

RESEARCH ARTICLE

Household air pollution and arthritis in low- and middle-income countries: Cross-sectional evidence from the World Health Organization's study on Global Ageing and Adult Health

Shelby S. Yamamoto^{1*}, Elaine Yacyshyn², Gian S. Jhangri¹, Arvind Chopra³, Divya Parmar⁴, C. Allyson Jones⁵

1 School of Public Health, University of Alberta, Edmonton, Canada, **2** Division of Rheumatology, Faculty of Medicine & Dentistry, University of Alberta, Edmonton, Canada, **3** Centre for Rheumatic Diseases, Pune, India, **4** School of Health Sciences, City, University of London, London, England, United Kingdom, **5** Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, Canada

* shelby.yamamoto@ualberta.ca



OPEN ACCESS

Citation: Yamamoto SS, Yacyshyn E, Jhangri GS, Chopra A, Parmar D, Jones CA (2019) Household air pollution and arthritis in low- and middle-income countries: Cross-sectional evidence from the World Health Organization's study on Global Ageing and Adult Health. *PLoS ONE* 14(12): e0226738. <https://doi.org/10.1371/journal.pone.0226738>

Editor: Hisham Zerriffi, University of British Columbia, CANADA

Received: June 22, 2018

Accepted: December 6, 2019

Published: December 27, 2019

Copyright: © 2019 Yamamoto et al. This is an open access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Data Availability Statement: The data used in this study is publicly available from <http://www.who.int/healthinfo/survey/en/> upon registration.

Funding: The authors received no specific funding for this work.

Competing interests: The authors have declared that no competing interests exist.

Abstract

Background

Evidence points to a clear link between air pollution exposure and several chronic diseases though investigations regarding arthritis are still lacking. Emerging evidence suggests an association between ambient air pollution and rheumatoid arthritis. Household air pollution exposure, conversely, is largely unstudied but may be an important consideration for arthritis, particularly in low- and middle-income countries (LMICs), where cooking and heating activities can generate high indoor air pollutant levels.

Methods

We investigated the association of household air pollution (electricity vs. gas; kerosene/paraffin; coal/charcoal; wood; or agriculture/crop/animal dung/shrubs/grass as the main fuel used for cooking) and arthritis in six LMICs (China, Ghana, India, Mexico, the Russian Federation, South Africa) using data from Wave I of the World Health Organization Study on Global AGEing and Adult Health (SAGE) (2007–2010). Multivariable analyses were adjusted for sociodemographic, household and lifestyle characteristics and several comorbidities.

Results

The use of gas (aOR = 1.76, 95%CI: 1.40–2.21); coal (aOR = 1.74, 95%CI: 1.22–2.47); wood (aOR = 1.69, 95%CI: 1.30–2.19); or agriculture/crop/animal dung/shrubs/grass: aOR = 1.95 (1.46–2.61) fuels for cooking were strongly associated with an increased odds of arthritis, compared to electricity in cluster and stratified adjusted analyses. Gender (female), age (≥ 50 years), overweight ($25.0 \leq \text{BMI} < 30.0 \text{ kg/m}^2$), obesity ($\text{BMI} \geq 30.0 \text{ kg/m}^2$),

former and current alcohol consumption, and the comorbidities angina pectoris, diabetes, chronic lung disease, depression and hypertension were also associated with a higher odds of arthritis. Underweight (BMI<18.5 kg/m²) and higher education levels (college/university completed/post-graduate studies) were associated with a lower odds of arthritis.

Conclusions

These findings suggest that exposure to household air pollution from cook fuels is associated with an increased odds of arthritis in these regions, which warrants further investigation.

Background

Household air pollution continues to be a public health issue, particularly for those in low- and middle-income countries (LMICs).[1] A significant source of household air pollution is generated from cooking and heating activities that rely on solid biomass fuels.[2–5] Approximately 3 billion people globally still largely rely on solid biomass fuels.[6]

Air pollution is associated with number of chronic adverse health effects, including non-communicable diseases such as cardiovascular disease, chronic obstructive pulmonary disease and lung cancer.[1, 7–12] However, very few studies have explored the impact of air pollution on arthritis, particularly in LMIC settings.[13–18] Though the age standardized prevalence of osteoarthritis (OA) and rheumatoid arthritis (RA) in areas such as South and East Asia have been estimated to be lower than in North America, the disability-adjusted life years (DALYs), a measure of disease burden, is often much higher in these regions.[19, 20] For example, the mean DALYs for hip and knee OA (2010) in South Asia were estimated to be 2,466 (per 100,000) compared to 1,117 (per 100,000) in North America.[19] The burden of OA, specifically, is exacerbated in LMICs as a result of ageing populations, lack of access to preventative and therapeutic interventions and greater numbers of people with moderate to severe forms of the disease.[19, 21, 22] Similarly, DALYs for RA (2010) for women in South Asia were estimated to be 445 (per 1,000) and 338 (per 1,000) for women in North America.[20] Global estimates may also be underestimated due to the underdiagnosis of the condition in some LMIC settings.[20, 23, 24]

Most OA and RA studies have focused on smoking as an important environmental risk factor.[25–28] However, emerging evidence from high-income countries (HICs) suggests that ambient air pollution exposure is also a risk factor for RA.[13–18] Investigations concerning household air pollution and OA have not yet been undertaken. Household air pollution may similarly be an important risk factor in LMICs where indoor air pollution levels can be high, [5] though this is currently unexplored. Proposed biological pathways for the air pollution-RA relationship could be related to oxidative stress and immune suppression, similar to those mechanisms proposed for smoking.[16, 29, 30] Pathways linking OA and air pollution are currently unexplored. Cartilage loss from smoking may be associated with OA progression.[31, 32] The aim of this study was to examine the association between household air pollution and arthritis in LMICs.

Methods

Sample

Data from wave I of the multiwave panel World Health Organization (WHO) Study on Global AGEing and Adult Health (SAGE) (2007–2010) was used for this study.[33] Data from face-

to-face interviews were obtained from standardized questionnaires in six LMICs: China (n = 13,656), Ghana (n = 4,776), India (n = 10,829), Mexico (n = 2,349), the Russian Federation (n = 3,640) and South Africa (n = 3,064). Questionnaires were translated according to the World Health Survey protocol and the validity and reliability of the instruments were tested in a pilot survey across data collection sites.[34] Nationally representative samples were selected from populations in these countries and included those aged ≥ 18 years, with a particular focus on those ≥ 50 years old.[33] A stratified multistage cluster sampling design was used with household-level analysis weights and person-level analysis weights calculated and post-stratified for each country.[33] Further information regarding the study, sampling approach and weighting scheme used in SAGE is published elsewhere.[33, 35]

Outcome

The outcome in this study, arthritis (yes, no), was derived using the algorithm of Arokiasamy et al, based on several SAGE survey questions.[36] Participants were considered to have arthritis if they responded yes to the questions: “Have you ever been diagnosed with/told you have arthritis (a disease of the joints, or by other names rheumatism or osteoarthritis)?” or “Have you been taking medications or other treatment for it during the last 12 months?”[36, 37] Participants were also coded as having arthritis if they responded yes to questions 1, 2 and 4 and “About 30 minutes or less” to question 3: (Q1) “During the last 12 months, have you experienced, pain, aching, stiffness or swelling in or around the joints (like arms, hands, legs or feet) which were not related to an injury and lasted for more than a month?”; (Q2) “During the last 12 months, have you experienced stiffness in the joint in the morning after getting up from bed, or after a long rest of the joint without movement?”; (Q3) “How long did this stiffness last?”; and (Q4) “Did this stiffness go away after exercise or movement in the joint?”[36] As the determination of the outcome relied on self-reports and symptoms, we were unable to distinguish between different types of arthritis.

Exposure

Exposure to household air pollution was assessed in a question that asked participants about the main type of fuel used in the household for cooking. A series of eight options were provided, which were further grouped into (1) electricity; (2) gas; (3) kerosene/paraffin; (4) coal/charcoal; (5) wood; and (6) agriculture/crop/animal dung/shrubs/grass for this study as strata counts for some options were small.

Covariates

A number of covariates identified *a priori* from the literature were also examined in this study. Socio-demographic characteristics included: age (18–49, 50–59, 60–69 and ≥ 70 years); gender (male, female); marital status (currently married/cohabitating, never married/separated/divorced/widowed); highest education level (primary school or less, secondary school completed, high school or equivalent completed, and college/university completed/post-graduate studies), body mass index (BMI) (underweight: $\text{BMI} < 18.5 \text{ kg/m}^2$, normal weight: $18.5 \leq \text{BMI} < 25.0 \text{ kg/m}^2$, overweight: $25.0 \leq \text{BMI} < 30.0 \text{ kg/m}^2$, obese: $\text{BMI} \geq 30.0 \text{ kg/m}^2$), setting (urban, rural), and country (China, Ghana, India, Mexico, Russia, South Africa). Household income was assessed using a combination of assets, income, household expenditures (food, goods, services, health care), which were included in this study as quintiles (1: lowest to 5: highest).[33]

Lifestyle characteristics included tobacco use, alcohol use and physical activity. Tobacco use was assessed as never, former or current user. Similarly, alcohol use was also classified as never, former and current drinker. Leisure, occupation-related and transport-related physical activity

was assessed in the survey and grouped into: <75 minutes of vigorous or <150 minutes of moderate activity per week; or ≥ 75 minutes of vigorous or ≥ 150 minutes of moderate activity per week, according to the WHO Global Recommendations on Physical Activity for Health.[38]

Several comorbidities (angina, diabetes, chronic lung disease (emphysema, bronchitis, chronic obstructive pulmonary disease), asthma, depression, hypertension and stroke) were assessed using questions from the survey. The algorithms of Arokiasamy et al.[36] were similarly applied to code participants as not afflicted (no) or afflicted (yes).

Statistical analyses

Data were first examined descriptively with percentages presented for categorical variables, median and IQR (interquartile range) for continuous variables, by country. Pooled data were also examined. Complete case analysis using multivariable logistic regression was conducted to investigate the relationship between household air pollution and arthritis status. Models were constructed by sequentially adding the blocks of covariates previously identified and described starting with a base model of individual and household risk factors (socio-demographic plus household). Model 2 incorporated lifestyle characteristics and model 3 included comorbidities. Sensitivity analyses were run by country (solid vs non-solid fuels). Further examinations also examined the two countries with the highest proportion of electricity users for cooking (Russia and South Africa) and consistent results were obtained (data not shown). Analyses stratified by gender were also conducted to investigate potential effect modification. Interactions were similarly examined in pooled analyses. Strata and cluster variables (primary sampling units) provided in the dataset were incorporated into the analyses to account for the stratified, multistage clustered sampling design of the study. Post-stratified person-level weights, based on sample selection and a post-stratification factor, were included to account for the study sampling design in the analyses.[33] All analyses were performed using SAS 9.4.

Ethical approval and informed consent

The SAGE study received ethical approval from the World Health Organization Ethical Review Committee and organizations in each country in the study prior to data collection. Informed written consent was sought and obtained from all participants.[34]

Results

Pooled and country-level participant characteristics

Education levels varied widely between the countries, with Russia reporting the highest levels of education and India the lowest (Table 1). The prevalence of overweight participants was highest in Mexico (49.4%) with obesity prevalence the highest in South Africa (29.6%). Current tobacco use was most frequently reported in India, followed by China. Russia had the highest proportion of people with current use of alcohol (53%).

Pooled multivariable analyses

Participant characteristics by gender. The median age of men and women in the study was 42.7 (IQR: 34.4–49.8) and 42.1 (IQR: 33.4–51.4) years, respectively. Obesity ($\text{BMI} \geq 30.0 \text{ kg/m}^2$) was higher among women compared to men (9.2% and 4.2%, respectively), though the proportion of overweight was similar (20.9% for both). Sixty percent of men compared to 11.3% of women reported current use of tobacco products. Current alcohol consumption was 35.8% among men and 9.1% among women (descriptive participant characteristics by gender not shown).

Table 1. Characteristics of participants by country and pooled*.

Characteristics %	China (N = 13,656)	Ghana (N = 4,776)	India (N = 10,829)	Mexico (N = 2,349)	Russia (N = 3,640)	South Africa (N = 3,064)	Total pooled (N = 38,314)
Socio-demographic							
Gender							
Male	50.9	50.1	51.2	47.8	43.6	44.7	49.9
Female	49.1	49.9	48.8	52.2	56.4	55.3	50.1
Age (years)							
18 to 49	74.6	75.4	75.3	73.2	58.5	75.0	73.0
50 to 59	11.5	9.9	12.2	13.6	19.4	12.5	12.7
60 to 69	8.2	6.8	7.6	6.9	10.1	7.6	8.1
≥70	5.8	7.9	4.9	6.4	11.9	4.9	6.2
Median (years)	44	42	40	39	46	43	43
Interquartile range (IQR)	38–50	35–49	30–49	32–51	36–58	32–50	35–51
Marital status							
Currently married/cohabitating	89.4	73.1	82.1	70.6	60.5	52.0	81.5
Never/separated/divorced/widowed	10.6	26.9	17.9	29.4	39.5	48.0	18.5
Education							
Primary school or less	38.2	63.6	61.2	52.4	3.1	36.2	43.9
Secondary school completed	32.5	10.8	15.8	23.4	10.1	27.0	22.3
High school (or equivalent) completed	20.6	21.0	14.8	11.8	64.3	29.4	23.7
College/university completed/post-graduate	8.7	4.5	8.2	12.4	22.6	7.5	10.1
BMI classification (kg/m ²)							
Underweight (BMI<18.5)	4.2	9.1	36.0	0.9	1.5	3.0	17.2
Normal (18.5≤BMI<25.0)	63.6	57.1	52.4	21.2	41.2	36.8	55.3
Overweight (25.0≤BMI<30.0)	27.5	21.1	9.0	49.4	36.8	30.5	20.9
Obese (BMI≥30.0)	4.8	12.6	2.6	28.6	20.5	29.6	6.7
Household							
Primary cook fuel type							
Electricity	4.9	0.1	0.1	0.9	18.6	75.8	6.7
Gas	50.5	8.9	19.3	90.8	79.7	4.3	38.9
Kerosene/paraffin	0.0	0.4	0.9	0.0	0.1	11.2	0.8
Coal/charcoal	4.1	33.9	2.4	0.1	0.1	0.3	3.3
Wood	12.6	54.9	60.3	8.2	1.5	8.1	31.7
Agriculture/crop/animal dung/shrub/grass	27.8	1.7	17.0	0.0	0.0	0.2	18.7
Income quintile							
1 st (lowest—poorest)	9.9	15.3	20.7	15.4	12.2	17.2	15.0
2 nd	16.3	17.0	21.1	24.4	12.7	20.0	18.0
3 rd	18.9	19.8	20.0	20.8	13.5	22.6	18.8
4 th	23.8	22.3	18.1	13.8	25.3	20.8	21.5
5 th (highest—richest)	31.1	25.6	20.1	25.6	36.3	19.4	26.7
Residential area							
Urban	47.7	45.3	25.3	76.3	80.5	73.1	43.1
Rural	52.3	54.7	74.7	23.7	19.5	26.9	56.9
Lifestyle							
Tobacco use							
Never	63.6	84.1	54.9	58.2	60.6	65.6	60.0

(Continued)

Table 1. (Continued)

Characteristics %	China (N = 13,656)	Ghana (N = 4,776)	India (N = 10,829)	Mexico (N = 2,349)	Russia (N = 3,640)	South Africa (N = 3,064)	Total pooled (N = 38,314)
Former	3.5	7.7	2.3	16.1	13.4	7.4	4.4
Current	32.9	8.2	42.8	25.7	26.0	27.1	35.6
Alcohol consumption							
Never	64.1	44.8	82.9	41.8	17.0	72.8	66.2
Former	9.1	24.0	8.3	26.8	29.2	9.0	11.4
Current	26.8	31.2	8.9	31.5	53.8	18.2	22.4
Leisure time physical activity							
<75 minutes vigorous or <150 minutes moderate activity per week	84.5	85.4	83.6	89.5	76.9	88.1	83.3
≥75 minutes vigorous or ≥150 minutes moderate activity per week	15.5	14.6	16.4	10.5	23.1	11.9	16.7
Occupation-related physical activity							
<75 minutes vigorous or <150 minutes moderate activity per week	41.8	23.3	25.2	59.8	19.0	49.7	32.1
≥75 minutes vigorous or ≥150 minutes moderate activity per week	58.2	76.7	74.8	40.2	81.0	50.3	67.9
Transport-related physical activity							
<75 minutes vigorous or <150 minutes moderate activity per week	58.3	41.1	40.0	55.0	31.2	72.9	47.6
≥75 minutes vigorous or ≥150 minutes moderate activity per week	41.7	58.9	60.0	45.0	68.8	27.1	52.4
Co-morbidities							
Arthritis	15.9	14.0	15.2	7.9	23.2	12.4	16.4
Angina pectoris	4.0	2.7	5.5	2.1	17.4	3.1	6.2
Diabetes	2.8	2.2	3.2	10.3	3.6	3.4	3.1
Chronic lung disease	5.7	2.3	10.1	14.7	15.7	5.1	8.7
Asthma	2.0	2.8	6.8	2.3	3.4	3.9	4.3
Depression	1.4	5.1	11.7	11.9	5.2	7.3	6.4
Hypertension	37.8	43.9	24.3	12.2	42.7	54.5	33.4
Stroke	0.9	1.3	1.0	1.8	2.4	1.6	1.1

* Post-stratified weighted, by country

<https://doi.org/10.1371/journal.pone.0226738.t001>

Arthritis. Overall, arthritis (16.4%) was the second most prevalent condition, after hypertension (33.4%) (Table 1). Of all the countries, the prevalence of arthritis was highest in Russia (23.2%) followed by China (15.9%) and India (15.2%) (Table 1). The prevalence of arthritis was higher in women (19.5%) compared to men (13.2%). Among the four age groups, the prevalence of arthritis was highest among those ≥70 years (Table 2). In those with less education, a higher prevalence of arthritis was also observed. The distribution of arthritis was similar between income quintiles. A higher prevalence of arthritis was observed among those that were overweight and obese. The prevalence of arthritis was also higher among those with comorbid conditions (Table 2).

Household air pollution. Overall, gas and wood were the primary fuels used most often by the households for cooking (38.9% and 31.7%, respectively). Mexico had the highest proportion of gas users (90.8%). South Africa reported the highest proportion of participants using electricity for cooking (Table 1). The proportion using wood for cooking was greatest in India, while China reported the highest proportion using agriculture/crop/animal dung/shrub/grass for cooking. The prevalence of arthritis was lowest among those using kerosene/

Table 2. Multivariable model examining variables associated with arthritis in pooled sample (N = 38,314)*.

Characteristics	Arthritis	Model 1**			Model 2***			Model 3****		
	%	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Socio-demographic										
Gender										
Male	13.2	1.00			1.00			1.00		
Female	19.5	1.46	1.27–1.69	<0.001	1.72	1.45–2.03	<0.001	1.77	1.49–2.09	<0.001
Age (years)										
18 to 49	11.5	1.00			1.00			1.00		
50 to 59	25.5	2.30	2.01–2.64	<0.001	2.33	2.03–2.67	<0.001	2.06	1.79–2.37	<0.001
60 to 69	31.1	3.06	2.67–3.50	<0.001	3.11	2.73–3.54	<0.001	2.48	2.15–2.86	<0.001
≥70	35.5	3.70	3.18–4.31	<0.001	3.84	3.31–4.46	<0.001	2.78	2.36–3.28	<0.001
Marital status										
Currently married/cohabitating	16.0	1.00			1.00			1.00		
Never/separated/divorced/widowed	18.0	0.91	0.76–1.09	0.31	0.91	0.76–1.09	0.31	0.91	0.74–1.09	0.29
Education										
Primary school or less	19.4	1.00			1.00			1.00		
Secondary school completed	15.4	0.93	0.75–1.15	0.49	0.96	0.77–1.18	0.69	0.93	0.76–1.15	0.52
High school (or equivalent) completed	15.3	0.78	0.62–0.98	0.03	0.81	0.65–1.02	0.07	0.82	0.66–1.01	0.07
College/university completed/post-graduate	7.9	0.41	0.29–0.59	<0.001	0.44	0.31–0.62	<0.001	0.45	0.32–0.64	<0.001
BMI classification (kg/m ²)										
Underweight (BMI<18.5)	13.5	0.77	0.66–0.91	0.002	0.77	0.66–0.91	0.002	0.75	0.64–0.89	<0.001
Normal (18.5≤BMI<25.0)	14.6	1.00			1.00			1.00		
Overweight (25.0≤BMI<30.0)	19.1	1.28	1.10–1.50	0.001	1.29	1.11–1.50	0.001	1.20	1.03–1.40	0.02
Obese (BMI≥30.0)	30.4	2.02	1.57–2.59	<0.001	2.05	1.61–2.61	<0.001	1.70	1.31–2.21	<0.001
Household										
Primary cook fuel type										
Electricity	12.2	1.00			1.00			1.00		
Gas	16.7	1.58	1.22–2.04	<0.001	1.65	1.27–2.14	<0.001	1.74	1.33–2.27	<0.001
Kerosene/paraffin	10.2	0.94	0.51–1.72	0.83	0.94	0.51–1.73	0.85	1.08	0.59–1.98	0.80
Coal/charcoal	15.3	1.66	1.12–2.48	0.01	1.72	1.17–2.54	0.006	1.81	1.23–2.67	0.003
Wood	15.8	1.66	1.23–2.24	0.001	1.69	1.25–2.28	<0.001	1.72	1.26–2.33	<0.001
Agriculture/crop/animal dung/shrub/grass	18.5	1.90	1.39–2.62	<0.001	1.93	1.41–2.65	<0.001	1.96	1.41–2.71	<0.001
Income quintile										
1 st (lowest—poorest)	18.3	1.00			1.00			1.00		
2 nd	16.4	0.87	0.69–1.10	0.24	0.88	0.70–1.10	0.26	0.89	0.71–1.13	0.35
3 rd	17.3	1.00	0.83–1.20	0.98	1.00	0.83–1.20	0.97	1.00	0.82–1.21	0.96
4 th	16.9	0.97	0.81–1.16	0.74	0.97	0.81–1.17	0.76	1.01	0.83–1.21	0.96
5 th (highest—richest)	14.2	0.90	0.73–1.13	0.37	0.90	0.72–1.12	0.34	0.94	0.75–1.19	0.61
Setting										
Urban	15.8	1.00						1.00		
Rural	16.8	1.05	0.88–1.25	0.59	1.02	0.85–1.23	0.84	1.05	0.86–1.26	0.65
Country										
China	15.9	1.00			1.00			1.00		
Ghana	14.0	0.81	0.62–1.05	0.11	0.78	0.59–1.03	0.08	0.78	0.60–1.02	0.07
India	15.2	1.07	0.88–1.30	0.53	1.16	0.95–1.43	0.15	0.98	0.80–1.20	0.85
Mexico	7.9	0.36	0.25–0.51	<0.001	0.33	0.23–0.47	<0.001	0.30	0.20–0.44	<0.001
Russia	23.2	1.61	1.22–2.12	<0.001	1.32	0.98–1.78	0.07	1.05	0.75–1.48	0.77
South Africa	12.4	0.94	0.67–1.31	0.70	0.96	0.68–1.35	0.81	0.96	0.67–1.37	0.81

(Continued)

Table 2. (Continued)

Characteristics	Arthritis	Model 1**			Model 2***			Model 3****		
	%	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Lifestyle										
Tobacco use										
Never	17.0				1.00			1.00		
Former	18.0				1.06	0.78–1.43	0.72	0.96	0.71–1.31	0.81
Current	15.2				1.07	0.93–1.24	0.32	1.05	0.91–1.21	0.50
Alcohol consumption										
Never	15.6				1.00			1.00		
Former	20.1				1.35	1.07–1.69	0.01	1.28	1.02–1.60	0.04
Current	16.6				1.47	1.21–1.80	<0.001	1.50	1.22–1.84	<0.001
Leisure time physical activity										
<75 minutes vigorous or <150 minutes moderate activity per week	17.3				1.00			1.00		
≥75 minutes vigorous or ≥150 minutes moderate activity per week	11.7				0.87	0.68–1.12	0.28	0.89	0.69–1.13	0.33
Occupation-related physical activity										
<75 minutes vigorous or <150 minutes moderate activity per week	16.2				1.00			1.00		
≥75 minutes vigorous or ≥150 minutes moderate activity per week	16.5				1.05	0.90–1.22	0.54	1.09	0.93–1.28	0.28
Transport-related physical activity										
<75 minutes vigorous or <150 minutes moderate activity per week	17.7				1.00			1.00		
≥75 minutes vigorous or ≥150 minutes moderate activity per week	15.1				0.92	0.81–1.04	0.17	0.96	0.85–1.08	0.49
Co-morbidities										
Angina pectoris										
No	14.6							1.00		
Yes	43.2							2.37	1.76–3.18	<0.001
Diabetes										
No	15.9							1.00		
Yes	32.2							1.37	1.06–1.78	0.02
Chronic lung disease										
No	14.7							1.00		
Yes	34.4							1.76	1.43–2.16	<0.001
Asthma										
No	15.6							1.00		
Yes	33.1							1.28	0.997–1.64	0.05
Depression										
No	15.2							1.00		
Yes	34.3							2.31	1.90–2.80	<0.001
Hypertension										
No	12.9							1.00		
Yes	23.3							1.24	1.08–1.42	0.002
Stroke										
No	16.2							1.00		
Yes	31.2							1.10	0.82–1.46	0.53

* Post-stratified person-level weights applied

** Model 1 includes socio-demographic and household characteristics

*** Model 2 includes Model 1 characteristics and lifestyle characteristics

**** Model 3 includes Model 2 characteristics and comorbidities

<https://doi.org/10.1371/journal.pone.0226738.t002>

paraffin for cooking (Table 2). Conversely, the prevalence of arthritis was highest among those using agriculture/crop/animal dung/shrub/grass products as cooking fuel.

In adjusted analyses, the type of primary cooking fuel used by the household was associated with arthritis in this study. Compared to electricity, all other forms of fuel, except kerosene/paraffin were associated with an increased odds of arthritis. The highest odds of arthritis were observed among those who used agriculture/crop/animal dung/shrub or grass fuels (Table 2).

Age and gender were also strongly associated with arthritis in the study. Women were much more likely to have arthritis compared to men (Table 2). The odds of arthritis also increased across age groups, with those in the highest age category (≥ 70 years) 2.78 times as likely to have arthritis compared to those in the youngest age category (18–49) (trend test: $p = 0.002$). Only the highest level of education (college/university completed/post-graduate studies) was associated with a lower odds of arthritis compared to primary or less education (aOR = 0.45, 95%CI: 0.32–0.64, trend test: $p < 0.001$). Underweight (BMI < 18.5 kg/m²) was associated with a decreased odds of arthritis (aOR = 0.75, 95%CI: 0.64–0.89) whereas obesity was associated with an increased odds of arthritis (aOR = 1.70, 95%CI: 1.31–2.21) compared to those of normal weight. Urbanicity was not found to be associated with arthritis. Participants in Mexico were much less likely to report having arthritis. When explored in further analyses (solid vs non-solid fuels) by country, the association was no longer apparent. Former and current alcohol use was also associated with an increased odds of arthritis, compared to never drinkers. Participants with arthritis were also more likely to have comorbidities including angina pectoris, diabetes, chronic lung disease, depression and hypertension.

Gender-stratified multivariable analyses. Compared to electricity, the use of gas, wood and agriculture/crop/animal dung/shrub/grass as primary cooking fuels were associated with an increased odds of arthritis in men. Among women, the use of gas, coal/charcoal and agriculture/crop/animal dung/shrub/grass as primary cooking fuels were linked to a higher odds of arthritis compared to electricity (Table 3). Higher odds of arthritis with the use of most fuel types were observed among men as compared to women. In both men and women, older ages were also strongly associated with a higher odds of arthritis (Table 3). College or university level education or higher was associated with a lower odds of arthritis among both men and women, compared to primary or less. A negative association with arthritis among underweight and a positive association with arthritis among overweight and obese participants was only observed in women. Current tobacco use and alcohol consumption was associated with an increased odds of arthritis in women compared to those who never smoked or drank. A positive association between former and current alcohol use and arthritis was observed in men compared to never users. Comorbidities angina pectoris, chronic lung disease, depression and hypertension were associated with an increased odds of arthritis among both men and women. Among women, diabetes was also associated with a higher odds of arthritis.

Discussion

The use of gas, coal/charcoal, wood and agriculture/crop/animal dung/shrubs/grass for cooking was associated with an increased odds of arthritis compared to electricity in this study. Gender (female), older ages (50–59, 60–69, ≥ 70 years), overweight ($25.0 \leq \text{BMI} < 30$ kg/m²) and obese ($\text{BMI} \geq 30.0$ kg/m²), former and current alcohol consumption, and having angina pectoris, diabetes, chronic lung disease, depression or hypertension were also associated with a higher odds of arthritis in the pooled analyses. Underweight (BMI < 18.5 kg/m²), higher education (college/university completed/post-graduate studies) were associated with a lower odds of arthritis.

Table 3. Multivariable model examining variables associated with arthritis by gender (N = 38,314)*.

Variable	Arthritis %	Men (N = 16,397)				Women (N = 21,917)			
		OR	95% CI	p-value	Arthritis %	OR	95% CI	p-value	
Socio-demographic									
Age (years)									
18 to 49	4.7	1.00			6.8	1.00			
50 to 59	10.5	2.11	1.66–2.67	<0.001	15.0	2.03	1.67–2.47	<0.001	
60 to 69	12.1	2.42	1.95–3.00	<0.001	19.0	2.44	1.99–2.99	<0.001	
≥70	13.3	3.01	2.34–3.88	<0.001	22.2	2.54	2.04–3.18	<0.001	
Marital status									
Currently married/cohabitating	7.3	1.00			8.7	1.00			
Never/separated/divorced/widowed	3.5	0.69	0.48–1.01	0.05	14.4	1.04	0.79–1.38	0.78	
Education									
Primary school or less	6.9	1.00			12.5	1.00			
Secondary school completed	7.9	1.06	0.78–1.44	0.69	7.5	0.81	0.67–0.99	0.03	
High school (or equivalent) completed	5.7	0.75	0.59–0.97	0.03	9.6	0.85	0.64–1.12	0.25	
College/university completed/post-graduate	4.2	0.52	0.33–0.82	0.004	3.8	0.39	0.23–0.64	<0.001	
BMI classification (kg/m ²)									
Underweight (BMI<18.5)	6.3	0.80	0.58–1.09	0.16	7.2	0.72	0.60–0.86	<0.001	
Normal (18.5≤BMI<25.0)	6.4	1.00			8.1	1.00			
Overweight (25.0≤BMI<30.0)	7.2	1.10	0.84–1.43	0.50	11.9	1.27	1.03–1.56	0.03	
Obese (BMI≥30.0)	6.6	1.43	0.84–2.46	0.19	23.7	1.86	1.42–2.43	<0.001	
Household									
Cook fuel type									
Electricity	3.2	1.00			9.0	1.00			
Gas	5.8	2.11	1.37–3.24	<0.001	11.0	1.54	1.15–2.06	0.004	
Kerosene/paraffin	2.7	0.87	0.31–2.40	0.79	7.4	1.26	0.65–2.46	0.49	
Coal/charcoal	3.9	1.37	0.85–2.20	0.19	11.3	2.05	1.09–3.87	0.03	
Wood	7.6	2.50	1.60–3.91	<0.001	8.2	1.31	0.91–1.87	0.15	
Agriculture/crop/animal dung/shrub/grass	8.4	2.48	1.57–3.93	<0.001	10.1	1.65	1.18–2.32	0.004	
Income quintile									
1 st (lowest—poorest)	7.9	1.00			10.3	1.00			
2 nd	6.6	0.80	0.58–1.11	0.18	9.8	0.97	0.74–1.26	0.80	
3 rd	7.4	0.90	0.66–1.23	0.51	10.0	1.03	0.84–1.27	0.76	
4 th	6.4	0.83	0.61–1.12	0.22	10.5	1.11	0.90–1.38	0.33	
5 th (highest—richest)	5.5	0.89	0.66–1.19	0.43	8.8	1.00	0.76–1.30	0.97	
Setting									
Urban	5.0	1.00			10.8	1.00			
Rural	7.8	1.17	0.81–1.70	0.40	9.1	0.99	0.78–1.24	0.90	
Country									
China	9.5	1.00			15.6	1.00			
Ghana	10.4	0.76	0.52–1.09	0.14	13.7	0.73	0.48–1.12	0.15	
India	7.9	0.83	0.58–1.19	0.32	13.4	1.02	0.80–1.31	0.87	
Mexico	4.6	0.23	0.13–0.38	<0.001	12.6	0.34	0.20–0.57	<0.001	
Russia	10.6	1.17	0.71–1.93	0.54	29.2	0.98	0.67–1.43	0.90	
South Africa	7.2	0.95	0.52–1.74	0.87	20.0	0.85	0.57–1.27	0.43	
Lifestyle									
Tobacco use									
Never	3.3	1.00			13.7	1.00			

(Continued)

Table 3. (Continued)

Variable	Arthritis %	Men (N = 16,397)				Women (N = 21,917)			
		OR	95% CI	p-value	Arthritis %	OR	95% CI	p-value	
Former	13.2	0.83	0.59–1.17	0.30	4.7	1.12	0.66–1.89	0.68	
Current	11.4	0.91	0.77–1.09	0.30	3.8	1.25	1.01–1.55	0.04	
Alcohol consumption									
Never	4.3	1.00			11.4	1.00			
Former	10.7	1.35	1.05–1.73	0.02	9.4	1.14	0.77–1.70	0.51	
Current	11.2	1.40	1.16–1.68	<0.001	5.4	1.67	1.12–2.50	0.01	
Leisure time physical activity									
<75 minutes vigorous or <150 minutes moderate activity per week	6.8	1.00			10.5	1.00			
≥75 minutes vigorous or ≥150 minutes moderate activity per week	5.3	0.84	0.61–1.16	0.28	6.3	0.97	0.65–1.46	0.90	
Occupation-related physical activity									
<75 minutes vigorous or <150 minutes moderate activity per week	6.8	1.00			9.3	1.00			
≥75 minutes vigorous or ≥150 minutes moderate activity per week	6.5	1.00	0.77–1.29	0.98	10.0	1.17	0.99–1.37	0.06	
Transport-related physical activity									
<75 minutes vigorous or <150 minutes moderate activity per week	6.7	1.00			11.1	1.00			
≥75 minutes vigorous or ≥150 minutes moderate activity per week	6.5	0.89	0.73–1.09	0.26	8.6	1.00	0.86–1.16	0.95	
Co-morbidities									
Angina pectoris									
No	5.8	1.00			8.8	1.00			
Yes	18.1	2.60	1.54–4.40	<0.001	25.2	2.21	1.75–2.80	<0.001	
Diabetes									
No	6.4	1.00			9.5	1.00			
Yes	13.7	1.42	0.86–2.34	0.17	18.5	1.33	1.03–1.73	0.03	
Chronic lung disease									
No	5.7	1.00			9.0	1.00			
Yes	15.9	1.70	1.30–2.24	<0.001	18.5	1.74	1.35–2.24	<0.001	
Asthma									
No	6.1	1.00			9.5	1.00			
Yes	16.5	1.24	0.86–1.80	0.25	16.7	1.29	0.97–1.72	0.08	
Depression									
No	6.0	1.00			9.2	1.00			
Yes	15.3	3.00	2.13–4.23	<0.001	19.0	1.85	1.53–2.24	<0.001	
Hypertension									
No	5.4	1.00			7.5	1.00			
Yes	9.0	1.27	1.03–1.57	0.03	14.3	1.23	1.05–1.44	0.01	
Stroke									
No	6.5	1.00			9.7	1.00			
Yes	12.7	1.09	0.73–1.65	0.67	18.5	1.12	0.77–1.64	0.55	

* Post-stratified person-level weights applied

<https://doi.org/10.1371/journal.pone.0226738.t003>

Arthritis, ambient air pollution and smoking

The prevalence of arthritis in this study varied widely by country. Musculoskeletal diseases are the second leading causes of disability globally and osteoarthritis is associated has been associated with the greatest increases over the last 20 years.[39] Another study examining chronic diseases among older adults (>65 years) in Latin America (Cuba, Dominican Republic, Peru,

Venezuela, Mexico), China and India reported an overall prevalence of arthritis comparable to that observed in the current study (18.2%) [40]. The prevalence of self-reported arthritis by country in urban and rural areas, respectively, was 14.5% and 22.3% (Mexico); 14.2% and 1.9% (China); and 18.2% and 51.1% (India) [22]. The reported prevalence among older adults (>65 years of age) from another meta-analysis study in South Africa was higher than that reported in this study (2.5% for rheumatoid arthritis; 29.5% to 82.7% for osteoarthritis) [41]. Similarly, the estimate of self-reported joint pain across the life course of adults (≥ 18 years) in a study of Russia was 44% [42]. Limited data regarding the prevalence of arthritis in Ghana outside of the SAGE studies were found.

Earlier studies have reported associations between ambient air pollution and RA. In a US-based study, Hart et al. [15] observed a 31% increased risk of incident RA among women living within 50m of primary (interstate and non-interstate) and secondary roads, though a second study did not observe an association with specific ambient pollutants. [18] Similar findings from a large study in Vancouver, Canada also showed a dose-response relationship with distance from highways or major roads and incident RA; however, no associations with specific pollutants were found except for ground level ozone. [16] Other studies have similarly observed associations between ambient air pollution and RA, RA biomarkers or clinical indicators (e.g. swollen joints) but not consistently with specific pollutants. [13, 14, 17, 43, 44]

Investigations of associations between ambient air pollution and arthritis have been preceded by studies focused on tobacco smoke and occupational health. Prior work has generally shown cigarette smoking to be a risk factor for the development and severity of RA. [25, 45–52] Conversely, smoking has been observed to have a protective effect in terms of hip, hand and knee OA in some, but not all studies, though the mechanism is unclear with confounding a potential issue. [28, 53–64] In this study, use of tobacco (former, current) was not found to be associated with arthritis in pooled or gender-stratified analyses. The proportion of women who used tobacco products in the study was very low, characteristic of low-income countries, [65–67] although the proportion of men who used tobacco in this study was relatively higher as compared to HIC. [67] In this study we did not specifically assess smoking but rather tobacco use, which also included snuff and chewing tobacco. [68]

Arthritis and household air pollution

Use of gas, coal/charcoal, wood and agriculture/crop/animal dung/shrubs/grass fuels for cooking were positively associated with higher odds of arthritis compared to electricity. Only kerosene/paraffin was not associated with arthritis, though the proportion of users was very low (overall prevalence of 0.8%). These findings are congruent with others. In a study in Stockholm, sulfur dioxide, modelled as a marker of home heating sources, was associated with an increased odds of RA in anti-citrullinated protein antibody-negative RA phenotype individuals with less than a university education. [18] Dahlgren et al. [69] also observed an increased odds of rheumatic diseases and systemic lupus erythematosus with exposure to volatiles, reduced sulfur compounds, heavy metals and house dust in New Mexico. Occupational exposures (mineral dust, insecticides, and textiles) have also been associated with an increased risk of RA. [45, 49, 70, 71] Studies investigating air pollution and OA are currently lacking.

Potential biological mechanisms linking air pollution exposure and autoimmune diseases like RA may be similar to those of smoking, which include oxidative stress and immune suppression. [16, 29, 30] Air pollution-induced oxidative stress may lead to the production of pro-inflammatory cytokines, promoting the maturation of airway-resident dendritic cells that migrate to lymph nodes and activate lymphocytes, triggering autoimmune responses in susceptible individuals. [72] Particulate matter may also promote disease via oxygen-free radical-

generating activity, DNA oxidative damage and mutagenicity.[43] Potential biological mechanisms that may link osteoarthritis and air pollution are currently unexplored.[62, 73] However, proposed pathways include ozone-related vitamin D deficiency, the action of non-dioxin-like polychlorinated biphenyls or systemic inflammation leading to OA progression.[74–76] Studies of smoking have found an association with cartilage loss, which may also explain our findings.[31, 32] Exposure to air pollution from cooking activities is not likely to be transient, with exposures occurring throughout different life stages (in utero, infancy, childhood, adulthood), [77, 78] particularly in women, which may have ramifications in terms of the development of arthritis.

Cook fuel type may be an indicator of household socioeconomic status in LMIC,[79] which may be another explanation for the association between air pollution and arthritis, though adjustment for both education level and income quintile in this study did not attenuate this relationship. College/university or higher education was found to be protective for arthritis in this study, compared to those with primary school or less. Lower socioeconomic status and education levels independently have been associated with an increased risk of RA and OA in prior studies.[45, 80–84]

Repetitive joint stress from the collection and carrying of fuel, or the use of wood and charcoal stoves, which are typically lower to the ground and can involve sitting, kneeling, bowing or squatting,[85] may also partly explain this relationship. Squatting, bending and kneeling during cooking is typical when using stoves that burn biomass fuels in many regions.[86–89] The association among those who report using gas as the main fuel for cooking may be due to mixed stove and/or fuel use. Cooking is an activity that is conducted almost daily.[90–92] Sports, occupational or other socio-behavioural activities may be risk factors for OA related to the stress they place on joints.[93–98] A systematic review and dose-response meta-analysis found a 26% increased odds of OA per 5,000 hours of kneeling or squatting from pooled case-control studies that examined occupation-related exposures in men and women.[99] The impact of occupational and household activities requires further investigation.

Arthritis and sociodemographic characteristics

In this study, older age and female gender were strongly associated with arthritis, which is consistent with the findings of several other studies.[13, 21, 100] We also observed a higher odds of arthritis among women classified as overweight and obese and lower odds among those classified as underweight, compared to those of normal weight. Obesity is a known risk factor for OA.[21, 45, 101–103] Although a complex relationship exists between arthritis and obesity, increased force on articular cartilage and subsequent breakdown can result from higher body weight.[104] No significant associations between arthritis and participants' country were observed, with the exception of Mexico. The lower odds observed in Mexico could be due to underreporting or regional variations (within Mexico) in the reporting of arthritis.[105]

Arthritis and lifestyle characteristics

The former and current consumption of alcohol among men was also associated with a higher odds of arthritis, compared to those who never drank. A systematic review and meta-analysis found that low to moderate alcohol consumption was associated with a lower risk of RA in both men and women.[106] Magnusson et al.[61] also observed that alcohol consumption was associated with current joint inflammation among those with hand OA. The positive association may also be related to the occurrence of gout, the most common inflammatory arthritis among men. Choi et al. observed increasing risk of gout with increasing levels of alcohol consumption in a US-based study.[107]

Arthritis and comorbidities

In our study, we also observed that arthritis was associated with a number of different comorbidities, including angina pectoris, diabetes, chronic lung disease, depression and hypertension. Greater numbers of comorbidities have been found to be associated with RA and OA in other studies. [21, 36, 108–111] Multimorbidity is also associated with older age and being female. [111, 112] There is also emerging evidence for the independent role of metabolic syndromes (e.g. diabetes, hypertension, obesity) in the development of osteoarthritis. [75, 113]

Strengths and limitations

We had the opportunity to examine household air pollution and other factors in relation to arthritis. A strength of this study is its focus on LMIC, understudied populations, and use of large datasets for the analyses. However, there are several limitations that need to be considered together with the interpretation of these findings. Importantly, we were unable to distinguish between the different types of arthritis in this study, as diagnoses relied on self-reports and questions rather than physician- and/or laboratory-confirmed diagnoses. Validation studies of some self-reported measures against gold standard laboratory tests were planned for later waves but not available in Wave I. Symptoms of other non-arthritic conditions such as fibromyalgia can present similarly to arthritis. [114] Variability in terms of the level of accuracy in the reporting of different chronic diseases among elderly populations has been previously observed. [115–118] The diagnosis of arthritis is often difficult without the aid of other clinical, radiological or biological measurements, which are often lacking in LMIC settings. [23, 119–122] However, the sensitivity and specificity of combinations of answers regarding arthritis were checked against a Diagnostic Item Probability Study (2003) carried out as part of the validation of symptom questions used in the diagnosis of chronic diseases the first wave of the World Health Surveys. [123] Here on the primary focus of our discussions have concerned OA and RA, two of the most common types of arthritis, as studies of other types are scarce. Globally, OA is also the most prevalent type of arthritis. [19]

A limitation in air pollution studies concerns the assessment of exposures. In this study, the use of the primary type of fuel used for cooking is a proxy for household air pollution exposure. The assumption is that solid biomass fuels produce levels of household air pollution greater than gas fuels, though mixed fuel and stove use by households is likely more typical. [124–126] Information about mixed fuel and stove use was not available in the data. Thus, the associations reported here may neglect other critical exposure aspects. Further, data limitations prevented us from refining these exposures based on the type of stove used, presence of a chimney or hood and the location of cooking activities, though these variables were available in the dataset. Of those that responded, 83.4% reported using an open stove or fire for cooking, 43.5% reported the presence of a chimney or hood and 58.7% reported cooking in a separate room of the house. Multiple imputation was not undertaken due to a combination of factors related to the proportion of missing data (~50%) and indeterminate missing data mechanisms and patterns. [127, 128]

We were also unable to consider potential effects from ambient air pollution, which may be a significant exposure source in some of these regions, or other forms of household air pollution, such as those stemming from boiling water (other than for cooking) as well as heating and lighting activities. [1, 129, 130] We included setting (urban vs. rural) in our models as a proxy indicator for ambient air pollution exposure and did not observe an association, though analyses with more refined measures are warranted. Additionally, we cannot rule out the plausible possibility of reverse causality, given the study's cross-sectional design. Those with

arthritis may be unable to work or reduce their working hours, resulting in reduced income, which can have ramifications in terms of the type of fuels used in households.[131]

Cumulative or past exposures may be an important consideration in the development of arthritis. Questions about type of fuel used in this study focused on those mainly used in the household. As such, we are unable to draw any definitive conclusions as to the temporal relationships between household air pollution exposure and the development of arthritis. Air pollution may also be associated with the progression of the disease or worsening of symptoms.

Conclusions

This study is among the first to examine the association between household air pollution and arthritis within LMICs, where the burden of these exposures is typically highest. Findings suggest that exposure to household air pollution is associated with an increased odds of arthritis. Future work focused on prospectively measured levels of household and ambient air pollution in these settings, biomarkers of exposure and exposures in relation to the development and progression of different types of arthritis is recommended.

Author Contributions

Conceptualization: Shelby S. Yamamoto, Elaine Yacyshyn, Gian S. Jhangri, Arvind Chopra, Divya Parmar, C. Allyson Jones.

Data curation: Shelby S. Yamamoto, Divya Parmar.

Formal analysis: Shelby S. Yamamoto, Gian S. Jhangri.

Investigation: Shelby S. Yamamoto, Arvind Chopra.

Methodology: Shelby S. Yamamoto, Elaine Yacyshyn, Gian S. Jhangri, Divya Parmar, C. Allyson Jones.

Writing – original draft: Shelby S. Yamamoto, Elaine Yacyshyn, Gian S. Jhangri, Arvind Chopra, Divya Parmar, C. Allyson Jones.

Writing – review & editing: Shelby S. Yamamoto, Elaine Yacyshyn, Gian S. Jhangri, Arvind Chopra, Divya Parmar, C. Allyson Jones.

References

1. Landrigan PJ, Fuller R, Acosta NJR, Adeyi O, Arnold R, Basu NN, et al. The Lancet Commission on pollution and health. *Lancet*. 2018; 391(10119):462–512. [https://doi.org/10.1016/S0140-6736\(17\)32345-0](https://doi.org/10.1016/S0140-6736(17)32345-0) PMID: 29056410.
2. Smith KR, Bruce N, Balakrishnan K, Adair-Rohani H, Balmes J, Chafe Z, et al. Millions Dead: How Do We Know and What Does It Mean? Methods Used in the Comparative Risk Assessment of Household Air Pollution. *Annu Rev Publ Health*. 2014; 35:185–206. <https://doi.org/10.1146/annurev-publhealth-032013-182356> WOS:000336207500013. PMID: 24641558
3. Smith KR, Samet JM, Romieu I, Bruce N. Indoor air pollution in developing countries and acute lower respiratory infections in children. *Thorax*. 2000; 55(6):518–32. <https://doi.org/10.1136/thorax.55.6.518> WOS:000087367100016. PMID: 10817802
4. Fullerton DG, Bruce N, Gordon SB. Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. *T Roy Soc Trop Med H*. 2008; 102(9):843–51. <https://doi.org/10.1016/j.trstmh.2008.05.028> WOS:000259461600002. PMID: 18639310
5. Bruce N, Perez-Padilla R, Albalak R. Indoor air pollution in developing countries: a major environmental and public health challenge. *B World Health Organ*. 2000; 78(9):1078–92. WOS:000089263900003.
6. Bonjour S, Adair-Rohani H, Wolf J, Bruce NG, Mehta S, Pruss-Ustun A, et al. Solid Fuel Use for Household Cooking: Country and Regional Estimates for 1980–2010. *Environ Health Persp*. 2013; 121(7):784–90. <https://doi.org/10.1289/ehp.1205987> WOS:000323711000016. PMID: 23674502

7. Krewski D, Jerrett M, Burnett RT, Ma R, Hughes E, Shi Y, et al. Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality. *Res Rep Health Eff Inst.* 2009;(140):5–114; discussion 5–36. PMID: [19627030](#).
8. Laden F, Schwartz J, Speizer FE, Dockery DW. Reduction in fine particulate air pollution and mortality—Extended follow-up of the Harvard six cities study. *Am J Resp Crit Care.* 2006; 173(6):667–72. <https://doi.org/10.1164/rccm.200503-443OC> WOS:000236182100014. PMID: [16424447](#)
9. Beelen R, Stafoggia M, Raaschou-Nielsen O, Andersen ZJ, Xun WW, Katsouyanni K, et al. Long-term Exposure to Air Pollution and Cardiovascular Mortality An Analysis of 22 European Cohorts. *Epidemiology.* 2014; 25(3):368–78. <https://doi.org/10.1097/EDE.000000000000076> WOS:000337313300007. PMID: [24589872](#)
10. Hamra G, Guha N., Cohen A., Laden F., Raaschou-Nielsen O., Samet JM., Vineis PI, Forastiere F., Saldiva P., Yorifuji T., Loomis D. Outdoor Particulate Matter Exposure and Lung Cancer: A Systematic Review and Meta-Analysis. *Environ Health Persp.* 2014; 122(11):A294–A. <https://doi.org/10.1289/ehp.122-A294> WOS:000344759500005.
11. Kurmi OP, Semple S, Simkhada P, Smith WC, Ayres JG. COPD and chronic bronchitis risk of indoor air pollution from solid fuel: a systematic review and meta-analysis. *Thorax.* 2010; 65(3):221–8. <https://doi.org/10.1136/thx.2009.124644> PMID: [20335290](#).
12. Forouzanfar MH, Afshin A, Alexander LT, Anderson HR, Bhutta ZA, Biryukov S, et al. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet.* 2016; 388(10053):1659–724. [https://doi.org/10.1016/S0140-6736\(16\)31679-8](https://doi.org/10.1016/S0140-6736(16)31679-8) WOS:000385285000010. PMID: [27733284](#)
13. Bernatsky S, Smargiassi A, Johnson M, Kaplan GG, Barnabe C, Svenson L, et al. Fine particulate air pollution, nitrogen dioxide, and systemic autoimmune rheumatic disease in Calgary, Alberta. *Environ Res.* 2015; 140:474–8. <https://doi.org/10.1016/j.envres.2015.05.007> WOS:000357904100054. PMID: [25988990](#)
14. Chang KH, Hsu CC, Muo CH, Hsu CY, Liu HC, Kao CH, et al. Air pollution exposure increases the risk of rheumatoid arthritis: A longitudinal and nationwide study. *Environ Int.* 2016; 94:495–9. <https://doi.org/10.1016/j.envint.2016.06.008> WOS:000382339000054. PMID: [27302847](#)
15. Hart JE, Laden F, Pueff RC, Costenbader KH, Karlson EW. Exposure to Traffic Pollution and Increased Risk of Rheumatoid Arthritis. *Environ Health Persp.* 2009; 117(7):1065–9. <https://doi.org/10.1289/ehp.0800503> WOS:000267621200024. PMID: [19654914](#)
16. De Roos AJ, Koehoorn M, Tamburic L, Davies HW, Brauer M. Proximity to Traffic, Ambient Air Pollution, and Community Noise in Relation to Incident Rheumatoid Arthritis. *Environ Health Persp.* 2014; 122(10):1075–80. <https://doi.org/10.1289/ehp.1307413> WOS:000343136200019. PMID: [24905961](#)
17. Gan RW, Deane KD, Zerbe GO, Demoruelle MK, Weisman MH, Buckner JH, et al. Relationship between air pollution and positivity of RA-related autoantibodies in individuals without established RA: a report on SERA. *Ann Rheum Dis.* 2013; 72(12):2002–5. <https://doi.org/10.1136/annrheumdis-2012-202949> WOS:000326877500022. PMID: [23572338](#)
18. Hart JE, Kallberg H, Laden F, Bellander T, Costenbader KH, Holmqvist M, et al. Ambient air pollution exposures and risk of rheumatoid arthritis: results from the Swedish EIRA case-control study. *Ann Rheum Dis.* 2013; 72(6):888–94. <https://doi.org/10.1136/annrheumdis-2012-201587> WOS:000318907100022. PMID: [22833374](#)
19. Cross M, Smith E, Hoy D, Nolte S, Ackerman I, Fransen M, et al. The global burden of hip and knee osteoarthritis: estimates from the Global Burden of Disease 2010 study. *Ann Rheum Dis.* 2014; 73(7):1323–30. <https://doi.org/10.1136/annrheumdis-2013-204763> WOS:000337914300020. PMID: [24553908](#)
20. Cross M, Smith E, Hoy D, Carmona L, Wolfe F, Vos T, et al. The global burden of rheumatoid arthritis: estimates from the Global Burden of Disease 2010 study. *Ann Rheum Dis.* 2014; 73(7):1316–22. <https://doi.org/10.1136/annrheumdis-2013-204627> WOS:000337914300019. PMID: [24550173](#)
21. Gabriel SE, Michaud K. Epidemiological studies in incidence, prevalence, mortality, and comorbidity of the rheumatic diseases. *Arthritis Res Ther.* 2009; 11(3):229. <https://doi.org/10.1186/ar2669> PMID: [19519924](#); PubMed Central PMCID: PMC2714099.
22. Sousa RM, Ferri CP, Acosta D, Albanese E, Guerra M, Huang Y, et al. Contribution of chronic diseases to disability in elderly people in countries with low and middle incomes: a 10/66 Dementia Research Group population-based survey. *Lancet.* 2009; 374(9704):1821–30. [https://doi.org/10.1016/S0140-6736\(09\)61829-8](https://doi.org/10.1016/S0140-6736(09)61829-8) PMID: [19944863](#); PubMed Central PMCID: PMC2854331.
23. Rudan I, Sidhu S, Papan A, Meng SJ, Yu XW, Wang W, et al. Prevalence of rheumatoid arthritis in low-and middle-income countries: A systematic review and analysis. *J Glob Health.* 2015; 5(1):132–41. ARTN 010409 <https://doi.org/10.7189/jogh.05.010409> WOS:000370619100014. PMID: [25969732](#)

24. Halabi H, Alarfaj A, Alawneh K, Alballa S, Alsaied K, Badsha H, et al. Challenges and opportunities in the early diagnosis and optimal management of rheumatoid arthritis in Africa and the Middle East. *Int J Rheum Dis*. 2015; 18(3):268–75. <https://doi.org/10.1111/1756-185X.12320> WOS:000354019400003. PMID: 24620997
25. Klareskog L, Stolt P, Lundberg K, Kallberg H, Bengtsson C, Grunewald J, et al. A new model for an etiology of rheumatoid arthritis. *Arthritis Rheum*. 2006; 54(1):38–46. <https://doi.org/10.1002/art.21575> WOS:000234605200006. PMID: 16385494
26. Silman AJ, Newman J, MacGregor AJ. Cigarette smoking increases the risk of rheumatoid arthritis—Results from a nationwide study of disease-discordant twins. *Arthritis Rheum*. 1996; 39(5):732–5. <https://doi.org/10.1002/art.1780390504> WOS:A1996UJ81300003. PMID: 8639169
27. Stolt P, Bengtsson C, Nordmark B, Lindblad S, Lundberg I, Klareskog L, et al. Quantification of the influence of cigarette smoking on rheumatoid arthritis: results from a population based case-control study, using incident cases. *Ann Rheum Dis*. 2003; 62(9):835–41. <https://doi.org/10.1136/ard.62.9.835> WOS:000184792800010. PMID: 12922955
28. Silverwood V, Blagojevic-Bucknall M, Jinks C, Jordan JL, Protheroe J, Jordan KP. Current evidence on risk factors for knee osteoarthritis in older adults: a systematic review and meta-analysis. *Osteoarthr Cartilage*. 2015; 23(4):507–15. <https://doi.org/10.1016/j.joca.2014.11.019> WOS:000351227700003. PMID: 25447976
29. Essouma M, Noubiap JJN. Is air pollution a risk factor for rheumatoid arthritis? *J Inflamm-Lond*. 2015; 12. ARTN 48 10.1186/s12950-015-0092-1. WOS:000358573100001.
30. Farhat SCL, Silva CA, Orione MAM, Campos LMA, Sallum AME, Braga ALF. Air pollution in autoimmune rheumatic diseases: A review. *Autoimmun Rev*. 2011; 11(1):14–21. <https://doi.org/10.1016/j.autrev.2011.06.008> WOS:000297896700003. PMID: 21763467
31. Amin S, Niu J, Guermazi A, Grigoryan M, Hunter DJ, Clancy M, et al. Cigarette smoking and the risk for cartilage loss and knee pain in men with knee osteoarthritis. *Ann Rheum Dis*. 2007; 66(1):18–22. <https://doi.org/10.1136/ard.2006.056697> PMID: 17158140; PubMed Central PMCID: PMC1798417.
32. Ding C, Cicuttini F, Blizzard L, Jones G. Smoking interacts with family history with regard to change in knee cartilage volume and cartilage defect development. *Arthritis Rheum*. 2007; 56(5):1521–8. <https://doi.org/10.1002/art.22591> PMID: 17469130.
33. Kowal P, Chatterji S, Naidoo N, Biritwum R, Fan W, Ridaura RL, et al. Data Resource Profile: The World Health Organization Study on global AGEing and adult health (SAGE). *International Journal of Epidemiology*. 2012; 41(6):1639–49. <https://doi.org/10.1093/ije/dys210> WOS:000313128000019. PMID: 23283715
34. Kowal P, Biritwum R., Haldia K.R., Isingo R., Kumogola Y., Mathur A., Naidoo N., Urassa M., Chatterji S. WHO Study on global AGEing and adult health (SAGE): Summary results of a pilot in three countries. SAGE Working Paper No. 2. Geneva: World Health Organization, 2012.
35. Naidoo N. SAGE Working Paper No. 5: WHO Study on global AGEing and adult health (SAGE) Waves 0 and 1—Sampling information for China, Ghana, India, Mexico, Russia and South Africa. Geneva: 2012.
36. Arokiasamy P, Uttamacharya U, Jain K, Biritwum RB, Yawson AE, Wu F, et al. The impact of multimorbidity on adult physical and mental health in low- and middle-income countries: what does the study on global ageing and adult health (SAGE) reveal? *Bmc Med*. 2015; 13. ARTN 178 10.1186/s12916-015-0402-8. WOS:000358833000002.
37. Chatterji S, Kowal P. WHO Study on Global AGEing and Adult Health (SAGE): Wave 1, 2007–2010 Individual Questionnaire Set A. Ann Arbor, Michigan: 2010.
38. WHO. Global Recommendations on Physical Activity for Health. Geneva: World Health Organization, 2010.
39. Horton R. GBD 2010: understanding disease, injury, and risk. *Lancet*. 2012; 380(9859):2053–4. [https://doi.org/10.1016/S0140-6736\(12\)62133-3](https://doi.org/10.1016/S0140-6736(12)62133-3) WOS:000312387000002. PMID: 23245595
40. Sousa RM, Ferri CP, Acosta D, Guerra M, Huang YQ, Jacob KS, et al. "The contribution of chronic diseases to the prevalence of dependence among older people in Latin America, China and India: a 10/66 Dementia Research Group population-based survey". *Bmc Geriatr*. 2010; 10. ArtN 53 10.1186/1471-2318-10-53. WOS:000208731600053.
41. Usenbo A, Kramer V, Young T, Musekiwa A. Prevalence of Arthritis in Africa: A Systematic Review and Meta-Analysis. *Plos One*. 2015; 10(8). ARTN e0133858 10.1371/journal.pone.0133858. WOS:000358942700026.
42. Galushko E, Erdes, S., editor Prevalence of Arthritis in Adult Population in Russia2009: European Journal of Pain.

43. Bernatsky S, Smargiassi A, Barnabe C, Svenson LW, Brand A, Martin RV, et al. Fine particulate air pollution and systemic autoimmune rheumatic disease in two Canadian provinces. *Environ Res.* 2016; 146:85–91. <https://doi.org/10.1016/j.envres.2015.12.021> WOS:000371196000011. PMID: 26724462
44. Sun G, Hazlewood G, Bernatsky S, Kaplan GG, Eksteen B, Barnabe C. Association between Air Pollution and the Development of Rheumatic Disease: A Systematic Review. *Int J Rheumatol.* 2016. Unsp 5356307 <https://doi.org/10.1155/2016/5356307> WOS:000387401700001. PMID: 27847517
45. Anderson R, Meyer PWA, Ally MMTM, Tikly M. Smoking and Air Pollution as Pro-Inflammatory Triggers for the Development of Rheumatoid Arthritis. *Nicotine Tob Res.* 2016; 18(7):1556–65. <https://doi.org/10.1093/ntr/ntw030> WOS:000379826500003. PMID: 26957528
46. Criswell LA, Merlino LA, Cerhan JR, Mikuls TR, Mudano AS, Burma M, et al. Cigarette smoking and the risk of rheumatoid arthritis among postmenopausal women: Results from the Iowa women's health study. *Am J Med.* 2002; 112(6):465–71. [https://doi.org/10.1016/s0002-9343\(02\)01051-3](https://doi.org/10.1016/s0002-9343(02)01051-3) WOS:000175126000005. PMID: 11959057
47. Di Giuseppe D, Discacciati A, Orsini N, Wolk A. Cigarette smoking and risk of rheumatoid arthritis: a dose-response meta-analysis. *Arthritis Research & Therapy.* 2014; 16(2). ARTN R61 10.1186/ar4498. WOS:000338993100014.
48. Hazes JM, Dijkmans BA, Vandenbroucke JP, de Vries RR, Cats A. Lifestyle and the risk of rheumatoid arthritis: cigarette smoking and alcohol consumption. *Ann Rheum Dis.* 1990; 49(12):980–2. <https://doi.org/10.1136/ard.49.12.980> PMID: 2270970; PubMed Central PMCID: PMC1004291.
49. Hoovestol RA, Mikuls TR. Environmental Exposures and Rheumatoid Arthritis Risk. *Curr Rheumatol Rep.* 2011; 13(5):431–9. <https://doi.org/10.1007/s11926-011-0203-9> WOS:000208771400011. PMID: 21785978
50. Klareskog L, Catrina AI, Paget S. Rheumatoid arthritis. *Lancet.* 2009; 373(9664):659–72. [https://doi.org/10.1016/S0140-6736\(09\)60008-8](https://doi.org/10.1016/S0140-6736(09)60008-8) WOS:000263563500031. PMID: 19157532
51. Lee HS, Irigoyen P, Kern M, Lee A, Battilwalla F, Khalili H, et al. Interaction between smoking, the shared epitope, and anti-cyclic citrullinated peptide—A mixed picture in three large North American rheumatoid arthritis cohorts. *Arthritis Rheum.* 2007; 56(6):1745–53. <https://doi.org/10.1002/art.22703> WOS:000247164300004. PMID: 17530703
52. Padyukov L, Silva C, Stolt P, Alfredsson L, Klareskog L, Rheumatoid EI. A gene-environment interaction between smoking and shared epitope genes in HLA-DR provides a high risk of seropositive rheumatoid arthritis. *Arthritis Rheum.* 2004; 50(10):3085–92. <https://doi.org/10.1002/art.20553> WOS:000224508400005. PMID: 15476204
53. Blagojevic M, Jinks C, Jeffery A, Jordan KP. Risk factors for onset of osteoarthritis of the knee in older adults: a systematic review and meta-analysis. *Osteoarthr Cartilage.* 2010; 18(1):24–33. <https://doi.org/10.1016/j.joca.2009.08.010> WOS:000273677500005. PMID: 19751691
54. Cooper C, Inskip H, Croft P, Campbell L, Smith G, McLaren M, et al. Individual risk factors for hip osteoarthritis: Obesity, hip injury and physical activity. *Am J Epidemiol.* 1998; 147(6):516–22. WOS:000072590400002. <https://doi.org/10.1093/oxfordjournals.aje.a009482> PMID: 9521177
55. Felson DT, Anderson JJ, Naimark A, Hannan MT, Kannel WB, Meenan RF. Does smoking protect against osteoarthritis? *Arthritis Rheum.* 1989; 32(2):166–72. <https://doi.org/10.1002/anr.1780320209> PMID: 2920052.
56. Hart DJ, Spector TD. Cigarette smoking and risk of osteoarthritis in women in the general population: the Chingford study. *Ann Rheum Dis.* 1993; 52(2):93–6. <https://doi.org/10.1136/ard.52.2.93> PMID: 8447703; PubMed Central PMCID: PMC1004985.
57. Hui M, Doherty M, Zhang WY. Does smoking protect against osteoarthritis? Meta-analysis of observational studies. *Ann Rheum Dis.* 2011; 70(7):1231–7. <https://doi.org/10.1136/ard.2010.142323> WOS:000291028800010. PMID: 21474488
58. Johnsen MB, Vie GA, Winsvold BS, Bjørngaard JH, Asvold BO, Gabrielsen ME, et al. The Causal Role of Smoking on the Risk of Hip or Knee Replacement Due to Primary Osteoarthritis. A Mendelian Randomization Analysis of the Nord-Trøndelag Health Study. *Osteoarthr Cartilage.* 2017; 25:S181–S2. <https://doi.org/10.1016/j.joca.2017.02.313> WOS:000406888100318.
59. Jonsson H, Olafsdottir S, Sigurdardottir S, Aspelund T, Eiriksdottir G, Sigurdsson S, et al. Incidence and prevalence of total joint replacements due to osteoarthritis in the elderly: risk factors and factors associated with late life prevalence in the AGES-Reykjavik Study. *Bmc Musculoskel Dis.* 2016; 17. ARTN 14 10.1186/s12891-016-0864-7. WOS:000367875000006.
60. Kang K, Shin JS, Lee J, Lee YJ, Kim MR, Park KB, et al. Association between direct and indirect smoking and osteoarthritis prevalence in Koreans: a cross-sectional study. *Bmj Open.* 2016; 6(2). <https://doi.org/10.1136/bmjopen-2015-010062> WOS:000381514500085. PMID: 26892791
61. Magnusson K, Mathiessen A, Hammer HB, Kvien TK, Slatkowsky-Christensen B, Natvig B, et al. Smoking and alcohol use are associated with structural and inflammatory hand osteoarthritis features.

- Scand J Rheumatol. 2017; 46(5):388–95. <https://doi.org/10.1080/03009742.2016.1257736> WOS:000411129500009. PMID: 28145147
62. Pearce F, Hui M, Ding CH, Doherty M, Zhang WY. Does Smoking Reduce the Progression of Osteoarthritis? Meta-Analysis of Observational Studies. *Arthrit Care Res.* 2013; 65(7):1026–33. <https://doi.org/10.1002/acr.21954> WOS:000321184000003. PMID: 23335563
 63. Wilder FV, Hall BJ, Barrett JP. Smoking and osteoarthritis: Is there an association? The Clearwater Osteoarthritis Study. *Osteoarthr Cartilage.* 2003; 11(1):29–35. <https://doi.org/10.1053/joca.2002.0857> WOS:000180645300004. PMID: 12505484
 64. Zhang Y, Zeng C, Li H, Yang T, Deng ZH, Yang Y, et al. Relationship between cigarette smoking and radiographic knee osteoarthritis in Chinese population: a cross-sectional study. *Rheumatol Int.* 2015; 35(7):1211–7. <https://doi.org/10.1007/s00296-014-3202-0> WOS:000354709500010. PMID: 25588371
 65. Hosseinpoor AR, Parker LA, d'Espaignet ET, Chatterji S. Social Determinants of Smoking in Low- and Middle-Income Countries: Results from the World Health Survey. *Plos One.* 2011; 6(5). ARTN e20331 10.1371/journal.pone.0020331. WOS:000291097600045.
 66. Palipudi KM, Gupta PC, Sinha DN, Andes LJ, Asma S, McAfee T, et al. Social Determinants of Health and Tobacco Use in Thirteen Low and Middle Income Countries: Evidence from Global Adult Tobacco Survey. *Plos One.* 2012; 7(3). ARTN e33466 10.1371/journal.pone.0033466. WOS:000303309100050.
 67. WHO. WHO Report on the Global Tobacco Epidemic, 2017: Monitoring tobacco use and prevention policies. Geneva: World Health Organization, 2017.
 68. WHO. SAGE Wave 1: 2007–2010: World Health Organization; 2017. Available from: <http://www.who.int/healthinfo/sage/cohorts/en/index2.html>.
 69. Dahlgren J, Takhar H, Anderson-Mahoney P, Kotlerman J, Tarr J, Warshaw R. Cluster of systemic lupus erythematosus (SLE) associated with an oil field waste site: A cross sectional study (vol 6, pg 8, 2007). *Environ Health-Glob.* 2007; 6. ArtN 15 10.1186/1476-069x-6-15. WOS:000247335000001.
 70. Olsson AR, Skogh T, Axelson O, Wingren G. Occupations and exposures in the work environment as determinants for rheumatoid arthritis. *Occup Environ Med.* 2004; 61(3):233–8. <https://doi.org/10.1136/oem.2003.007971> WOS:000189217500007. PMID: 14985518
 71. Too CL, Muhamad NA, Ilar A, Padyukov L, Alfredsson L, Klareskog L, et al. Occupational exposure to textile dust increases the risk of rheumatoid arthritis: results from a Malaysian population-based case-control study. *Ann Rheum Dis.* 2016; 75(6):997–1002. <https://doi.org/10.1136/annrheumdis-2015-208278> WOS:000376440900013. PMID: 26681695
 72. Ritz SA. Air pollution as a potential contributor to the 'epidemic' of autoimmune disease. *Med Hypotheses.* 2010; 74(1):110–7. <https://doi.org/10.1016/j.mehy.2009.07.033> WOS:000273918500034. PMID: 19665849
 73. Jarvholm B, Lewold S, Malchau H, Vingard E. Age, bodyweight, smoking habits and the risk of severe osteoarthritis in the hip and knee in men. *Eur J Epidemiol.* 2005; 20(6):537–42. <https://doi.org/10.1007/s10654-005-4263-x> WOS:000231222900008. PMID: 16121763
 74. Abella V, Santoro A, Scotece M, Conde J, Lopez-Lopez V, Lazzaro V, et al. Non-dioxin-like polychlorinated biphenyls (PCB 101, PCB 153 and PCB 180) induce chondrocyte cell death through multiple pathways. *Toxicol Lett.* 2015; 234(1):13–9. <https://doi.org/10.1016/j.toxlet.2015.02.001> PMID: 25659934.
 75. Courties A, Sellam J, Berenbaum F. Metabolic syndrome-associated osteoarthritis. *Curr Opin Rheumatol.* 2017; 29(2):214–22. <https://doi.org/10.1097/BOR.0000000000000373> WOS:000400408800014. PMID: 28072592
 76. Manicourt DH, Devogelaer JP. Urban tropospheric ozone increases the prevalence of vitamin D deficiency among Belgian postmenopausal women with outdoor activities during summer. *J Clin Endocrinol Metab.* 2008; 93(10):3893–9. <https://doi.org/10.1210/jc.2007-2663> PMID: 18628525.
 77. Holland P, Berney L, Blane D, Smith GD, Gunnell DJ, Montgomery SM. Life course accumulation of disadvantage: childhood health and hazard exposure during adulthood. *Soc Sci Med.* 2000; 50(9):1285–95. [https://doi.org/10.1016/s0277-9536\(99\)00375-5](https://doi.org/10.1016/s0277-9536(99)00375-5) WOS:000085613800011. PMID: 10728848
 78. Vanker A, Gie RP, Zar HJ. Early-life exposures to environmental tobacco smoke and indoor air pollution in the Drakenstein Child Health Study: Impact on child health. *Samj S Afr Med J.* 2018; 108(2):71–2. <https://doi.org/10.7196/SAMJ.2017.v108i2.13088> WOS:000425233500001. PMID: 29429431
 79. Gupta G, Kohlin G. Preferences for domestic fuel: Analysis with socio-economic factors and rankings in Kolkata, India. *Ecol Econ.* 2006; 57(1):107–21. <https://doi.org/10.1016/j.ecolecon.2005.03.010> WOS:000237051400008.

80. Bengtsson C, Nordmark B, Klareskog L, Lundberg I, Alfredsson L, Grp ES. Socioeconomic status and the risk of developing rheumatoid arthritis: results from the Swedish EIRA study. *Ann Rheum Dis*. 2005; 64(11):1588–94. <https://doi.org/10.1136/ard.2004.031666> WOS:000232581100011. PMID: 15843455
81. Callahan LF, Cleveland RJ, Shreffler J, Schwartz TA, Schoster B, Randolph R, et al. Associations of educational attainment, occupation and community poverty with knee osteoarthritis in the Johnston County (North Carolina) osteoarthritis project. *Arthritis Research & Therapy*. 2011; 13(5). ARTN R169 10.1186/ar3492. WOS:000301174600028.
82. Canizares M, Power JD, Perruccio AV, Badley EM. Association of regional racial/cultural context and socioeconomic status with arthritis in the population: A multilevel analysis. *Arthritis Rheum-Arthr*. 2008; 59(3):399–407. <https://doi.org/10.1002/art.23316> WOS:000253851900015. PMID: 18311772
83. Pedersen M, Jacobsen S, Klarlund M, Frisch M. Socioeconomic status and risk of rheumatoid arthritis: A Danish case-control study. *Journal of Rheumatology*. 2006; 33(6):1069–74. WOS:000237955300008. PMID: 16622905
84. Reyes C, Garcia-Gil M, Elorza JM, Mendez-Boo L, Hermosilla E, Javaid MK, et al. Socio-economic status and the risk of developing hand, hip or knee osteoarthritis: a region-wide ecological study. *Osteoarthritis Cartilage*. 2015; 23(8):1323–9. <https://doi.org/10.1016/j.joca.2015.03.020> WOS:000358434600011. PMID: 25819582
85. Duflo E, Greenstone M., Hanna R. Cooking Stoves, Indoor Air Pollution and Respiratory Health in Rural Orissa. *Economic & Political Weekly*. 2008; 43(32):71–6.
86. Makonese T, Bradnum CMS. Public participation in technological innovation: The case of the Tshulu stove development programme. *J Energy South Afr*. 2017; 28(1):13–24. <https://doi.org/10.17159/2413-3051/2017/v28i1a1379> WOS:000401973700002.
87. Nayak J, Singh S.P., Moharana G. Occupational Health Hazard Faced By Farm Women at their Work-places. Bhubaneswar, India: Indian Council of Agricultural Research, 2013.
88. Remigios MV. The Significance of Culture as a Household Energy Determinant: The Case of Chiwundura Communal Area, Zimbabwe. *Journal of Human Ecology*. 2014; 43(3):343–9.
89. Zuk M, Rojas L, Blanco S, Serrano P, Cruz J, Angeles F, et al. The impact of improved wood-burning stoves on fine particulate matter concentrations in rural Mexican homes. *J Expo Sci Env Epid*. 2007; 17(3):224–32. <https://doi.org/10.1038/sj.jes.7500499> WOS:000246561100002. PMID: 16721411
90. Balakrishnan K, Sankar S, Parikh J, Padmavathi R, Srividya K, Venugopal V, et al. Daily average exposures to respirable particulate matter from combustion of biomass fuels in rural households of southern India. *Environ Health Perspect*. 2002; 110(11):1069–75. <https://doi.org/10.1289/ehp.021101069> PMID: 12417476; PubMed Central PMCID: PMC1241061.
91. Parikh J. Hardships and health impacts on women due to traditional cooking fuels: A case study of Himachal Pradesh, India. *Energy Policy*. 2011; 39(12):7587–94. <https://doi.org/10.1016/j.enpol.2011.05.055> WOS:000298363400011.
92. Torres-Duque C, Maldonado D, Perez-Padilla R, Ezzati M, Viegi G, Forum of International Respiratory Studies Task Force on Health Effects of Biomass E. Biomass fuels and respiratory diseases: a review of the evidence. *Proc Am Thorac Soc*. 2008; 5(5):577–90. <https://doi.org/10.1513/pats.200707-100RP> PMID: 18625750.
93. Cheng YL, Macera CA, Davis DR, Ainsworth BE, Troped PJ, Blair SN. Physical activity and self-reported, physician-diagnosed osteoarthritis: is physical activity a risk factor? *Journal of Clinical Epidemiology*. 2000; 53(3):315–22. [https://doi.org/10.1016/s0895-4356\(99\)00168-7](https://doi.org/10.1016/s0895-4356(99)00168-7) WOS:000086574900014. PMID: 10760643
94. Coggon D, Kellingray S, Inskip H, Croft P, Campbell L, Cooper C. Osteoarthritis of the hip and occupational lifting. *Am J Epidemiol*. 1998; 147(6):523–8. WOS:000072590400003. <https://doi.org/10.1093/oxfordjournals.aje.a009483> PMID: 9521178
95. Fransen M, Bridgett L, March L, Hoy D, Penserga E, Brooks P. The epidemiology of osteoarthritis in Asia. *Int J Rheum Dis*. 2011; 14(2):113–21. <https://doi.org/10.1111/j.1756-185X.2011.01608.x> WOS:000289901600002. PMID: 21518309
96. Spector TD, Harris PA, Hart DJ, Cicuttini FM, Nandra D, Etherington J, et al. Risk of osteoarthritis associated with long-term weight-bearing sports. *Arthritis Rheum*. 1996; 39(6):988–95. <https://doi.org/10.1002/art.1780390616> WOS:A1996UQ19200014. PMID: 8651993
97. Zhang YQ, Hunter DJ, Nevitt MC, Xu L, Niu JB, Lui LY, et al. Association of squatting with increased prevalence of radiographic tibiofemoral knee osteoarthritis—The Beijing Osteoarthritis study. *Arthritis Rheum*. 2004; 50(4):1187–92. <https://doi.org/10.1002/art.20127> WOS:000220763600020. PMID: 15077301

98. Cooper C, Mcalindon T, Coggon D, Egger P, Dieppe P. Occupational Activity and Osteoarthritis of the Knee. *Ann Rheum Dis*. 1994; 53(2):90–3. <https://doi.org/10.1136/ard.53.2.90> WOS: A1994MW08700002. PMID: [8129467](https://pubmed.ncbi.nlm.nih.gov/8129467/)
99. Verbeek J, Mischke C, Robinson R, Ijaz S, Kuijer P, Kievit A, et al. Occupational Exposure to Knee Loading and the Risk of Osteoarthritis of the Knee: A Systematic Review and a Dose-Response Meta-Analysis. *Saf Health Work*. 2017; 8(2):130–42. <https://doi.org/10.1016/j.shaw.2017.02.001> WOS:000408470900002. PMID: [28593068](https://pubmed.ncbi.nlm.nih.gov/28593068/)
100. Verzijl N, DeGroot J, Ben Zaken C, Braun-Benjamin O, Maroudas A, Bank RA, et al. Crosslinking by advanced glycation end products increases the stiffness of the collagen network in human articular cartilage—A possible mechanism through which age is a risk factor for osteoarthritis. *Arthritis Rheum*. 2002; 46(1):114–23. [https://doi.org/10.1002/1529-0131\(200201\)46:1<114::AID-ART10025>3.0.CO;2-P](https://doi.org/10.1002/1529-0131(200201)46:1<114::AID-ART10025>3.0.CO;2-P) WOS:000173428100014. PMID: [11822407](https://pubmed.ncbi.nlm.nih.gov/11822407/)
101. Cicuttini FM, Baker JR, Spector TD. The association of obesity with osteoarthritis of the hand and knee in women: A twin study. *Journal of Rheumatology*. 1996; 23(7):1221–6. WOS: A1996UV68100018. PMID: [8823696](https://pubmed.ncbi.nlm.nih.gov/8823696/)
102. Guh DP, Zhang W, Bansback N, Amarsi Z, Birmingham CL, Anis AH. The incidence of co-morbidities related to obesity and overweight: A systematic review and meta-analysis. *Bmc Public Health*. 2009; 9. ArtN 88 10.1186/1471-2458-9-88. WOS:000265066400002.
103. Lieveense AM, Bierma-Zeinstra SMA, Verhagen AP, van Baar ME, Verhaar JAN, Koes BW. Influence of obesity on the development of osteoarthritis of the hip: a systematic review. *Rheumatology*. 2002; 41(10):1155–62. <https://doi.org/10.1093/rheumatology/41.10.1155> WOS:000178769100013. PMID: [12364636](https://pubmed.ncbi.nlm.nih.gov/12364636/)
104. Lementowski PW, Zelicof SB. Obesity and osteoarthritis. *Am J Orthop (Belle Mead NJ)*. 2008; 37(3):148–51. PMID: [18438470](https://pubmed.ncbi.nlm.nih.gov/18438470/).
105. Moreno-Montoya J, Alvarez-Nemegyei J, Sanin LH, Perez-Barbosa L, Trejo-Valdivia B, Santana N, et al. Association of Regional and Cultural Factors With the Prevalence of Rheumatoid Arthritis in the Mexican Population A Multilevel Analysis. *Jcr-J Clin Rheumatol*. 2015; 21(2):57–62. <https://doi.org/10.1097/Rhu.0000000000000223> WOS:000350762600002. PMID: [25710855](https://pubmed.ncbi.nlm.nih.gov/25710855/)
106. Jin ZC, Xiang C, Cai Q, Wei X, He J. Alcohol consumption as a preventive factor for developing rheumatoid arthritis: a dose-response meta-analysis of prospective studies. *Ann Rheum Dis*. 2014; 73(11):1962–7. <https://doi.org/10.1136/annrheumdis-2013-203323> WOS:000343308200018. PMID: [23897767](https://pubmed.ncbi.nlm.nih.gov/23897767/)
107. Choi HK, Atkinson K, Karlson EW, Willett W, Curhan G. Alcohol intake and risk of incident gout in men: a prospective study. *Lancet*. 2004; 363(9417):1277–81. [https://doi.org/10.1016/S0140-6736\(04\)16000-5](https://doi.org/10.1016/S0140-6736(04)16000-5) WOS:000220904900009. PMID: [15094272](https://pubmed.ncbi.nlm.nih.gov/15094272/)
108. Dougados M, Soubrier M, Antunez A, Balint P, Balsa A, Buch MH, et al. Prevalence of comorbidities in rheumatoid arthritis and evaluation of their monitoring: results of an international, cross-sectional study (COMORA). *Ann Rheum Dis*. 2014; 73(1):62–8. <https://doi.org/10.1136/annrheumdis-2013-204223> WOS:000327835100015. PMID: [24095940](https://pubmed.ncbi.nlm.nih.gov/24095940/)
109. Gabriel SE. Why do people with rheumatoid arthritis still die prematurely? *Ann Rheum Dis*. 2008; 67:30–4. <https://doi.org/10.1136/ard.2008.098038> WOS:000261149200004. PMID: [19022810](https://pubmed.ncbi.nlm.nih.gov/19022810/)
110. Gullick NJ, Scott DL. Co-morbidities in established rheumatoid arthritis. *Best Pract Res Cl Rh*. 2011; 25(4):469–83. <https://doi.org/10.1016/j.berh.2011.10.009> WOS:000298717500003. PMID: [22137918](https://pubmed.ncbi.nlm.nih.gov/22137918/)
111. Violan C, Foguet-Boreu Q, Flores-Mateo G, Salisbury C, Blom J, Freitag M, et al. Prevalence, Determinants and Patterns of Multimorbidity in Primary Care: A Systematic Review of Observational Studies. *Plos One*. 2014; 9(7). ARTN e102149 10.1371/journal.pone.0102149. WOS:000339558100020.
112. Lenzi J, Avaldi VM, Rucci P, Pieri G, Fantini MP. Burden of multimorbidity in relation to age, gender and immigrant status: a cross-sectional study based on administrative data. *Bmj Open*. 2016; 6(12). ARTN e012812 10.1136/bmjopen-2016-012812. WOS:000391303600085.
113. Sellam J, Berenbaum F. Is osteoarthritis a metabolic disease? *Joint Bone Spine*. 2013; 80(6):568–73. <https://doi.org/10.1016/j.jbspin.2013.09.007> WOS:000327770300003. PMID: [24176735](https://pubmed.ncbi.nlm.nih.gov/24176735/)
114. Croft P, Schollum J, Silman A. Population Study of Tender Point Counts and Pain as Evidence of Fibromyalgia. *Brit Med J*. 1994; 309(6956):696–9. <https://doi.org/10.1136/bmj.309.6956.696> WOS: A1994PH40700014. PMID: [7950521](https://pubmed.ncbi.nlm.nih.gov/7950521/)
115. Galenkamp H, Huisman M, Braam AW, Schellevis FG, Deeg DJ. Disease prevalence based on older people's self-reports increased, but patient-general practitioner agreement remained stable, 1992–2009. *J Clin Epidemiol*. 2014; 67(7):773–80. <https://doi.org/10.1016/j.jclinepi.2014.02.002> PMID: [24739465](https://pubmed.ncbi.nlm.nih.gov/24739465/).
116. Haapanen N, Miilunpalo S, Pasanen M, Oja P, Vuori I. Agreement between questionnaire data and medical records of chronic diseases in middle-aged and elderly Finnish men and women. *Am J*

- Epidemiol. 1997; 145(8):762–9. <https://doi.org/10.1093/aje/145.8.762> WOS:A1997WU60400011. PMID: 9126003
117. Kriegsman DMW, Penninx BWJH, vanEijk JTM, Boeke AJP, Deeg DJH. Self-reports and general practitioner information on the presence of chronic diseases in community dwelling elderly—A study on the accuracy of patients self-reports and on determinants of inaccuracy. *Journal of Clinical Epidemiology*. 1996; 49(12):1407–17. [https://doi.org/10.1016/s0895-4356\(96\)00274-0](https://doi.org/10.1016/s0895-4356(96)00274-0) WOS:A1996VY92400012. PMID: 8970491
 118. Skinner KM, Miller DR, Lincoln E, Lee A, Kazis LE. Concordance between respondent self-reports and medical records for chronic conditions: experience from the Veterans Health Study. *J Ambul Care Manage*. 2005; 28(2):102–10. <https://doi.org/10.1097/00004479-200504000-00002> PMID: 15923944.
 119. Arnett FC, Edworthy SM, Bloch DA, Mcshane DJ, Fries JF, Cooper NS, et al. The American-Rheumatism-Association 1987 Revised Criteria for the Classification of Rheumatoid-Arthritis. *Arthritis Rheum*. 1988; 31(3):315–24. <https://doi.org/10.1002/art.1780310302> WOS:A1988M824100002. PMID: 3358796
 120. Chopra A. Disease burden of rheumatic diseases in India: COPCORD perspective. *Indian Journal of Rheumatology*. 2015; 10:70–7.
 121. Chopra A, Abdel-Nasser A. Epidemiology of rheumatic musculoskeletal disorders in the developing world. *Best Pract Res Clin Rh*. 2008; 22(4):583–604. <https://doi.org/10.1016/j.berh.2008.07.001> WOS:000259895300002. PMID: 18783739
 122. Mody GM, Cardiel MH. Challenges in the management of rheumatoid arthritis in developing countries. *Best Pract Res Clin Rh*. 2008; 22(4):621–41. <https://doi.org/10.1016/j.berh.2008.04.003> WOS:000259895300004. PMID: 18783741
 123. Moussavi S, Chatterji S, Verdes E, Tandon A, Patel V, Ustun B. Depression, chronic diseases, and decrements in health: results from the World Health Surveys. *Lancet*. 2007; 370(9590):851–8. [https://doi.org/10.1016/S0140-6736\(07\)61415-9](https://doi.org/10.1016/S0140-6736(07)61415-9) PMID: 17826170.
 124. Dasgupta S, Huq M, Khaliqzaman M, Pandey K, Wheeler D. Indoor air quality for poor families: new evidence from Bangladesh. *Indoor Air*. 2006; 16(6):426–44. <https://doi.org/10.1111/j.1600-0668.2006.00436.x> WOS:000241832600004. PMID: 17100664
 125. Masera OR, Saatkamp BD, Kammen DM. From linear fuel switching to multiple cooking strategies: A critique and alternative to the energy ladder model. *World Dev*. 2000; 28(12):2083–103. [https://doi.org/10.1016/S0305-750x\(00\)00076-0](https://doi.org/10.1016/S0305-750x(00)00076-0) WOS:000165782100004.
 126. Cheng CY, Urpelainen J. Fuel stacking in India: Changes in the cooking and lighting mix, 1987–2010. *Energy*. 2014; 76:306–17. <https://doi.org/10.1016/j.energy.2014.08.023> WOS:000344444600031.
 127. Dong YR, Peng CYJ. Principled missing data methods for researchers. *Springerplus*. 2013; 2. Unsp 222 <https://doi.org/10.1186/2193-1801-2-222> WOS:000209465000021. PMID: 23853744
 128. Sterne JAC, White IR, Carlin JB, Spratt M, Royston P, Kenward MG, et al. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *Bmj-Brit Med J*. 2009; 339. ARTN b2393 10.1136/bmj.b2393. WOS:000267678300003.
 129. Lam NL, Smith KR, Gauthier A, Bates MN. Kerosene: A Review of Household Uses and Their Hazards in Low- and Middle-Income Countries. *J Toxicol Env Heal B*. 2012; 15(6):396–432. <https://doi.org/10.1080/10937404.2012.710134> WOS:000308248300002. PMID: 22934567
 130. Carter E, Archer-Nicholls S, Ni K, Lai AM, Niu HJ, Secrest MH, et al. Seasonal and Diurnal Air Pollution from Residential Cooking and Space Heating in the Eastern Tibetan Plateau. *Environ Sci Technol*. 2016; 50(15):8353–61. <https://doi.org/10.1021/acs.est.6b00082> WOS:000381063200048. PMID: 27351357
 131. Verstappen SMM. The impact of socio-economic status in rheumatoid arthritis. *Rheumatology*. 2017; 56(7):1051–2. <https://doi.org/10.1093/rheumatology/kew428> WOS:000404610700002. PMID: 27940587