6-4.4)	1.3 (0.5-1.9)	<0.001
Atmospheric pressure (in hPa) (Mean (SD))	1,016.9 (4.8)	1,018.0 (3.2)	1,018.1 (3.5)	1,018.4 (4.5)	1,017.4 (3.8)	1,014.0 (7.0)	1,015.5 (3.5)	<0.001
Relative humidity (in %) (Mean (SD))	74.4 (10.9)	79.2 (7.5)	72.5 (7.8)	79.5 (9.5)	59.7 (9.3)	81.8 (7.9)	74.3 (3.8)	<0.001
Wind speed (in m/s) (Mean (SD))	2.4 (1.3)	1.3 (0.4)	0.8 (0.2)	4.1 (1.2)	3.3 (0.6)	2.4 (0.8)	1.8 (0.4)	<0.001

^a Abbreviations: °C: Degrees Celsius; hPa: Hectopascals IQR=Interquartile range; mm: Millimetres; m/s: Meters per second; SD: Standard deviation.

Table 5
Associations between total outdoor physical activity in minutes per day in the study sample.^{a-d}

Weather parameter	Model	B (SE)
Temperature (in °C)	Model 1	2.67 (0.34)
	Model 2	1.52 (0.40)^e
Precipitation (in mm)	Model 1	-0.28 (0.85)
	Model 2	-1.48 (0.92)
Atmospheric pressure (in hPa)	Model 1	-0.10 (0.39)
	Model 2	-0.33 (0.43)
Relative humidity (in %)	Model 1	-0.65 (0.17)
	Model 2	-0.77 (0.19)^f
Wind speed (in m/s)	Model 1	-14.53 (1.36)
	Model 2	-0.89 (2.59)

^a Abbreviations: °C: Degrees Celsius; B: Unstandardized coefficient; hPa: Hectopascals; mm: Millimetres; m/s: Meters per second; SE: Standard error; in bold: p<0.05.

^b Model 1: Adjusted for age, and sex (reference category: men).

^c Model 2: Additionally adjusted for country (reference category: Sweden), educational level (reference category: not better educated than secondary education), Body Mass Index, number of chronic diseases (reference category: no chronic diseases other than osteoarthritis), anxiety (reference category: not anxious), depression (reference category: not depressed), mastery, physical activity pattern (reference category: normal physical activity pattern), functional limitations (reference category: quartiles 1-3), and osteoarthritis (reference category: no osteoarthritis).

^d In all models, all variables were included simultaneously.

^e There was a statistically significant OA by temperature interaction effect on total outdoor physical activity in minutes per day in the full sample. Therefore, the association in this model was not additionally adjusted for osteoarthritis.

^f There was a statistically significant country by humidity interaction effect on total outdoor physical activity in minutes per day in the full sample. Therefore, the association in this model was not adjusted for country.