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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-012826
Article Type:	Research
Date Submitted by the Author:	26-May-2016
Complete List of Authors:	Rantakokko, Merja; Jyvaskylan Yliopisto, Gerontology Research Center and Department of Health Sciences Wilkie, Ross; Keele University, Research Institure for Primary Care and Health Sciences
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	Participation, Mobility, Osteoarthritis, Environment

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Understanding the role of environmental factors for the onset of restricted mobility outside the home among older adults with osteoarthritis.

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Key words: Participation, environment, older adults, mobility

Word count: 3015

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ABSTRACT

Objectives: The study examines how environmental factors contribute to the onset of restricted mobility outside the home among older adults with osteoarthritis.

Methods: Prospective cohort study of adults aged 50 years and over with osteoarthritis (N=1802). Logistic regression tested the association between the onset of restricted mobility outside the home and health, sociodemographic and perceived environmental barriers (hills and steep slopes, inaccessible public buildings, poor pavement condition, lack of access to public parks or sport facilities, heavy traffic or speeding cars, and poor weather). The potential moderating role of environmental barriers on the association between health factors and onset was examined using interaction terms and stratified analysis.

Results: Of 1802 participants, 13.5% (n=243) reported the onset of restricted mobility outside the home at three-year follow-up. Walking disability, anxiety, depression, cognitive impairment and obesity, and all environmental barriers were associated with onset after adjustment for confounders. There were significant but less than multiplicative interactions between hills and steep slopes that make it difficult to move outdoors with walking disability (p=.030), anxiety (p=.037), depression (p=.002) and cognitive impairment (p=.029); poor pavement conditions and anxiety (p=.036), and heavy traffic or speeding cars and depression (p=.036).

Conclusion: For older adults with osteoarthritis, environmental barriers have a greater role on its impact when associated morbidities and walking disability exist. Awareness of environmental barriers is important when aiming to maintain mobility and activities outside the home despite health conditions in older adults.

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Strengths and limitations of this study

- A large population-based sample of older adults with osteoarthritis, identified using medical records, and high response rate.
- Longitudinal study on a topic that has not been widely studied.
- The three year gap between time points may miss changes in health and mobility status.
- The generalisability of the study may be limited by the characteristics of the study sample; the area covered by this study is more deprived on health, education and employment, but with fewer barriers to housing and services than England as a whole

INTRODUCTION

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Mobility outside the home is important for maintenance of independence and good quality of life in old age.[1] Restricted mobility outside the home is the most common form of participation restriction among older people and is associated with chronic health conditions [2], physical function, socio-demographic and environmental factors.[3, 4] The International Classification of Functioning, Disability and Health (ICF) highlights the role of environmental factors as barriers or facilitators of participation.[5] A number of studies have shown the associations between environmental barriers, e.g. poor quality streets and long distances, with functional limitations [6, 7] and restricted participation among older adults [8, 9] but have not identified the role or mechanism that would further direct targets or interventions.

Older adults with osteoarthritis are especially vulnerable to environmental challenges due to physical limitation and symptoms such as pain and stiffness [5, 6, 9, 10]. Osteoarthritis is the most common joint condition in adults and globally is the fastest increasing major health condition.[11, 12] It is a common reason for health care consultation (one out of every twenty consultations to primary care in adults aged over 50 years is for osteoarthritis), and is also a common comorbidity in persons seen in primary care for other reasons.[13] Previous studies have identified several health factors that are associated with poor outcomes among older adults with OA, such as pain, multimorbidity, obesity, depression and functional limitations.[2, 4, 14] However it is unclear if environmental factors have a significant role on the impact of osteoarthritis on mobility outside the home in older adults.

In this study we used the ICF framework [5] to organise information and determine if features of the physical environmental moderate the association between health conditions

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and the onset of restricted mobility outside the home in older adults with osteoarthritis. Specifically, the study examines whether (i) pain, comorbidity (anxiety, depression, obesity, cognitive impairment, and multimorbidity) and physical disability (i.e. walking disability) are associated with an increased the risk of the onset of restricted mobility outside the home at 3-year follow-up among older adults with osteoarthritis and (ii) these associations were moderated by environmental factors.

METHODS

Study population

The North Staffordshire Osteoarthritis project (NorStOP) is a population-based prospective cohort study.[15] The NorStOP sampling frame comprised all individuals aged 50 years and over who were registered to receive care from one of six general practices in North Staffordshire, United Kingdom (UK). For this study, potential participants were those who gave written consent for medical record review and who received a diagnosis of osteoarthritis during a primary care consultation between 2000 and 2008. At baseline (2005) potential participants were mailed questionnaires and at three year follow-up (2008); reminders were sent at two and four weeks after the initial mailing.

Analyses for this paper included those who (i) consulted for osteoarthritis from 2000 to 2008 (the study period of NorStOp), (ii) were free of restricted mobility outside the home at baseline and (iii) had completed the item on mobility outside the home at three year follow-up (n=1802). (Figure 1).

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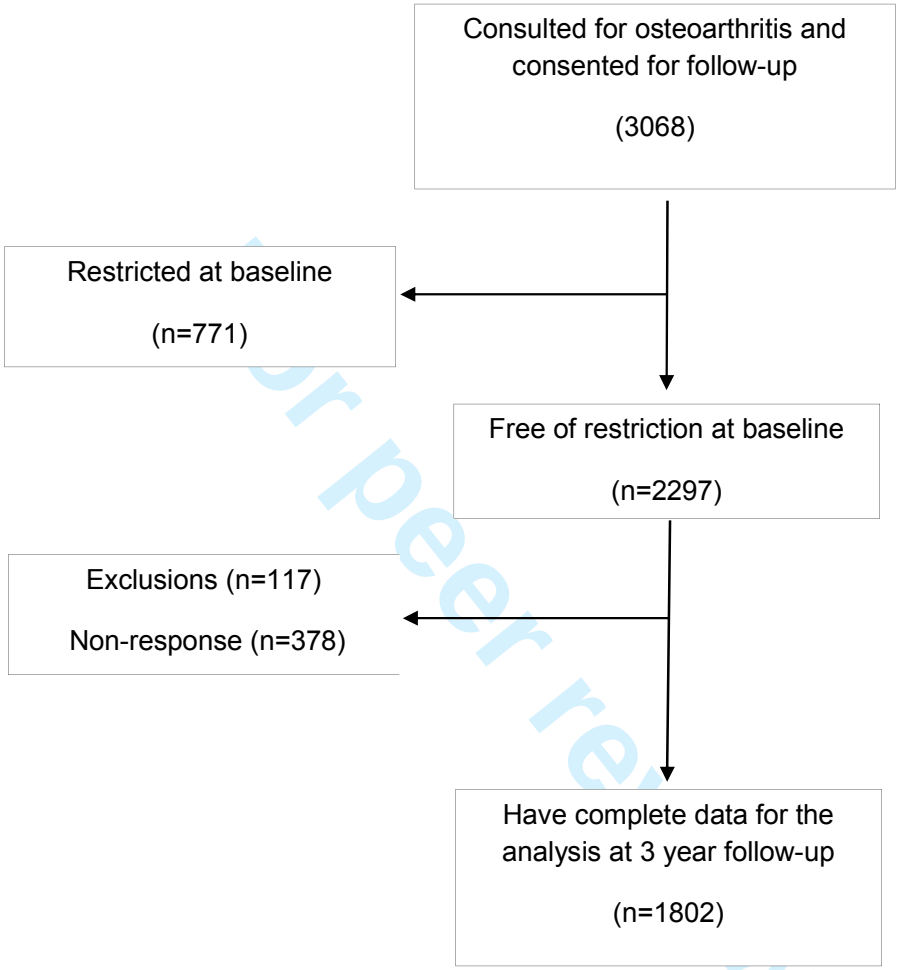
Figure 1. Flow diagram of participants



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Identification of osteoarthritis

General practitioners in the study used the Read system to code all reasons for clinical encounters in primary care consultations.[16] The Read codes cross-map to ICD9/ICD-10 (for diseases).

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Morbidity data (i.e. symptoms and diseases) in this system are grouped into 18 Read chapters. Data on these diagnostic groups were aggregated starting in 2000, continuing through the time of the follow-up questionnaire in 2008. Individuals were defined as having osteoarthritis if they had at least one consultation during this period primarily for osteoarthritis based on Read codes (N05 category) for primary care consultations.[16] As osteoarthritis is a long-standing, gradually progressive chronic condition, it was assumed that a clinician-established diagnosis at any point during the study period implied that osteoarthritis was likely present at least to some degree during the entire period of observation.

Measurements

Restricted mobility outside the home was assessed with one item from the Keele Assessment of Participation (KAP) instrument.[17] KAP is a valid and reliable measurement tool to capture perceived participation restriction in population studies. Participants were asked whether "during the past 4 weeks, have you moved around outside your home, as and when you wanted" with response options 'all the time, most of the time, some of the time, a little of the time and none of the time'. Participants were considered to be restricted for the mobility outside the home if reported being able to move outside the home 'as and when wanted' for 'some, a little or none of the time'. Onset of restricted mobility was defined as moving from no restriction at baseline to restricted mobility at three-year follow-up point.

All ***health exposures*** were assessed at baseline. *Walking disability and bodily pain* were measured using single items from the Short Form-36 physical functioning subscale.[18] For walking disability, participants were asked whether their health limited walking more than a mile; responses were categorized to walking disability (limited a lot) and no disability

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(limited a little and not limited at all). For *bodily pain* participants were asked "How much bodily pain have you had during the past 4 weeks?"; response options were categorized to 'none/mild' and 'moderate /severe'.

Multimorbidity was defined using general practice consultation Read code data. As defined above a count of comorbidity from the remaining 18 Read codes was then categorized using a previously validated method,[19] to identify multimorbidity (i.e. ≥4. Morbidities).

Anxiety and depression was assessed with the Hospital Anxiety and Depression scale (HADS).[20] HADS is a fourteen item scale (7 items of anxiety, 7 items for depression) and targets on how a person has felt in the past week. Each item is scored from 0 to 3 with total score between 0 and 21 for either anxiety or depression. Score of 8/21 is identified as cut-off point for anxiety or depression [21] and was used to dichotomize anxiety and depression as possible/probable case (scores 8-21) vs. no case (scores 0-7). *Cognitive impairment* was measured using Cognitive and Alertness behavior subscale of Functional Limitations Profile [22] and categorized into no impairment (score 0) and impairment (score ≥ 1).

Body Mass Index (BMI) was calculated based on self-reported weight and height and categorized into obese (BMI >30 kg/m^2) and other (BMI < 30 kg/m^2).[23]

Environmental barriers were assessed using a structured questionnaire at three-year follow-up. Participants were asked to indicate how much they agreed or disagreed with statements related to environment barriers to moving around outside the home; live in an area with hills and steep slopes that make it difficult to move around outside (referred to as hills and steep slopes hereafter), inaccessible public buildings make it difficult to move around, poor pavement condition stops me from going out, lack of access to public parks or sport facilities stops me from going out, heavy traffic or speeding cars stop me going out, and adverse weather stops me going out. The answers were on a 5-point scale from 'strongly disagree' to

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'strongly agree'. For the analyses each environmental barrier was identified by responses of agree or strongly agree and compared to no barrier (neither disagree nor agree, disagree, strongly disagree).

Potential confounders included demographic factors (age, gender) and socio-economic factors (occupational class (professional/managerial, semi-routine, routine))[24]; and educational attainment (further education, or not)).

Statistical analyses

Differences in distribution in health exposures, environmental barriers, and potential confounders between those with and without onset of restricted mobility outside the home were tested with Chi Square for categorical variables, and t-test for continuous variables. Univariate logistic regression analyses was used to examine for the association between baseline health exposures and environmental barriers and the onset of restricted mobility outside the home at three year follow-up, first unadjusted then adjusted for age, gender, and socioeconomic factors (Model 1).

The independent effect of health and environmental factors on the onset of mobility restriction outside the home was then assessed over two stages with reference to the conceptual model of the ICF.[5] In the first stage the "health" model was derived: all health factors were entered simultaneously into the model with age, gender and socio-economic factors as potential confounders (Model 2). In the second stage all environmental factors were entered separately, adjusted for all health factors and confounders (Models 3-8). Associations are summarized by odds ratios with 95% confidence intervals. Concordance indexes (C-statistic) were calculated to evaluate model fit. A C-statistic of 0.5 indicates that model is no better than chance in

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making a prediction, more than 0.7 is considered reasonable and more than 0.8 indicates strong predictive ability.[25]

To examine if environmental factors moderated the association between morbidities and onset of restricted mobility outside the home interaction terms were added to the health model separately (Model 2). Health (Model 2) and environmental factors (Models 3-8) significant at 5% level were included in the interaction analysis. For significant interactions, stratified analyses were conducted. Analyses were conducted with STATA 14.0 (StataCorp 2015, College Station, TX, StataCorp LP).

RESULTS

Of the 1802 participants free of participation restriction at baseline, 243 (13.5%) reported onset of restricted mobility outside the home three years later. Onset of restricted mobility outside the home was more common among those with walking disability, severe pain, anxiety, depression, cognitive impairment, obesity and environmental barriers. There were no differences for multimorbidity (p=.088). (Table 1)

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Table 1. Characteristics of the study population at baseline overall and stratified by the onset of restricted mobility outside the home at three-year follow-up.

	Total	Onset of restriction		P value
		Yes	No	
	n=1802	n=243	n= 1559	
	% (n)	% (n)	% (n)	
Health				
Walking disability	18.2 (328)	46.9 (114)	13.7 (214)	<.001
Multimorbidity, ≥4	83.5 (1504)	87.2 (212)	82.9 (1292)	.088
Anxiety	25.7 (463)	40.3 (98)	23.4 (365)	<.001
Depression	9.3 (167)	19.8 (48)	7.6 (119)	<.001
Pain				<.001
None / Mild	54.8 (988)	36.6 (89)	57.7 (899)	
Moderate /severe	45.2 (814)	63.4 (154)	42.3 (660)	
Cognitive impairment	39.7 (715)	57.2 (139)	37.0 (576)	<.001
BMI				.005
Obese	18.2 (328)	25.1 (61)	17.1 (267)	
Other	79.4 (1431)	71.6 (174)	80.6 (1257)	
Unknown	2.4 (43)	3.3 (8)	2.3 (35)	
Confounders				
Female	56.4 (1193)	59.3 (185)	55.9 (1008)	.270
Age, mean (SD)	65.8 (8.9)	69.9 (8.9)	65.1 (7.7)	<.001
Occupational class				.001
Managerial/professional	23.3 (493)	17.6 (55)	24.3 (438)	
Semi-routine	20.0 (423)	20.8 (65)	19.9 (358)	
Routine/manual	51.8 (1096)	52.9 (165)	51.7 (931)	
Other	4.8 (102)	8.7 (27)	4.2 (75)	
Full time education	15.6 (281)	7.8 (19)	16.8 (262)	.001
Environmental barriers				
Hills and steep slopes	12.5 (226)	34.6 (84)	9.1 (142)	<.001
Inaccessible public buildings	4.1 (73)	12.8 (31)	2.7 (42)	<.001
Poor pavement condition	6.4 (115)	16.1 (39)	4.9 (76)	<.001
Lack of access to parks	3.4 (61)	9.9 (24)	2.4 (37)	<.001
Heavy traffic or speeding cars	2.4 (44)	6.6 (16)	1.8 (28)	<.001
Adverse weather	12.7 (228)	33.7 (82)	9.4 (146)	<.001

Associations with onset of restricted mobility outside the home

Following adjustment for confounders, walking disability (adjusted odds ratio (OR)=4.5, 95% confidence interval (95%CI) 3.4 to 6.1), anxiety (OR=2.5, 95%CI 1.9 to 3.4), depression

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(OR=3.4, 95%CI 2.3 to 5.0), pain (OR=2.3, 95%CI 1.8 to 3.1), cognitive impairment (OR=2.1, 95%CI 1.6 to 2.8), and obesity (OR=2.1, 95%CI 1.5 to 3.0) were associated with the onset of restricted mobility outside the home. In the multivariable health model (Model 2), pain was not significantly associated with onset of restricted mobility outside the home (OR=1.3, 95%CI 0.9 to 1.8). All environmental factors were associated with onset of restriction after adjustment for confounders and all health exposures (Table 2).

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TABLE 2. Associations between morbidity, walking disability and environmental factors and the onset of participation restriction in mobility outside the home in older adults with osteoarthritis; odds ratios and 95% confidence intervals.

	Crude OR (95%CI)	Model 1 OR (95%CI)	Model 2 OR (95%CI)	Model 3 OR (95%CI)	Model 4 OR (95%CI)	Model 5 OR (95%CI)	Model 6 OR (95%CI)	Model 7 OR (95%CI)	Model 8 OR (95%CI)
Walking disability	5.6 (4.2 to 7.4)	4.5 (3.4 to 6.1)	3.3 (2.4 to 4.6)	2.9 (2.0 to 4.0)	3.2 (2.3 to 4.4)	3.2 (2.3 to 4.5)	3.2 (2.3 to 4.5)	3.2 (2.3 to 4.5)	3.1 (2.2 to 4.4)
Anxiety	2.2 (1.7 to 2.9)	2.5 (1.9 to 3.4)	1.6 (1.1 to 2.3)	1.7 (1.2 to 2.5)	1.6 (1.1 to 2.3)	1.6 (1.1 to 2.2)	1.5 (1.1 to 2.2)	1.6 (1.1 to 2.2)	1.5 (1.0 to 2.1)
Depression	3.0 (2.1 to 4.3)	3.4 (2.3 to 5.0)	1.6 (1.0 to 2.5)	1.5 (0.9 to 2.3)	1.5 (0.98 to 2.4)	1.6 (1.0 to 2.5)	1.5 (0.96 to 2.4)	1.6 (1.0 to 2.5)	1.5 (0.9 to 2.3)
Pain									
None/Mild	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Moderate /Severe	2.4 (1.8 to 3.1)	2.3 (1.8 to 3.1)	1.3 (0.9 to 1.8)	1.2 (0.9 to 1.7)	1.3 (0.9 to 1.7)	1.2 (0.9 to 1.7)	1.3 (0.9 to 1.8)	1.3 (0.9 to 1.8)	1.2 (0.9 to 1.7)
Cognitive impairment	2.3 (1.7 to 3.0)	2.1 (1.6 to 2.8)	1.5 (1.1 to 2.0)	1.3 (0.98 to 1.9)	1.4 (1.0 to 1.9)	1.4 (1.0 to 2.0)	1.5 (1.1 to 2.0)	1.5 (1.1 to 2.0)	1.4 (1.0 to 1.9)
BMI									
Obesity (BMI > 30)	1.7 (1.2 to 2.3)	2.1 (1.5 to 3.0)	1.5 (1.0 to 2.1)	1.4 (0.99 to 2.1)	1.5 (1.0 to 2.1)	1.4 (0.99 to 2.1)	1.5 (1.0 to 2.1)	1.5 (1.0 to 2.1)	1.4 (0.9 to 2.0)
Other	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Environmental barriers									
Hills and steep slopes	5.3 (3.8 to 7.2)	4.4 (3.2 to 6.1)	-	3.3 (2.3 to 4.6)	-	-	-	-	-
Inaccessible public buildings	5.3 (3.3 to 8.6)	4.9 (3.0 to 8.2)	-	-	3.2 (1.8 to 5.5)	-	-	-	-
Poor pavement condition	3.7 (2.5 to 5.6)	3.4 (2.2 to 5.2)	-	-	-	2.4 (1.51 to 3.8)	-	-	-
Lack of access to parks	4.5 (2.6 to 7.7)	4.4 (2.5 to 7.6)	-	-	-	-	2.8 (1.5 to 5.0)	-	-
HeavyTraffic	3.9 (2.1 to 7.2)	4.2 (2.2 to 8.0)	-	-	-	-	-	2.9 (1.4 to 5.8)	-
Adverse weather	4.9 (3.6 to 6.8)	4.4 (3.2 to 6.1)	-	-	-	-	-	-	3.2 (2.2 to 4.5)
C-statistics			0.779	0.809	0.786	0.789	0.784	0.783	0.804

Model 1 adjusted for confounders: age, gender, socioeconomic factors.
Model 2 multivariate health model, all health exposures included, adjusted for confounders.
Model 3-8 multivariate model, adjusted for confounders
BMI, Body Mass Index
OR, Odds Ratio
95% CI, Confidence Interval

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Interactions There were significant but less than multiplicative interactions between hills and steep slopes that make it difficult to move outdoors and walking disability (adjusted OR=0.47, 95%CI 0.24 to 0.93), anxiety (OR=0.45, 95%CI 0.22 to 0.96), depression (OR=0.25, 95%CI 0.09 to 0.61) and cognitive impairment (OR=0.46, 95%CI 0.23 to 0.92). Significant but less than multiplicative interactions were also found between poor pavement condition and anxiety (OR=0.37, 95%CI 0.15 to 0.94), and between heavy traffic or speeding cars and depression (OR=0.14, 95%CI 0.02 to 0.88).

The prevalence of the onset of restricted mobility outside the home was higher among those living in an environment featured by hills and steep slopes, especially among those having walking disability or anxiety (Figure 2A). Among those with depression or cognitive impairment the prevalence of onset of restricted mobility was around the same with or without hills and steep slopes. Among people without depression, prevalence of restricted mobility was more common when hills and steep slopes and heavy traffic and speeding cars were present (Figure 2A and 2B).

Among those with anxiety, restricted mobility outside the home was equally common for the presence and absence of poor pavement condition. Among those without anxiety, restricted mobility was more common among those living in environment with poor pavement condition (Fig 2C).

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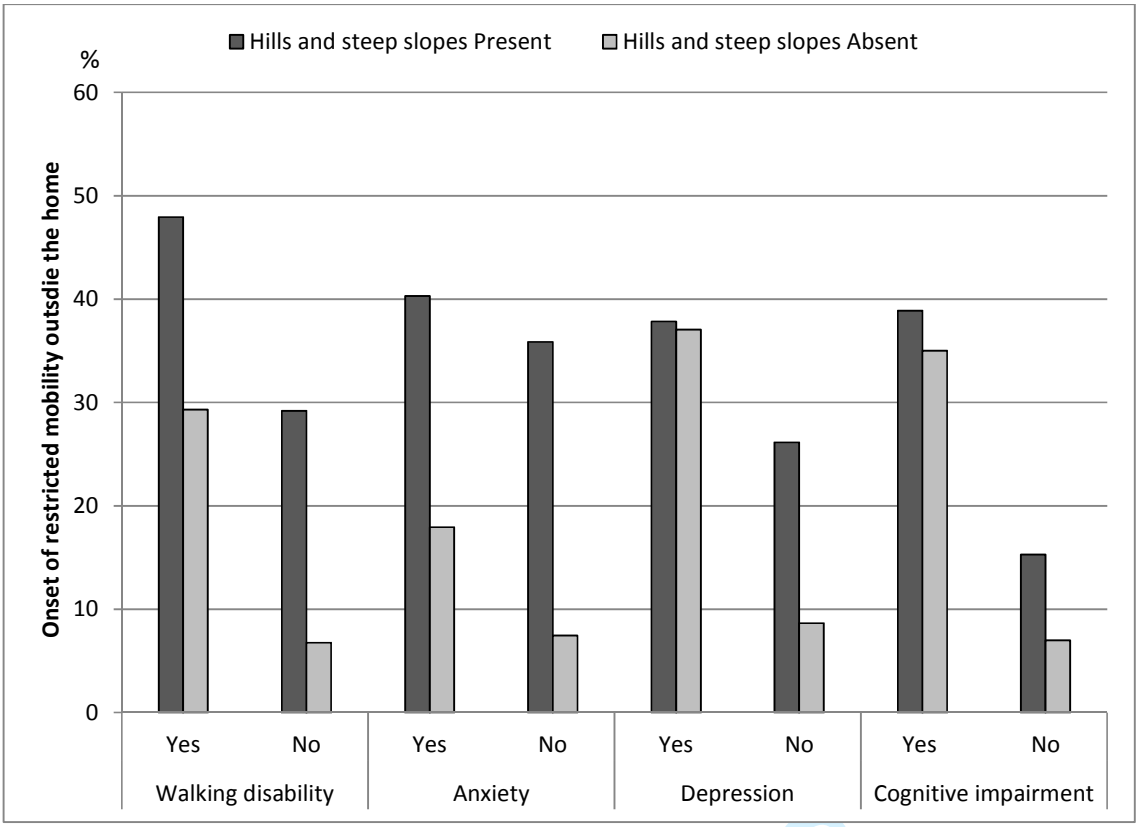
Figure 2. The prevalence of the onset of restricted mobility outside the home among people with and without health problems at baseline stratified by environmental barriers: A) Hills and steep slopes, B) Heavy traffic or speeding cars, C) Poor pavement condition.

A) Hills and steep slopes



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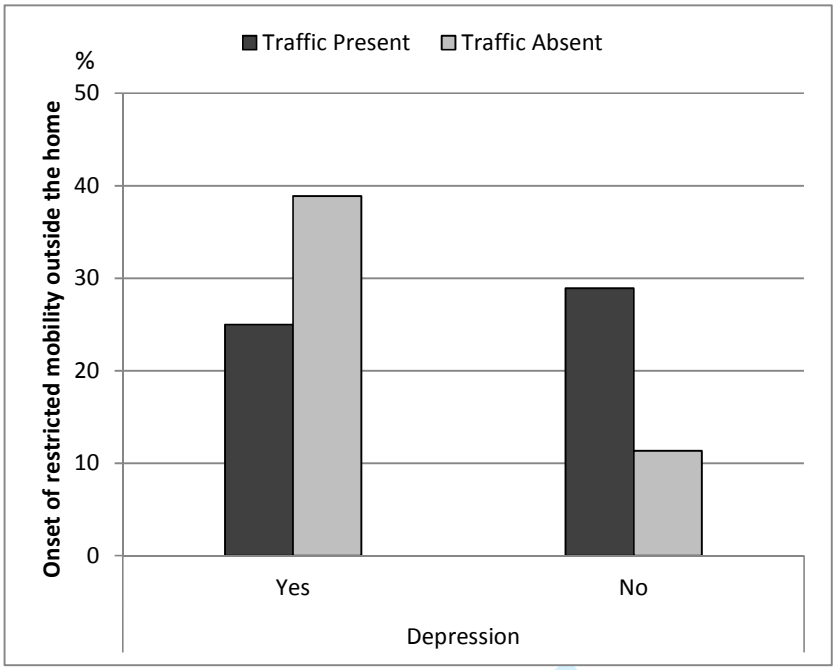
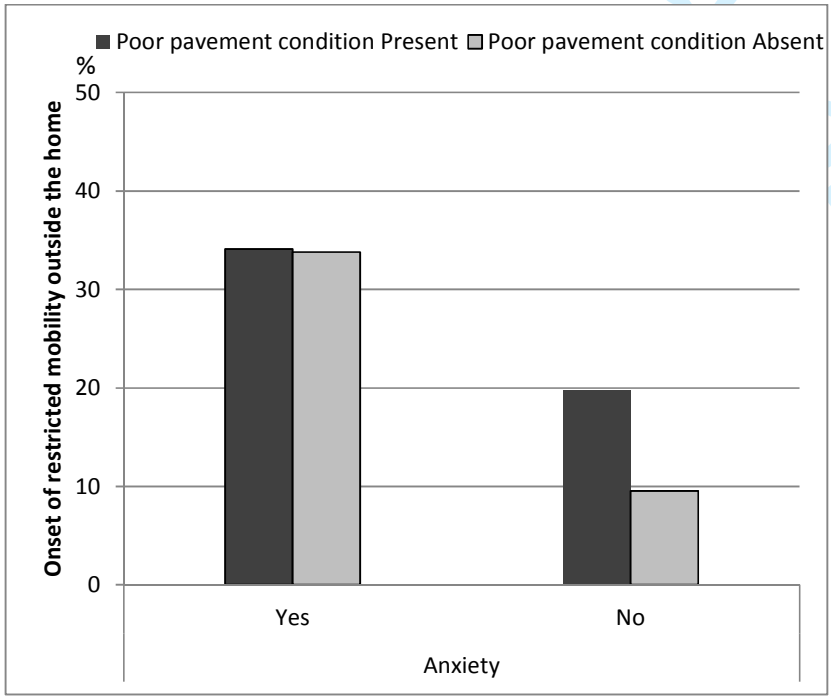
B) Heavy traffic or speeding cars



C) Poor pavement condition



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DISCUSSION

The aims of this study were to identify the role of environmental barriers on the onset of restricted mobility outside the home in older adults with osteoarthritis. All environmental factors were associated with onset of restricted mobility. There were significant but less than multiplicative interactions between environmental barriers and comorbidity and physical disability on the onset of restricted mobility. The impact of environmental barriers was greatest for individuals with comorbidity or physical disability; onset of restricted mobility outside the home was more common among those living in environments featured by hills and steep slopes, and especially when a person was having additional walking disability or anxiety.

Our findings support the theoretical model of the ICF by providing empirical evidence of the role of environmental factors on future restricted mobility. Our findings also give support to previous studies that have emphasized importance of using comprehensive models of mobility including physical, psychosocial and environmental determinants.[26, 27] It is possible that certain health conditions that lead to walking disability, increase risk of onset of participation restriction in demanding environments because the environment no longer supports the level of functional capacity.[10] While previous cross-sectional studies have shown the association between environmental characteristics and participation in out-of-home activities,[9] and an interaction between environmental characteristics (e.g. heavy traffic) and health for participating in voting, obtaining health care and interpersonal interaction,[28] our study goes beyond previous literature by identifying how environmental factors contribute to the onset of restricted mobility and link with common consequences or comorbidities in people with OA.

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In this study the most common environmental barriers were hills and steep slopes and adverse weather. Hills and steep slopes increase requirements for physical capability, and is a particular barrier for older adults with OA. People with difficulties in walking report more and different environmental barriers that affect their participation in community activities than those without difficulty.[28] This suggests that the interaction between person and the environment and the balance between these two, (i.e. person-environment fit),[10] is influential to whether a person is able to move outdoors or not. People may compensate for their impairments,[29] for example, by stopping to rest when moving outdoors or use assistive devices, but environmental barriers may make these compensations more difficult to perform, exacerbating the situation. For example, people with walking disability may be concerned for their safety when moving outdoors because of heavy traffic and speeding cars, especially when crossing the street.[30] People with depression or cognitive impairment may not encounter these barriers because they participate less or change how they participate to compensate for their impairment.[31]

Adverse weather is a common barrier for outdoor mobility among older adults and snow, ice and rainfall, increase the risk of participation restriction. [32] For example, icy conditions may increase difficulty to maintain balance leading to fear of falling despite of the health, thus restricting possibilities to participate in outdoor activities.[33] In this study adverse weather was associated with onset but there were no interactions with comorbidity or physical disability.

Older people most often go outdoors for the purposes of shopping, running daily errands and walking for exercise.[34] If public buildings for shopping or running daily errands are

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inaccessible, it may restrict possibilities for using these community amenities. Parks and green areas form important spaces for exercise and motivate people to go out.[35-37]. Poor access to these resources may be decisive when considering participation in outdoor activities, especially for people with OA.[38] The considerable prevalence of osteoarthritis indicates that this is an issue which impacts on a large number of adults in the population.

Strengths and limitations

The study has a number of strengths. The analysis was performed with a large population-based sample of older adults with osteoarthritis, identified using medical records. The response rate was high and was comparable to other population surveys. The available data covered a number of important factors in relation to the onset of mobility outside the home for older adults with osteoarthritis. The instruments used to identify restricted mobility outside the home, the symptoms of osteoarthritis and comorbidity, have been validated for use in population studies of older adults.[17, 18, 21, 22] The items measuring environmental barriers were reliable in pilot testing (weighted kappa values for test-retest (4-week period) ranged from 0.5 (moderate) to 0.9 (almost perfect)).

Study limitations were: Restricted mobility outside the home was measured by self-report and focused on person-perceived participation. This is the most appropriate method for capturing an individual's social participation however it is susceptible to measurement error and it may not take account of frequency of outdoor mobility. Responders that do not mobilise outdoors may report restricted mobility but not environmental barriers that they won't experience which may lead to underestimation of associations. The three year gap between time points may miss changes in health and mobility status. There may be other predictors and confounders which may be important but were not included in this study. For example, performance based measures, such as gait speed can be used as clinical marker of decline in

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participation.[39] Since performance, and especially gait patterns, may also be influenced by environmental features,[40] the combined association between these in relation to participation may form an interesting target for future research. The generalisability of the study may be limited by the characteristics of the study sample; the area covered by this study is more deprived on health, education and employment, but with fewer barriers to housing and services than England as a whole. As in most prospective studies, there was some loss to follow-up and missing data; those who dropped out of the analysis were more likely to be female (p=.010), have depression (p=.046), anxiety (p<.001) and walking disability (p=.001) than those included the sample. There were no differences for pain (p=.060), obesity (p=.650), cognitive impairment (p=.106) or multimorbidity (p=.281).

Conclusion

The findings of this study suggest that some environmental barriers have an important role in preventing older adults with osteoarthritis mobilising outside their home, particularly when impairments and walking disability are present. To prevent the onset of restricted mobility outside the home for older adults with osteoarthritis, both clinical and non-clinical approaches are required. Clinical approaches aimed at reducing pain, anxiety, depression and walking disability will be useful, but consideration of an individual's environment is important. Identifying older adults with osteoarthritis that live in more challenging environments can lead to a targeted approach to overcoming such barriers, within a rehabilitation programme. Approaches to reducing environmental barriers and community planning, such as improving access to public buildings, increasing mobility friendly environments where low physical and mental capacities do not prevent mobility and function, and the provision of public transport may prevent restricted mobility, improve social participation and support active ageing.

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Footnotes

Funding: NorStOp project was supported by the Medical Research Council, UK grant numbers [G9900220 and G0501798] and by the North Staffordshire Primary Care R&D Consortium. MR was supported by a personal grant from the Academy of Finland grant number [285747]. The study sponsors had no role in the study design; in the collection, analysis and interpretation of the data; in the writing of the report; or in the decision to submit the paper for publication.

Competing Interests: None declared.

Ethics approval: The North Staffordshire Local Research Ethics Committee granted approval and all participants gave written consent to participate.

Contributorship statement: MR and RW designed the research questions, plan of analyses, statistical analyses and interpreted the results and drafted the manuscript. MR was the main author of the manuscript.

Data sharing statement: The Research Institute for Primary Care and Health Sciences, Keele university has established data sharing arrangements to support joint publications and other research collaborations. Applications for access to anonymized data from our research databases are reviewed by the Centre's Data Custodian and Academic Proposal (DCAP) Committee and a decision regarding access to the data is made subject to the NRES ethical approval first provided for the study and to new analysis being proposed. Further information

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on our data sharing procedures can be found on the Centre's website (http://www.keele.ac.uk/pchs/publications/datasharingresources/) or by emailing the Centre's data manager (data-sharing-pcs@keele.ac.uk).

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract [In the abstract, page 1]
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found [page 1]
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported [page 2-3]
Objectives	3	State specific objectives, including any prespecified hypotheses [page 3]
Methods		
Study design	4	Present key elements of study design early in the paper [page 3]
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection [page 3]
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up [page 3-4] *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable [page 5-7]
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group [page 5-7]
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at [page 4]
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why [page 7-8]
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding [page 7-8]
		(*b*) Describe any methods used to examine subgroups and interactions [page 7-8]
		(*c*) Explain how missing data were addressed [page 3-4]
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses [page 18]

Continued on next page

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Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed [page 4]
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram [page 4]
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders [page 9-10]
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time [page 9]
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included [page 10-12]
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses [page 12-14]
Discussion		
Key results	18	Summarise key results with reference to study objectives [page 15]
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias [page 17-18]
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence [page 15-17]
Generalisability	21	Discuss the generalisability (external validity) of the study results [page 17-18]
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based [page 20]

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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BMJ Open

The role of environmental factors for the onset of restricted mobility outside the home among older adults with osteoarthritis: a prospective cohort study.

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-012826.R1
Article Type:	Research
Date Submitted by the Author:	01-Nov-2016
Complete List of Authors:	Rantakokko, Merja; Jyvaskylan Yliopisto, Gerontology Research Center and Department of Health Sciences Wilkie, Ross; Keele University, Research Institure for Primary Care and Health Sciences
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	Participation, Mobility, Osteoarthritis, Environment

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The role of environmental factors for the onset of restricted mobility outside the home among older adults with osteoarthritis: a prospective cohort study

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Key words: Participation, environment, older adults, mobility

Word count: 3293

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ABSTRACT

Objectives: The study examines how environmental factors contribute to the onset of restricted mobility outside the home among older adults with osteoarthritis.

Methods: Prospective cohort study of adults aged 50 years and over with osteoarthritis (N=1802). Logistic regression tested the association between the onset of restricted mobility outside the home and health, sociodemographic and perceived environmental barriers (hills and steep slopes, inaccessible public buildings, poor pavement condition, lack of access to public parks or sport facilities, heavy traffic or speeding cars, and poor weather). The potential moderating role of environmental barriers on the association between health factors and onset was examined using interaction terms and stratified analysis.

Results: Of 1802 participants, 13.5% (n=243) reported the onset of restricted mobility outside the home at three-year follow-up. Walking disability, anxiety, depression, cognitive impairment and obesity, and all environmental barriers were associated with onset after adjustment for confounders. There were significant but less than multiplicative interactions between hills and steep slopes that make it difficult to move outdoors with walking disability (p=.030), anxiety (p=.037), depression (p=.002) and cognitive impairment (p=.029); poor pavement conditions and anxiety (p=.036), and heavy traffic or speeding cars and depression (p=.036).

Conclusion: For older adults with osteoarthritis, environmental barriers have a greater role on its impact when associated morbidities and walking disability exist. Awareness of environmental barriers is important when aiming to maintain mobility and activities outside the home despite health conditions in older adults.

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Strengths and limitations of this study

- A large population-based sample of older adults with osteoarthritis, identified using medical records, and high response rate.
- Longitudinal study on a topic that has not been widely studied.
- The generalisability of the study may be limited by the characteristics of the study sample; the area covered by this study is more deprived on health, education and employment, but with fewer barriers to housing and services than England as a whole
- Use of perceived environmental barriers instead of objectively assessed features.

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INTRODUCTION

Mobility outside the home is important for maintenance of independence and good quality of life in old age.[1] Restricted mobility outside the home is the most common form of participation restriction among older people and is associated with chronic health conditions [2], physical function, socio-demographic and environmental factors.[3, 4] The International Classification of Functioning, Disability and Health (ICF) highlights the role of environmental factors as barriers or facilitators of participation.[5] A number of studies have shown the associations between environmental barriers, e.g. poor quality streets and long distances, with functional limitations [6, 7] and restricted participation among older adults [8, 9] but have not identified why. Environmental factors may moderate the relationship between impairments, such as pain, and restricted participation; that is the association between pain and restricted participation differs depending on the environment, for example, living in an area with lots of hills compared to living in an area that is flat. Identifying which environmental factors moderate the association between impairments and their impact is useful for directing interventions.

Older adults with osteoarthritis are especially vulnerable to environmental challenges due to physical limitation and symptoms such as pain and stiffness [5, 6, 9, 10]. Osteoarthritis is the most common joint condition in adults and globally is the fastest increasing major health condition.[11, 12] It is a common reason for health care consultation (one out of every twenty consultations to primary care in adults aged over 50 years is for osteoarthritis), and is also a common comorbidity in persons seen in primary care for other reasons.[13] Previous studies have identified several health factors that are associated with poor outcomes among older

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adults with osteoarthritis, such as pain, multimorbidity, obesity, depression and functional limitations.[2, 4, 14] However it is unclear if environmental factors moderate the impact of osteoarthritis on mobility outside the home in older adults.

In this study we used the ICF framework [5] to organise information and determine if features of the physical environmental moderate the association between health conditions and the onset of restricted mobility outside the home in older adults with osteoarthritis. Specifically, the study examines whether (i) pain, comorbidity (anxiety, depression, obesity, cognitive impairment, and multimorbidity) and physical disability (i.e. walking disability) are associated with an increased the risk of the onset of restricted mobility outside the home at 3-year follow-up among older adults with osteoarthritis and (ii) these associations were moderated by environmental factors.

METHODS

Study population

The North Staffordshire Osteoarthritis project (NorStOP) is a population-based prospective cohort study.[15] The NorStOP sampling frame comprised all individuals aged 50 years and over who were registered to receive care from one of six general practices in North Staffordshire, United Kingdom (UK). In the UK general practice registers offer a convenient sampling frame for population based studies. While it is difficult to accurately state the proportion of the UK population who are registered with a general practice due to duplicate registrations of individuals and those individuals who do not register (http://www.rcgp.org.uk/pdf/ISS_INFO_02_MAY06.pdf), it has been estimated that up to 98% of

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UK residents are registered. For this study, potential participants were those who gave written consent for medical record review and who received a diagnosis of osteoarthritis during a primary care consultation between 2000 and 2008. At baseline (2005) potential participants were mailed questionnaires and at three year follow-up (2008); reminders were sent at two and four weeks after the initial mailing.

Analyses for this paper included those who (i) consulted for osteoarthritis from 2000 to 2008 (the study period of NorStOp), (ii) were free of restricted mobility outside the home at baseline and (iii) had completed the item on mobility outside the home at three year follow-up (n=1802). (Figure 1).

Identification of osteoarthritis

General practitioners in the study used the Read system to code all reasons for clinical encounters in primary care consultations.[16] The Read codes cross-map to ICD9/ICD-10 (for diseases). Morbidity data (i.e. symptoms and diseases) in this system are grouped into 18 Read chapters. Data on these diagnostic groups were aggregated starting in 2000, continuing through the time of the follow-up questionnaire in 2008. Individuals were defined as having osteoarthritis if they had at least one consultation during this period primarily for osteoarthritis based on Read codes (N05 category) for primary care consultations.[16] As osteoarthritis is a long-standing, gradually progressive chronic condition, it was assumed that a clinician-established diagnosis at any point during the study period implied that osteoarthritis was likely present at least to some degree during the entire period of observation.

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Measurements

Restricted mobility outside the home was assessed with one item from the Keele Assessment of Participation (KAP) instrument.[17] KAP is a valid and reliable measurement tool to capture perceived participation restriction in population studies. Participants were asked whether "during the past 4 weeks, have you moved around outside your home, as and when you wanted" with response options 'all the time, most of the time, some of the time, a little of the time and none of the time'. Participants were considered to be restricted for the mobility outside the home if reported being able to move outside the home 'as and when wanted' for 'some, a little or none of the time'. Onset of restricted mobility was defined as moving from no restriction at baseline to restricted mobility at three-year follow-up point.

All ***health exposures*** were assessed at baseline. *Walking disability and bodily pain* were measured using single items from the Short Form-36 physical functioning subscale.[18] For walking disability, participants were asked whether their health limited walking more than a mile; responses were categorized to walking disability (limited a lot) and no disability (limited a little and not limited at all). For *bodily pain* participants were asked "How much bodily pain have you had during the past 4 weeks?"; response options were categorized to 'none/mild' and 'moderate /severe'.

Multimorbidity was defined using general practice consultation Read code data. As defined above a count of comorbidity from the remaining 18 Read codes was then categorized using a previously validated method,[19] to identify multimorbidity (i.e. ≥4. Morbidities).

Anxiety and depression was assessed with the Hospital Anxiety and Depression scale (HADS).[20] HADS is a fourteen item scale (7 items of anxiety, 7 items for depression) and targets on how a person has felt in the past week. Each item is scored from 0 to 3 with total

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score between 0 and 21 for either anxiety or depression. Score of 8/21 is identified as cut-off point for anxiety or depression [21] and was used to dichotomize anxiety and depression as possible/probable case (scores 8-21) vs. no case (scores 0-7). *Cognitive impairment* was measured using Cognitive and Alertness behavior subscale of Functional Limitations Profile [22] and categorized into no impairment (score 0) and impairment (score ≥ 1).

Body Mass Index (BMI) was calculated based on self-reported weight and height and categorized into obese (BMI >30 kg/m^2) and other (BMI < 30 kg/m^2).[23]

Environmental barriers were assessed using a structured questionnaire at three-year follow-up. Participants were asked to indicate how much they agreed or disagreed with statements related to environment barriers to moving around outside the home; live in an area with hills and steep slopes that make it difficult to move around outside (referred to as hills and steep slopes hereafter), inaccessible public buildings make it difficult to move around, poor pavement condition stops me from going out, lack of access to public parks or sport facilities stops me from going out, heavy traffic or speeding cars stop me going out, and adverse weather stops me going out. The answers were on a 5-point scale from 'strongly disagree' to 'strongly agree'. For the analyses each environmental barrier was identified by responses of agree or strongly agree and compared to no barrier (neither disagree nor agree, disagree, strongly disagree).

Potential confounders included demographic factors (age, gender) and socio-economic factors (occupational class (professional/managerial, semi-routine, routine))[24]; and educational attainment (further education, or not)).

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Statistical analyses

Differences in distribution in health exposures, environmental barriers, and potential confounders between those with and without onset of restricted mobility outside the home were tested with Chi Square for categorical variables, and t-test for continuous variables. Univariate logistic regression analyses was used to examine for the association between baseline health exposures and environmental barriers and the onset of restricted mobility outside the home at three year follow-up, first unadjusted then adjusted for age, gender, and socioeconomic factors (Model 1).

The independent effect of health and environmental factors on the onset of mobility restriction outside the home was then assessed over two stages with reference to the conceptual model of the ICF.[5] In the first stage the "health" model was derived: all health factors were entered simultaneously into the model with age, gender and socio-economic factors as potential confounders (Model 2). In the second stage all environmental factors were entered separately, adjusted for all health factors and confounders (Models 3-8). Associations are summarized by odds ratios with 95% confidence intervals. Concordance indexes (C-statistic) were calculated to evaluate model fit. A C-statistic of 0.5 indicates that model is no better than chance in making a prediction, more than 0.7 is considered reasonable and more than 0.8 indicates strong predictive ability.[25]

To examine if environmental factors moderated the association between morbidities and onset of restricted mobility outside the home interaction terms were added to the health model separately (Model 2). Health (Model 2) and environmental factors (Models 3-8) significant at 5% level were included in the interaction analysis. The output (odds ratio and confidence interval) relates to multiplicative interaction. If the confidence interval does not

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include 1.0 there is a significant difference in the association between the exposure and outcome by level of potential moderator. An odds ratio above 1.0 indicates that a multiplicative interaction has occurred and an odds ratio below 1.0 indicates that a multiplicative interaction has not taken place. For significant interactions, stratified analyses were conducted. Analyses were conducted with STATA 14.0 (StataCorp 2015, College Station, TX, StataCorp LP).

RESULTS

Of the 1802 participants free of participation restriction at baseline, 243 (13.5%) reported onset of restricted mobility outside the home three years later. Onset of restricted mobility outside the home was more common among those with walking disability, severe pain, anxiety, depression, cognitive impairment, obesity and environmental barriers. There were no differences for multimorbidity (p=.088). (Table 1)

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Table 1. Characteristics of the study population at baseline overall and stratified by the onset of restricted mobility outside the home at three-year follow-up.

	Total	Onset of restriction		P value
		Yes	No	
	n=1802	n=243	n= 1559	
	% (n)	% (n)	% (n)	
Health				
Walking disability	18.2 (328)	46.9 (114)	13.7 (214)	<.001
Multimorbidity, ≥4	83.5 (1504)	87.2 (212)	82.9 (1292)	.088
Anxiety	25.7 (463)	40.3 (98)	23.4 (365)	<.001
Depression	9.3 (167)	19.8 (48)	7.6 (119)	<.001
Pain				<.001
None / Mild	54.8 (988)	36.6 (89)	57.7 (899)	
Moderate /severe	45.2 (814)	63.4 (154)	42.3 (660)	
Cognitive impairment	39.7 (715)	57.2 (139)	37.0 (576)	<.001
BMI				.005
Obese	18.2 (328)	25.1 (61)	17.1 (267)	
Other	79.4 (1431)	71.6 (174)	80.6 (1257)	
Unknown	2.4 (43)	3.3 (8)	2.3 (35)	
Confounders				
Female	56.4 (1193)	59.3 (185)	55.9 (1008)	.270
Age, mean (SD)	65.8 (8.9)	69.9 (8.9)	65.1 (7.7)	<.001
Occupational class				.001
Managerial/professional	23.3 (493)	17.6 (55)	24.3 (438)	
Semi-routine	20.0 (423)	20.8 (65)	19.9 (358)	
Routine/manual	51.8 (1096)	52.9 (165)	51.7 (931)	
Other	4.8 (102)	8.7 (27)	4.2 (75)	
Full time education	15.6 (281)	7.8 (19)	16.8 (262)	.001
Environmental barriers				
Hills and steep slopes	12.5 (226)	34.6 (84)	9.1 (142)	<.001
Inaccessible public buildings	4.1 (73)	12.8 (31)	2.7 (42)	<.001
Poor pavement condition	6.4 (115)	16.1 (39)	4.9 (76)	<.001
Lack of access to parks	3.4 (61)	9.9 (24)	2.4 (37)	<.001
Heavy traffic or speeding cars	2.4 (44)	6.6 (16)	1.8 (28)	<.001
Adverse weather	12.7 (228)	33.7 (82)	9.4 (146)	<.001

Associations with onset of restricted mobility outside the home

Following adjustment for confounders, walking disability (adjusted odds ratio (OR)=4.5, 95% confidence interval (95% CI) 3.4 to 6.1), anxiety (OR=2.5, 95% CI 1.9 to 3.4),

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depression (OR=3.4, 95% CI 2.3 to 5.0), pain (OR=2.3, 95% CI 1.8 to 3.1), cognitive impairment (OR=2.1, 95% CI 1.6 to 2.8), and obesity (OR=2.1, 95% CI 1.5 to 3.0) were associated with the onset of restricted mobility outside the home. In the multivariable health model (Model 2), pain was not significantly associated with onset of restricted mobility outside the home (OR=1.3, 95% CI 0.9 to 1.8). All environmental factors were associated with onset of restriction after adjustment for confounders and all health exposures (Table 2).

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TABLE 2. Associations between morbidity, walking disability and environmental factors and the onset of participation restriction in mobility outside the home in older adults with osteoarthritis; odds ratios and 95% confidence intervals.

	Crude OR (95%CI)	Model 1 OR (95%CI)	Model 2 OR (95%CI)	Model 3 OR (95%CI)	Model 4 OR (95%CI)	Model 5 OR (95%CI)	Model 6 OR (95%CI)	Model 7 OR (95%CI)	Model 8 OR (95%CI)
Walking disability	5.6 (4.2 to 7.4)	4.5 (3.4 to 6.1)	3.3 (2.4 to 4.6)	2.9 (2.0 to 4.0)	3.2 (2.3 to 4.4)	3.2 (2.3 to 4.5)	3.2 (2.3 to 4.5)	3.2 (2.3 to 4.5)	3.1 (2.2 to 4.4)
Anxiety	2.2 (1.7 to 2.9)	2.5 (1.9 to 3.4)	1.6 (1.1 to 2.3)	1.7 (1.2 to 2.5)	1.6 (1.1 to 2.3)	1.6 (1.1 to 2.2)	1.5 (1.1 to 2.2)	1.6 (1.1 to 2.2)	1.5 (1.0 to 2.1)
Depression	3.0 (2.1 to 4.3)	3.4 (2.3 to 5.0)	1.6 (1.0 to 2.5)	1.5 (0.9 to 2.3)	1.5 (0.98 to 2.4)	1.6 (1.0 to 2.5)	1.5 (0.96 to 2.4)	1.6 (1.0 to 2.5)	1.5 (0.9 to 2.3)
Pain									
None/Mild	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Moderate /Severe	2.4 (1.8 to 3.1)	2.3 (1.8 to 3.1)	1.3 (0.9 to 1.8)	1.2 (0.9 to 1.7)	1.3 (0.9 to 1.7)	1.2 (0.9 to 1.7)	1.3 (0.9 to 1.8)	1.3 (0.9 to 1.8)	1.2 (0.9 to 1.7)
Cognitive impairment	2.3 (1.7 to 3.0)	2.1 (1.6 to 2.8)	1.5 (1.1 to 2.0)	1.3 (0.98 to 1.9)	1.4 (1.0 to 1.9)	1.4 (1.0 to 2.0)	1.5 (1.1 to 2.0)	1.5 (1.1 to 2.0)	1.4 (1.0 to 1.9)
BMI									
Obesity (BMI > 30)	1.7 (1.2 to 2.3)	2.1 (1.5 to 3.0)	1.5 (1.0 to 2.1)	1.4 (0.99 to 2.1)	1.5 (1.0 to 2.1)	1.4 (0.99 to 2.1)	1.5 (1.0 to 2.1)	1.5 (1.0 to 2.1)	1.4 (0.9 to 2.0)
Other	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Environmental barriers									
Hills and steep slopes	5.3 (3.8 to 7.2)	4.4 (3.2 to 6.1)	-	3.3 (2.3 to 4.6)	-	-	-	-	-
Inaccessible public buildings	5.3 (3.3 to 8.6)	4.9 (3.0 to 8.2)	-	-	3.2 (1.8 to 5.5)	-	-	-	-
Poor pavement condition	3.7 (2.5 to 5.6)	3.4 (2.2 to 5.2)	-	-	-	2.4 (1.51 to 3.8)	-	-	-
Lack of access to parks	4.5 (2.6 to 7.7)	4.4 (2.5 to 7.6)	-	-	-	-	2.8 (1.5 to 5.0)	-	-
HeavyTraffic	3.9 (2.1 to 7.2)	4.2 (2.2 to 8.0)	-	-	-	-	-	2.9 (1.4 to 5.8)	-
Adverse weather	4.9 (3.6 to 6.8)	4.4 (3.2 to 6.1)	-	-	-	-	-	-	3.2 (2.2 to 4.5)
C-statistics			0.779	0.809	0.786	0.789	0.784	0.783	0.804

Model 1 association between each exposure and restricted mobility outside the home, adjusted for confounders : age, gender, socioeconomic factors.
Model 2 multivariate health model, all health exposures included, adjusted for confounders.
Model 3-8 multivariate model, adjusted for confounders
BMI, Body Mass Index
OR, Odds Ratio
95% CI, Confidence Interval

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Interactions There were significant but less than multiplicative interactions between hills and steep slopes that make it difficult to move outdoors and walking disability (adjusted OR=0.47, 95% CI 0.24 to 0.93), anxiety (OR=0.45, 95% CI 0.22 to 0.96), depression (OR=0.25, 95% CI 0.09 to 0.61) and cognitive impairment (OR=0.46, 95% CI 0.23 to 0.92). Significant but less than multiplicative interactions were also found between poor pavement condition and anxiety (OR=0.37, 95% CI 0.15 to 0.94), and between heavy traffic or speeding cars and depression (OR=0.14, 95% CI 0.02 to 0.88) (See Appendix 1.).

The prevalence of the onset of restricted mobility outside the home was higher among those living in an environment featured by hills and steep slopes, especially among those having walking disability or anxiety (Figure 2A). Among those with depression or cognitive impairment the prevalence of onset of restricted mobility was around the same with or without hills and steep slopes. Among people without depression, prevalence of restricted mobility was more common when hills and steep slopes and heavy traffic and speeding cars were present (Figure 2A and 2B).

Among those with anxiety, restricted mobility outside the home was equally common for the presence and absence of poor pavement condition. Among those without anxiety, restricted mobility was more common among those living in environment with poor pavement condition (Fig 2C).

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DISCUSSION

The aims of this study were to identify the role of environmental barriers on the onset of restricted mobility outside the home in older adults with osteoarthritis. All environmental factors were associated with onset of restricted mobility. There were significant but less than multiplicative interactions between environmental barriers and comorbidity and physical disability on the onset of restricted mobility. The impact of environmental barriers was greatest for individuals with comorbidity or physical disability; onset of restricted mobility outside the home was more common among those living in environments featured by hills and steep slopes, and especially when a person was having additional walking disability or anxiety.

Our findings support the theoretical model of the ICF by providing empirical evidence of the role of environmental factors on future restricted mobility. Our findings also give support to previous studies that have emphasized importance of using comprehensive models of mobility including physical, psychosocial and environmental determinants.[26, 27] It is possible that certain health conditions that lead to walking disability, increase risk of onset of participation restriction in demanding environments because the environment no longer supports the level of functional capacity.[10] While previous cross-sectional studies have shown the association between environmental characteristics and participation in out-of-home activities,[9] and an interaction between environmental characteristics (e.g. heavy traffic) and health for participating in voting, obtaining health care and interpersonal interaction,[28] our study goes beyond previous literature by identifying how environmental factors contribute to the onset of restricted mobility and link with common consequences or comorbidities in people with osteoarthritis.

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In this study the most common environmental barriers were hills and steep slopes and adverse weather. Hills and steep slopes increase requirements for physical capability, and is a particular barrier for older adults with osteoarthritis. People with difficulties in walking report more and different environmental barriers that affect their participation in community activities than those without difficulty.[28] This suggests that the interaction between person and the environment and the balance between these two, (i.e. person-environment fit),[10] is influential to whether a person is able to move outdoors or not. People may compensate for their impairments,[29] for example, by stopping to rest when moving outdoors or use assistive devices, but environmental barriers may make these compensations more difficult to perform, exacerbating the situation. For example, people with walking disability may be concerned for their safety when moving outdoors because of heavy traffic and speeding cars, especially when crossing the street.[30] People with depression or cognitive impairment may not encounter these barriers because they participate less or change how they participate to compensate for their impairment.[31]

Adverse weather is a common barrier for outdoor mobility among older adults and snow, ice and rainfall, increase the risk of participation restriction. [32] For example, icy conditions may increase difficulty to maintain balance leading to fear of falling despite of the health, thus restricting possibilities to participate in outdoor activities.[33] In this study adverse weather was associated with onset but there were no interactions with comorbidity or physical disability.

Older people most often go outdoors for the purposes of shopping, running daily errands and walking for exercise.[34] If public buildings for shopping or running daily errands are

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inaccessible, it may restrict possibilities for using these community amenities. Parks and green areas form important spaces for exercise and motivate people to go out.[35-37]. Poor access to these resources may be decisive when considering participation in outdoor activities, especially for people with osteoarthritis.[38] The considerable prevalence of osteoarthritis indicates that this is an issue which impacts on a large number of adults in the population.

Strengths and limitations

The study has a number of strengths. The analysis was performed with a large population-based sample of older adults with osteoarthritis, identified using medical records. The response rate was high and was comparable to other population surveys. The available data covered a number of important factors in relation to the onset of mobility outside the home for older adults with osteoarthritis. The instruments used to identify restricted mobility outside the home, the symptoms of osteoarthritis and comorbidity, have been validated for use in population studies of older adults.[17, 18, 21, 22] The items measuring environmental barriers were reliable in pilot testing (weighted kappa values for test-retest (4-week period) ranged from 0.5 (moderate) to 0.9 (almost perfect)).

Study limitations were: Restricted mobility outside the home was measured by self-report and focused on person-perceived participation. This is the most appropriate method for capturing an individual's social participation however it is susceptible to measurement error and it may not take account of frequency of outdoor mobility. Responders that do not mobilise outdoors may report restricted mobility but not environmental barriers that they won't experience which may lead to underestimation of associations. Perceived environmental barriers were included in this analysis as they more appropriately capture the presence of environmental barriers that an individually encounters when mobilising outdoors. Whilst objective measures

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identify environmental features (e.g. population density, existence of hills) individuals may not perceive these or experience them as barriers to mobility. Perceived environmental barriers may be a more valid indicator than objectively measured neighbourhood features when studying restricted mobility outside the home. There may be other predictors and confounders which may be important but were not included in this study. For example, performance based measures, such as gait speed can be used as clinical marker of decline in participation.[39] Since performance, and especially gait patterns, may also be influenced by environmental features,[40] the combined association between these in relation to participation may form an interesting target for future research. The generalisability of the study may be limited by the characteristics of the study sample; the area covered by this study is more deprived on health, education and employment, but with fewer barriers to housing and services than England as a whole. As in most prospective studies, there was some loss to follow-up and missing data; those who dropped out of the analysis were more likely to be female (p=.010), have depression (p=.046), anxiety (p<.001) and walking disability (p=.001) than those included the sample. There were no differences for pain (p=.060), obesity (p=.650), cognitive impairment (p=.106) or multimorbidity (p=.281). Data on outdoor mobility was measured three years apart and restriction in mobility may vary during this period; we could not measure variation between the three year time points. Those who did not consent to medical record review were unhealthier at baseline; however the effect of this on the association between the exposures and restricted mobility is unknown.

Conclusion

The findings of this study suggest that some environmental barriers have an important role in preventing older adults with osteoarthritis mobilising outside their home, particularly when impairments and walking disability are present. To prevent the onset of restricted mobility

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outside the home for older adults with osteoarthritis, both clinical and non-clinical approaches are required. Clinical approaches aimed at reducing pain, anxiety, depression and walking disability will be useful, but consideration of an individual's environment is important. Identifying older adults with osteoarthritis that live in more challenging environments can lead to a targeted approach to overcoming such barriers, within a rehabilitation programme. Approaches to reducing environmental barriers and community planning, such as improving access to public buildings, increasing mobility friendly environments where low physical and mental capacities do not prevent mobility and function, and the provision of public transport may prevent restricted mobility, improve social participation and support active ageing.

Footnotes

Funding: NorStOp project was supported by the Medical Research Council, UK grant numbers [G9900220 and G0501798] and by the North Staffordshire Primary Care R&D Consortium. MR was supported by the Academy of Finland grant number [285747] and Finnish Ministry of Education and Culture. The study sponsors had no role in the study design; in the collection, analysis and interpretation of the data; in the writing of the report; or in the decision to submit the paper for publication.

Competing Interests: None declared.

Ethics approval: The North Staffordshire Local Research Ethics Committee granted approval and all participants gave written consent to participate.

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Contributorship statement: MR and RW designed the research questions, plan of analyses, statistical analyses and interpreted the results and drafted the manuscript. MR was the main author of the manuscript.

Data sharing statement: The Research Institute for Primary Care and Health Sciences, Keele university has established data sharing arrangements to support joint publications and other research collaborations. Applications for access to anonymized data from our research databases are reviewed by the Centre's Data Custodian and Academic Proposal (DCAP) Committee and a decision regarding access to the data is made subject to the NRES ethical approval first provided for the study and to new analysis being proposed. Further information on our data sharing procedures can be found on the Centre's website (http://www.keele.ac.uk/pchs/publications/datasharingresources/) or by emailing the Centre's data manager (data-sharing-pcs@keele.ac.uk).

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FIGURE LEGENDS

FIGURE 1. Flow diagram of participants

NOTE: * 117 baseline were excluded at three year-follow-up having met the exclusion criteria; (i) inability to complete the questionnaire due to poor health (e.g. cognitive impairment, dementia, stroke) and (ii) had expressed a wish to their doctor that they did not want to participate further in research studies.

FIGURE 2. The prevalence of the onset of restricted mobility outside the home among people with and without health problems at baseline stratified by environmental barriers: A) Hills and steep slopes, B) Heavy traffic or speeding cars, C) Poor pavement condition.

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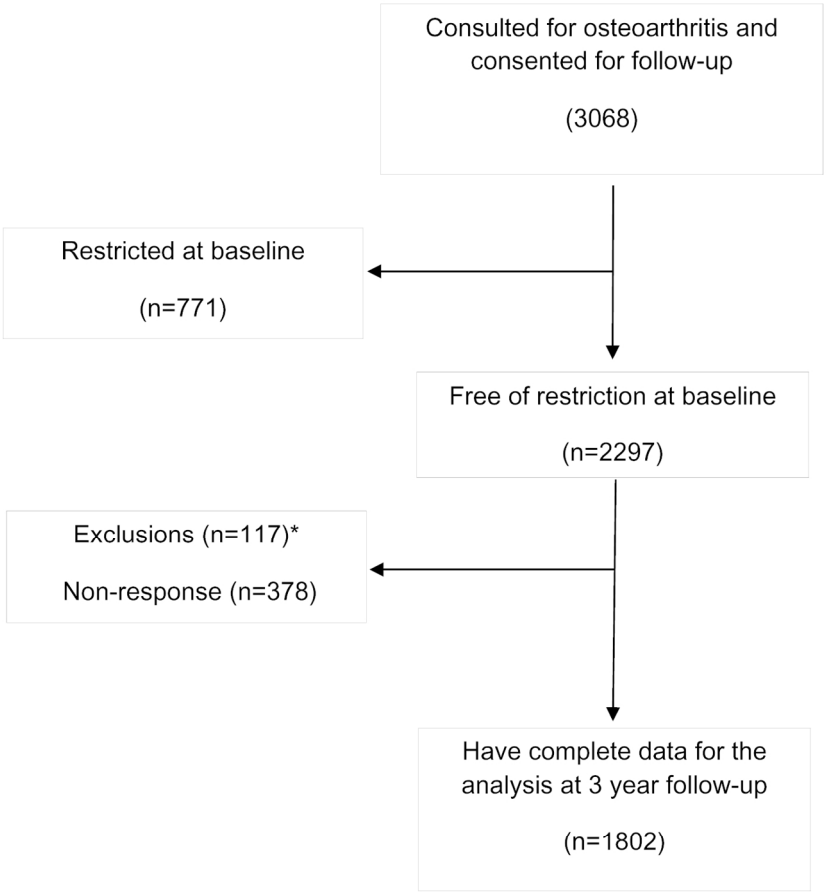

Figure 1. Flow diagram of participants.

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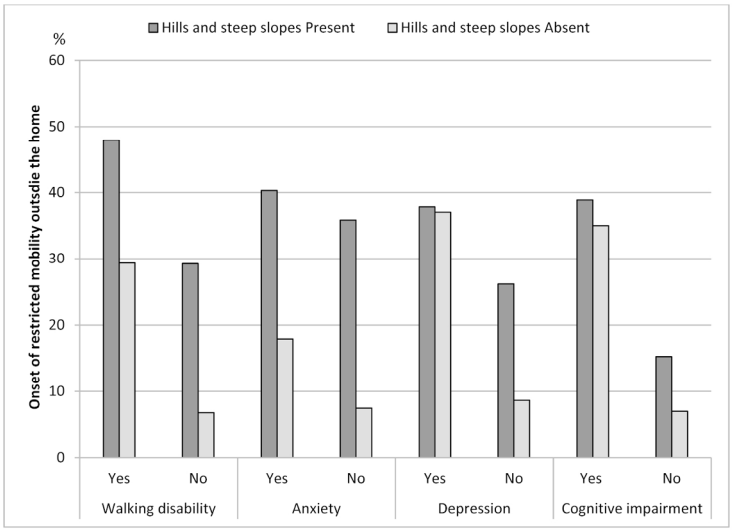
2A) Hills and steep slopes



2B) Heavy traffic or speeding cars

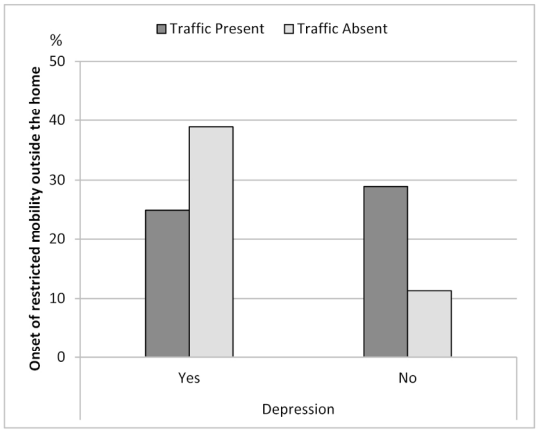


Figure 2. The prevalence of the onset of restricted mobility outside the home among people with and without health problems at baseline stratified by environmental barriers: A) Hills and steep slopes, B) Heavy traffic or speeding cars, C) Poor pavement condition.

135x199mm (300 x 300 DPI)

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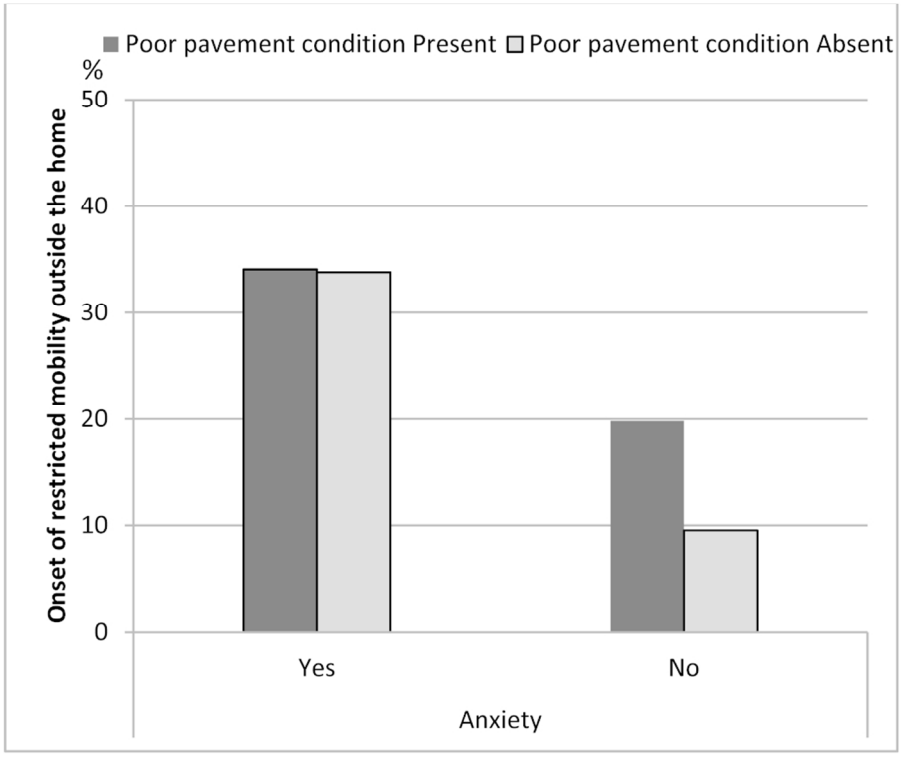
2C) Poor pavement condition



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APPENDIX 1. The interaction between environmental factors and morbidity on the onset of restricted mobility outside the home in older adults with osteoarthritis, adjusted odds ratios with 95% confidence intervals.

	Walking disability	Anxiety	Depression	Cognitive impairment	Obesity
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Hills	**0.47 (0.24-0.93)**	**0.45 (0.22-0.96)**	**0.25 (0.09-0.61)**	**0.46 (0.23-0.92)**	0.82 (0.36-1.84)
Public buildings	1.53 (0.50-4.71)	0.72 (0.24-2.15)	0.71 (0.20-2.57)	0.43 (0.14-1.29)	0.74 (0.20-2.67)
Pavement	0.60 (0.24-1.47)	**0.37 (0.15-0.94)**	0.52 (0.16-4.49)	0.50 (0.20-1.25)	1.56 (0.55-4.40)
Access to parks	0.91 (0.28-2.98)	0.34 (0.10-1.12)	0.47 (0.13-1.78)	0.55 (0.17-1.85)	2.19 (0.46-10.33)
Weather	0.50 (0.25-1.01)	0.79 (0.39-1.60)	1.23 (0.51-2.99)	0.54 (0.27-1.08)	0.50 (0.22-1.12)
Traffic	1.55 (0.37-6.50)	0.39 (0.09-1.60)	**0.14 (0.02-0.88)**	0.27 (0.07-1.07)	0.29 (0.05-1.56)
Crime	0.52 (0.22-1.22)	0.59 (0.25-1.39)	0.86 (0.31-2.37)	0.84 (0.35-2.03)	0.64 (0.24-1.73)

Adjusted for confounders: age and gender, socioeconomic factors, and all other health exposures.
Odds Ratio below 1 indicate less than multiplicative interaction, 95% confidence interval (CI) shows the statistical significance of the association. When 95% CI do not include 1, the association is considered as statistically significant.

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract [In the abstract, page 1]
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found [page 1]
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported [page 3-4]
Objectives	3	State specific objectives, including any prespecified hypotheses [page 4]
Methods		
Study design	4	Present key elements of study design early in the paper [page 4]
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection [page 4-5]
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up [page 4-6] *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable [page 5-7]
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group [page 5-7]
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at [page 4-6]
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why [page 7-9]
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding [page 9-10]
		(*b*) Describe any methods used to examine subgroups and interactions [page 8-9]
		(*c*) Explain how missing data were addressed [page 4-5]
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses [page 17]

Continued on next page

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Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed [page 4-6]
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram [Figure 1]
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders [page 9-10]
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time [page 10]
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included [page 10-11, appendix 1]
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses [page 12-14]
Discussion		
Key results	18	Summarise key results with reference to study objectives [page 14]
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias [page 16-17]
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence [page 14-18]
Generalisability	21	Discuss the generalisability (external validity) of the study results [page 16-17]
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based [page 18]

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-012826.R2
Article Type:	Research
Date Submitted by the Author:	07-Mar-2017
Complete List of Authors:	Rantakokko, Merja; Jyvaskylan Yliopisto, Gerontology Research Center and Department of Health Sciences Wilkie, Ross; Keele University, Research Institure for Primary Care and Health Sciences
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	Participation, Mobility, Osteoarthritis, Environment

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The role of environmental factors for the onset of restricted mobility outside the home among older adults with osteoarthritis: a prospective cohort study

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Key words: Participation, environment, older adults, mobility

Word count: 3463

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ABSTRACT

Objectives: The study examines how environmental factors contribute to the onset of restricted mobility outside the home among older adults with osteoarthritis.

Methods: Prospective cohort study of adults aged 50 years and over with osteoarthritis (N=1802). Logistic regression tested the association between the onset of restricted mobility outside the home and health, sociodemographic and perceived environmental barriers (hills and steep slopes, inaccessible public buildings, poor pavement condition, lack of access to public parks or sport facilities, heavy traffic or speeding cars, and poor weather). The potential moderating role of environmental barriers on the association between health factors and onset was examined using interaction terms and stratified analysis.

Results: Of 1802 participants, 13.5% (n=243) reported the onset of restricted mobility outside the home at three-year follow-up. Walking disability, anxiety, depression, cognitive impairment and obesity, and all environmental barriers were associated with onset after adjustment for confounders. Environmental barriers had an added contribution to the effect of the health conditions on onset of restricted mobility, which was attenuated when adjusted for confounders. The added contribution remained only for walking disability and the presence of hills and steep slopes; in the presence of both the association with onset of restricted mobility was stronger (OR 7.66, 95% CI 4.64 to 7.16) than in the presence of walking disability (3.60, 2.43 to 5.32) or the presence of hills and steep slopes alone (4.55, 2.89 to 7.16).

Conclusion: For older adults with osteoarthritis, environmental barriers are associated and add a contribution to that of morbidities and walking disability on the onset of restricted mobility outside the home. Awareness of environmental barriers is important when aiming to maintain mobility and activities outside the home despite health conditions in older adults.

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Strengths and limitations of this study

- A large population-based sample of older adults with osteoarthritis, identified using medical records, and high response rate.
- Longitudinal study on a topic that has not been widely studied.
- The generalisability of the study may be limited by the characteristics of the study sample; the area covered by this study is more deprived on health, education and employment, but with fewer barriers to housing and services than England as a whole
- A potential limitation is a use of perceived environmental barriers instead of objectively assessed features.

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INTRODUCTION

Mobility outside the home is important for maintenance of independence and good quality of life in old age.[1] Restricted mobility outside the home is the most common form of participation restriction among older people and is associated with chronic health conditions [2], physical function, socio-demographic and environmental factors.[3, 4] The International Classification of Functioning, Disability and Health (ICF) highlights the role of environmental factors as barriers or facilitators of participation.[5] A number of studies have shown the associations between environmental barriers, e.g. poor quality streets and long distances, with functional limitations [6, 7] and restricted participation among older adults [8, 9] but have not identified why. Environmental factors may moderate the relationship between impairments, such as pain, and restricted participation; that is the association between pain and restricted participation differs depending on the environment, for example, living in an area with lots of hills compared to living in an area that is flat. Identifying which environmental factors moderate the association between impairments and their impact is useful for directing interventions.

Older adults with osteoarthritis are especially vulnerable to environmental challenges due to physical limitation and symptoms such as pain and stiffness [5, 6, 9, 10]. Osteoarthritis is the most common joint condition in adults and globally is the fastest increasing major health condition.[11, 12] It is a common reason for health care consultation (one out of every twenty consultations to primary care in adults aged over 50 years is for osteoarthritis), and is also a common comorbidity in persons seen in primary care for other reasons.[13] Previous studies have identified several health factors that are associated with poor outcomes among older adults with osteoarthritis, such as pain, multimorbidity, obesity, depression and functional

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limitations.[2, 4, 14] However it is unclear if environmental factors moderate the impact of osteoarthritis on mobility outside the home in older adults.

In this study we used the ICF framework [5] to organise information and determine if features of the physical environmental moderate the association between health conditions and the onset of restricted mobility outside the home in older adults with osteoarthritis. Specifically, the study examines whether (i) pain, comorbidity (anxiety, depression, obesity, cognitive impairment, and multimorbidity) and physical disability (i.e. walking disability) at baseline are associated with an increased the risk of the onset of restricted mobility outside the home at 3 years later in older adults with osteoarthritis and (ii) these associations were moderated by environmental factors.

METHODS

Study population

The North Staffordshire Osteoarthritis project (NorStOP) is a population-based prospective cohort study.[15] The NorStOP sampling frame comprised all individuals aged 50 years and over who were registered to receive care from one of six general practices in North Staffordshire, United Kingdom (UK). In the UK general practice registers offer a convenient sampling frame for population based studies. While it is difficult to accurately state the proportion of the UK population who are registered with a general practice due to duplicate registrations of individuals and those individuals who do not register (http://www.rcgp.org.uk/pdf/ISS_INFO_02_MAY06.pdf), it has been estimated that up to 98% of UK residents are registered. For this study, potential participants were those who gave written

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consent for medical record review and who received a diagnosis of osteoarthritis during a primary care consultation between 2000 and 2008. At baseline (2005) potential participants were mailed questionnaires and at three year follow-up (2008); reminders were sent at two and four weeks after the initial mailing.

Analyses for this paper included those who (i) consulted for osteoarthritis from 2000 to 2008 (the study period of NorStOP), (ii) were free of restricted mobility outside the home at baseline and (iii) had completed the item on mobility outside the home at three year follow-up (n=1802). (Figure 1).

Identification of osteoarthritis

General practitioners in the study used the Read system to code all reasons for clinical encounters in primary care consultations.[16] The Read codes cross-map to ICD9/ICD-10 (for diseases). Morbidity data (i.e. symptoms and diseases) in this system are grouped into 18 Read chapters. Data on these diagnostic groups were aggregated starting in 2000, continuing through the time of the follow-up questionnaire in 2008. Individuals were defined as having osteoarthritis if they had at least one consultation during this period primarily for osteoarthritis based on Read codes (N05 category) for primary care consultations.[16] As osteoarthritis is a long-standing, gradually progressive chronic condition, it was assumed that a clinician-established diagnosis at any point during the study period implied that osteoarthritis was likely present at least to some degree during the entire period of observation.

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Measurements

Restricted mobility outside the home was assessed with one item from the Keele Assessment of Participation (KAP) instrument.[17] KAP is a valid and reliable measurement tool to capture perceived participation restriction in population studies. Participants were asked whether "during the past 4 weeks, have you moved around outside your home, as and when you wanted" with response options 'all the time, most of the time, some of the time, a little of the time and none of the time'. Participants were considered to be restricted for the mobility outside the home if reported being able to move outside the home 'as and when wanted' for 'some, a little or none of the time'. Onset of restricted mobility was defined as moving from no restriction at baseline to restricted mobility at three-year follow-up point.

All ***health exposures*** were assessed at baseline. *Walking disability and bodily pain* were measured using single items from the Short Form-36 physical functioning subscale.[18] For walking disability, participants were asked whether their health limited walking more than a mile; responses were categorized to walking disability (limited a lot) and no disability (limited a little and not limited at all). For *bodily pain* participants were asked "How much bodily pain have you had during the past 4 weeks?"; response options were categorized to 'none/mild' and 'moderate /severe'.

Multimorbidity was defined using general practice consultation Read code data. As defined above a count of comorbidity from the remaining 18 Read codes was then categorized using a previously validated method,[19] to identify multimorbidity (i.e. ≥4. Morbidities).

Anxiety and depression was assessed with the Hospital Anxiety and Depression scale (HADS).[20] HADS is a fourteen item scale (7 items of anxiety, 7 items for depression) and targets on how a person has felt in the past week. Each item is scored from 0 to 3 with total

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score between 0 and 21 for either anxiety or depression. Score of 8/21 is identified as cut-off point for anxiety or depression [21] and was used to dichotomize anxiety and depression as possible/probable case (scores 8-21) vs. no case (scores 0-7). *Cognitive impairment* was measured using Cognitive and Alertness behavior subscale of Functional Limitations Profile [22] and categorized into no impairment (score 0) and impairment (score ≥ 1).

Body Mass Index (BMI) was calculated based on self-reported weight and height and categorized into obese (BMI >30 kg/m^2) and other (BMI < 30 kg/m^2).[23]

Environmental barriers were assessed using a structured questionnaire at three-year follow-up. Participants were asked to indicate how much they agreed or disagreed with statements related to environment barriers to moving around outside the home; live in an area with hills and steep slopes that make it difficult to move around outside (referred to as hills and steep slopes hereafter), inaccessible public buildings make it difficult to move around, poor pavement condition stops me from going out, lack of access to public parks or sport facilities stops me from going out, heavy traffic or speeding cars stop me going out, and adverse weather stops me going out. The answers were on a 5-point scale from 'strongly disagree' to 'strongly agree'. The items measuring environmental barriers were reliable in pilot testing (weighted kappa values for test-retest (4-week period) ranged from 0.5 (moderate) to 0.9 (almost perfect)). For the analyses each environmental barrier was identified by responses of agree or strongly agree and compared to no barrier (neither disagree nor agree, disagree, strongly disagree).

Potential confounders included demographic factors (age, gender) and socio-economic factors (occupational class (professional/managerial, semi-routine, routine))[24]; and educational attainment (further education, or not)).

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Statistical analyses

Differences in distribution in health exposures, environmental barriers, and potential confounders between those with and without onset of restricted mobility outside the home were tested with Chi Square for categorical variables, and t-test for continuous variables. Univariate logistic regression analyses was used to examine for the association between baseline health exposures and environmental barriers and the onset of restricted mobility outside the home at three year follow-up, first unadjusted then adjusted for age, gender, and socioeconomic factors.

The independent effect of health and environmental factors on the onset of mobility restriction outside the home was then assessed over two stages with reference to the conceptual model of the ICF.[5] In the first stage the "health" model was derived: all health factors were entered simultaneously into the model with age, gender and socio-economic factors as potential confounders (Model 1). In the second stage all environmental factors were entered separately, adjusted for all health factors and confounders (Models 2-7). Associations are summarized by odds ratios with 95% confidence intervals. Concordance indexes (C-statistic) were calculated to evaluate model fit. A C-statistic of 0.5 indicates that model is no better than chance in making a prediction, more than 0.7 is considered reasonable and more than 0.8 indicates strong predictive ability.[25]

To examine if environmental factors moderated the association between morbidities and onset of restricted mobility outside the home interaction terms were added to the health model separately (Model 1). Health and environmental factors (Models 2-7) significant at 5% level were included in the interaction analysis. First, health*environmental barrier (e.g.

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walking difficulty*hills and steep slopes) terms were included. Where there was a significant interactions (i.e. $p<0.05$), a categorical interaction variable (e.g. no walking disability or hills and steep slopes, walking disability and no hills or steep slopes, no walking disability and hills and steep slopes, walking disability and steep slopes) was examined first in unadjusted and then in a fully adjusted model. Analyses were conducted with STATA 14.0 (StataCorp 2015, College Station, TX, StataCorp LP).

RESULTS

Of the 1802 participants free of participation restriction at baseline, 243 (13.5%) reported onset of restricted mobility outside the home three years later. Onset of restricted mobility outside the home was more common among those with walking disability, severe pain, anxiety, depression, cognitive impairment, obesity and environmental barriers. There were no differences for multimorbidity (p=.088). (Table 1)

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Table 1. Characteristics of the study population at baseline overall and stratified by the onset of restricted mobility outside the home at three-year follow-up.

	Total	Onset of restriction		P value
		Yes	No	
	n=1802	n=243	n= 1559	
	% (n)	% (n)	% (n)	
Health				
Walking disability	18.2 (328)	46.9 (114)	13.7 (214)	<.001
Multimorbidity, ≥4	83.5 (1504)	87.2 (212)	82.9 (1292)	.088
Anxiety	25.7 (463)	40.3 (98)	23.4 (365)	<.001
Depression	9.3 (167)	19.8 (48)	7.6 (119)	<.001
Pain				<.001
None / Mild	54.8 (988)	36.6 (89)	57.7 (899)	
Moderate /severe	45.2 (814)	63.4 (154)	42.3 (660)	
Cognitive impairment	39.7 (715)	57.2 (139)	37.0 (576)	<.001
BMI				.005
Obese	18.2 (328)	25.1 (61)	17.1 (267)	
Other	79.4 (1431)	71.6 (174)	80.6 (1257)	
Unknown	2.4 (43)	3.3 (8)	2.3 (35)	
Confounders				
Female	56.4 (1193)	59.3 (185)	55.9 (1008)	.270
Age, mean (SD)	65.8 (8.9)	69.9 (8.9)	65.1 (7.7)	<.001
Occupational class				.001
Managerial/professional	23.3 (493)	17.6 (55)	24.3 (438)	
Semi-routine	20.0 (423)	20.8 (65)	19.9 (358)	
Routine/manual	51.8 (1096)	52.9 (165)	51.7 (931)	
Other	4.8 (102)	8.7 (27)	4.2 (75)	
Full time education	15.6 (281)	7.8 (19)	16.8 (262)	.001
Environmental barriers				
Hills and steep slopes	12.5 (226)	34.6 (84)	9.1 (142)	<.001
Inaccessible public buildings	4.1 (73)	12.8 (31)	2.7 (42)	<.001
Poor pavement condition	6.4 (115)	16.1 (39)	4.9 (76)	<.001
Lack of access to parks	3.4 (61)	9.9 (24)	2.4 (37)	<.001
Heavy traffic or speeding cars	2.4 (44)	6.6 (16)	1.8 (28)	<.001
Adverse weather	12.7 (228)	33.7 (82)	9.4 (146)	<.001

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Associations with onset of restricted mobility outside the home

Following adjustment for confounders, walking disability (adjusted odds ratio (OR)=4.5, 95% confidence interval (95% CI) 3.4 to 6.1), anxiety (OR=2.5, 95% CI 1.9 to 3.4), depression (OR=3.4, 95% CI 2.3 to 5.0), pain (OR=2.3, 95% CI 1.8 to 3.1), cognitive impairment (OR=2.1, 95% CI 1.6 to 2.8), and obesity (OR=2.1, 95% CI 1.5 to 3.0) were associated with the onset of restricted mobility outside the home. In the multivariable health model (Model 1), pain was not significantly associated with onset of restricted mobility outside the home (OR=1.3, 95% CI 0.9 to 1.8). All environmental factors were associated with onset of restriction after adjustment for confounders and all health exposures (Table 2; models 2-7).

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TABLE 2. Associations between morbidity, walking disability and environmental factors and the onset of participation restriction in mobility outside the home in older adults with osteoarthritis; odds ratios and 95% confidence intervals.

	Crude	Associations adjusted for confounders*	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Walking disability	5.6 (4.2 to 7.4)	4.5 (3.4 to 6.1)	3.3 (2.4 to 4.6)	2.9 (2.0 to 4.0)	3.2 (2.3 to 4.4)	3.2 (2.3 to 4.5)	3.2 (2.3 to 4.5)	3.2 (2.3 to 4.5)	3.1 (2.2 to 4.4)
Anxiety	2.2 (1.7 to 2.9)	2.5 (1.9 to 3.4)	1.6 (1.1 to 2.3)	1.7 (1.2 to 2.5)	1.6 (1.1 to 2.3)	1.6 (1.1 to 2.2)	1.5 (1.1 to 2.2)	1.6 (1.1 to 2.2)	1.5 (1.0 to 2.1)
Depression	3.0 (2.1 to 4.3)	3.4 (2.3 to 5.0)	1.6 (1.0 to 2.5)	1.5 (0.9 to 2.3)	1.5 (0.98 to 2.4)	1.6 (1.0 to 2.5)	1.5 (0.96 to 2.4)	1.6 (1.0 to 2.5)	1.5 (0.9 to 2.3)
Pain									
None/Mild	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Moderate /Severe	2.4 (1.8 to 3.1)	2.3 (1.8 to 3.1)	1.3 (0.9 to 1.8)	1.2 (0.9 to 1.7)	1.3 (0.9 to 1.7)	1.2 (0.9 to 1.7)	1.3 (0.9 to 1.8)	1.3 (0.9 to 1.8)	1.2 (0.9 to 1.7)
Cognitive impairment	2.3 (1.7 to 3.0)	2.1 (1.6 to 2.8)	1.5 (1.1 to 2.0)	1.3 (0.98 to 1.9)	1.4 (1.0 to 1.9)	1.4 (1.0 to 2.0)	1.5 (1.1 to 2.0)	1.5 (1.1 to 2.0)	1.4 (1.0 to 1.9)
BMI									
Obesity (BMI > 30)	1.7 (1.2 to 2.3)	2.1 (1.5 to 3.0)	1.5 (1.0 to 2.1)	1.4 (0.99 to 2.1)	1.5 (1.0 to 2.1)	1.4 (0.99 to 2.1)	1.5 (1.0 to 2.1)	1.5 (1.0 to 2.1)	1.4 (0.9 to 2.0)
Other	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Environmental barriers									
Hills and steep slopes	5.3 (3.8 to 7.2)	4.4 (3.2 to 6.1)	-	3.3 (2.3 to 4.6)	-	-	-	-	-
Inaccessible public buildings	5.3 (3.3 to 8.6)	4.9 (3.0 to 8.2)	-	-	3.2 (1.8 to 5.5)	-	-	-	-
Poor pavement condition	3.7 (2.5 to 5.6)	3.4 (2.2 to 5.2)	-	-	-	2.4 (1.51 to 3.8)	-	-	-
Lack of access to parks	4.5 (2.6 to 7.7)	4.4 (2.5 to 7.6)	-	-	-	-	2.8 (1.5 to 5.0)	-	-
HeavyTraffic	3.9 (2.1 to 7.2)	4.2 (2.2 to 8.0)	-	-	-	-	-	2.9 (1.4 to 5.8)	-
Adverse weather	4.9 (3.6 to 6.8)	4.4 (3.2 to 6.1)	-	-	-	-	-	-	3.2 (2.2 to 4.5)
C-statistics			0.779	0.809	0.786	0.789	0.784	0.783	0.804

* The association between each exposure and the onset of restricted mobility outside the home, adjusted for confounders : age, gender, socioeconomic factors only.
Model 1 (health model): this is one multivariate model which presents the associations between each exposure and onset of restricted mobility outside the home, adjusted for all other exposure and confounders (age, gender and socioeconomic factors).
Models 2-7: each model is a multivariate model which includes the environmental factor, all morbidities, walking disability and confounders (age, gender and socioeconomic factors).
BMI, Body Mass Index
OR, Odds Ratio
95% CI, Confidence Interval

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Interactions There were significant interactions with an odds ratio and 95% confidence interval less than 1.0 between hills and steep slopes that make it difficult to move outdoors and walking disability (adjusted OR=0.47, 95% CI 0.24 to 0.93), anxiety (adjusted OR=0.45, 95% CI 0.22 to 0.96), depression (adjusted OR=0.25, 95% CI 0.09 to 0.61) and cognitive impairment (adjusted OR=0.46, 95% CI 0.23 to 0.92); between poor pavement condition and anxiety (OR=0.37, 95% CI 0.15 to 0.94), and between heavy traffic or speeding cars and depression (OR=0.14, 95% CI 0.02 to 0.88) (See Appendix 1).

For each of the significant interactions, in unadjusted analyses, the presence of the environmental barrier had an added contribution to the effect of the walking disability/anxiety/depression/cognitive impairment (Table 3), other than for heavy traffic and depression. The point estimate for the increased association of the joint presence attenuated with adjustment for confounders. The increased association for the presence of both health exposure and environmental factor remained only after adjustment for confounders for walking disability and the presence of hills and steep slopes; the presence of both walking disability and hills and slope had a stronger association with onset of restricted mobility (adjusted OR 7.66, 95% CI 4.64 to 7.16) than the presence of walking disability without hills and steep (3.60, 2.43 to 5.32) or the presence of steep slopes without walking disability (4.55, 2.89 to 7.16).

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Table 3. Associations between morbidity, walking disability and environmental factors, included as an interaction term, and the onset of participation restriction in mobility outside the home in older adults with osteoarthritis; odds ratios and 95% confidence intervals.

	Frequency of the onset of restricted mobility outside the home at 3 year-follow-up %	Crude OR (95%CI)	Associations adjusted for confounders* Adj. OR (95%CI)
Walking disability & hills and steep slopes			
No walking disability, no hills and steep slopes	6.8	1	1
Walking disability, no hills and steep slopes	29.3	5.71 (4.00 to 8.13)	3.60 (2.43 to 5.32)
No walking disability, hills and steep slopes	29.2	5.69 (3.69 to 8.78)	4.55 (2.89 to 7.16)
Walking disability, and hills and steep slopes	47.9	12.67 (8.05 to 19.94)	7.66 (4.64 to 7.16)
Anxiety & hills and steep slopes			
No anxiety, no hills and steep slopes	7.5	1	1
Anxiety no hills and steep slopes	17.9	2.71 (1.93 to 3.79)	2.09 (1.40 to 3.11)
No anxiety, hills and step slopes	35.9	6.93 (4.69 to 10.24)	4.21 (2.76 to 6.43)
Anxiety, and hills and steep slopes	40.3	8.38 (4.91 to 14.29)	4.04 (2.16 to 7.55)
Depression & hills and steep slopes			
No depression, no hills and steep slopes	8.6	1	1
Depression, no hills and steep slopes	26.2	3.74 (2.43 to 5.77)	2.18 (1.32 to 3.62)
No depression, hills and step slopes	37.0	6.22 (4.39 to 8.80)	4.14 (2.83 to 6.06)
Depression, and hills and steep slopes	37.8	6.43 (3.22 to 12.82)	2.22 (1.03 to 4.78)
Cognitive impairment & hills and steep slopes			
No cogntive impairment, no hills and steep slopes	7.0	1	1

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Cognitive impairment, no hills and steep slopes	15.3	2.40 (1.72 to 3.34)	1.64 (1.14 to 2.37)
No cognitive impairment, hills and step slopes	35.0	7.16 (4.44 to 11.56)	5.01 (3.00 to 8.38)
Cognitive impairment, and hills and steep slopes	38.9	8.47 (5.49 to 13.06)	3.81 (2.35 to 6.19)
Anxiety & poor pavement condition			
No anxiety, no poor pavements	9.5	1	1
Anxiety, no poor pavements	19.8	2.34 (1.72 to 3.18)	1.76 (1.21 to 2.55)
No anxiety, poor pavements	33.8	4.84 (2.86 to 8.19)	3.55 (2.01 to 6.27)
Anxiety, and difficult pavements	34.1	4.90 (2.56 to 9.40)	2.31 (1.09 to 4.90)
Depression & heavy traffic			
No depression, no heavy traffic	11.3	1	1
Depression, no heavy traffic	28.9	3.19 (2.19 to 4.65)	1.75 (1.11 to 2.76)
No depression, heavy traffic	38.9	4.99 (2.50 to 9.92)	4.25 (2.01 to 8.99)
Depression, and heavy traffic	25.0	2.61 (0.52 to 13.04)	1.01 (0.18 to 5.53)

* Adjusted for all morbidities, walking disability, age, gender and socioeconomic factors

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DISCUSSION

This study found that environmental barriers were associated with the onset of restricted mobility outside the home in older adults with osteoarthritis. In adults with osteoarthritis, the association between health conditions or walking disability and the onset of restricted mobility was greater when environmental barriers were present. This was particular so when older adults with osteoarthritis experienced walking disability.

Our findings support the theoretical model of the ICF by providing empirical evidence of the interaction between health and environmental factors on restricted mobility. Our findings also give support to previous studies that have emphasized importance of using comprehensive models of mobility including physical, psychosocial and environmental determinants.[26, 27] It is possible that certain health conditions that lead to walking disability, increase risk of onset of participation restriction in demanding environments because the environment no longer supports the level of functional capacity.[10] While previous cross-sectional studies have shown the association between environmental characteristics and participation in out-of-home activities,[9] and an interaction between environmental characteristics (e.g. heavy traffic) and health for participating in voting, obtaining health care and interpersonal interaction,[28] our study goes beyond previous literature by identifying how environmental factors contribute to the onset of restricted mobility and link with common consequences or comorbidities in people with osteoarthritis.

The odds ratio for the interaction term of less than 1 indicates that the association between the environmental barrier and onset is greater when the health condition/walking disability is absent. This is expected as onset of restricted mobility outside the home is associated with the

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health exposure and the frequency of onset is already high in those where the environmental barrier is absent. For example, 48% of those with walking difficulty and lived in an area with hills and steep slopes experienced the onset of restricted mobility compared with 29% who had walking disability but did not live in an area with hills.

In this study the most common environmental barriers were hills and steep slopes and adverse weather. Hills and steep slopes increase requirements for physical capability, and is a particular barrier for older adults with osteoarthritis. People with difficulties in walking report more and different environmental barriers that affect their participation in community activities than those without difficulty.[28] This suggests that the interaction between person and the environment and the balance between these two, (i.e. person-environment fit),[10] is influential to whether a person is able to move outdoors or not. People may compensate for their impairments,[29] for example, by stopping to rest when moving outdoors or use assistive devices, but environmental barriers may make these compensations more difficult to perform, exacerbating the situation. For example, people with walking disability may be concerned for their safety when moving outdoors because of heavy traffic and speeding cars, especially when crossing the street.[30] People with depression or cognitive impairment may not encounter these barriers because they participate less or change how they participate to compensate for their impairment.[31]

Adverse weather is a common barrier for outdoor mobility among older adults and snow, ice and rainfall, increase the risk of participation restriction. [32] For example, icy conditions may increase difficulty to maintain balance leading to fear of falling despite of the health, thus restricting possibilities to participate in outdoor activities.[33] In this study adverse

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weather was associated with onset but there were no interactions with comorbidity or physical disability.

Older people most often go outdoors for the purposes of shopping, running daily errands and walking for exercise.[34] If public buildings for shopping or running daily errands are inaccessible, it may restrict possibilities for using these community amenities. Parks and green areas form important spaces for exercise and motivate people to go out.[35-37]. Poor access to these resources may be decisive when considering participation in outdoor activities, especially for people with osteoarthritis.[38] The considerable prevalence of osteoarthritis indicates that this is an issue which impacts on a large number of adults in the population.

Strengths and limitations

The study has a number of strengths. The analysis was performed with a large population-based sample of older adults with osteoarthritis, identified using medical records. The response rate was high and was comparable to other population surveys. The sample size was sufficient to identify interactions; the sample size of 1802, had 98.6% power at the 0.05 significance level to identify an interaction between walking disability and hills and steep slopes. The available data covered a number of important factors in relation to the onset of mobility outside the home for older adults with osteoarthritis. The instruments used to identify restricted mobility outside the home, the symptoms of osteoarthritis and comorbidity, have been validated for use in population studies of older adults.[17, 18, 21, 22]

Study limitations were: Restricted mobility outside the home was measured by self-report and focused on person-perceived participation. This is the most appropriate method for capturing

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an individual's social participation however it is susceptible to measurement error and it may not take account of frequency of outdoor mobility. Responders that do not mobilise outdoors may report restricted mobility but not environmental barriers that they won't experience which may lead to underestimation of associations. Perceived environmental barriers were included in this analysis as they more appropriately capture the presence of environmental barriers that an individually encounters when mobilising outdoors. Whilst objective measures identify environmental features (e.g. population density, existence of hills) individuals may not perceive these or experience them as barriers to mobility. Perceived environmental barriers may be a more valid indicator than objectively measured neighbourhood features when studying restricted mobility outside the home. There may be other predictors and confounders which may be important but were not included in this study. For example, performance based measures, such as gait speed can be used as clinical marker of decline in participation.[39] Since performance, and especially gait patterns, may also be influenced by environmental features,[40] the combined association between these in relation to participation may form an interesting target for future research. The generalisability of the study may be limited by the characteristics of the study sample; the area covered by this study is more deprived on health, education and employment, but with fewer barriers to housing and services than England as a whole. As in most prospective studies, there was some loss to follow-up and missing data; those who dropped out of the analysis were more likely to be female (p=.010), have depression (p=.046), anxiety (p<.001) and walking disability (p=.001) than those included the sample. There were no differences for pain (p=.060), obesity (p=.650), cognitive impairment (p=.106) or multimorbidity (p=.281). Data on outdoor mobility was measured three years apart and restriction in mobility may vary during this period; we could not measure variation between the three year time points. There may also be changes in exposure status during the follow-up period which are not accounted for in the

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analysis. However, this is expected to be small, for example, 93% of those who were not depressed at baseline were not depressed at follow-up. In addition, we do not have information on possible relocation during the follow-up period; this may be a reason for the onset of restricted mobility outside the home although with the mailing procedure used for this survey suggests that this will be small. Those who did not consent to medical record review were unhealthier at baseline; however the effect of this on the association between the exposures and restricted mobility is unknown.

Conclusion

The findings of this study suggest that some environmental barriers have an important role in preventing older adults with osteoarthritis mobilising outside their home, particularly when impairments and walking disability are present. To prevent the onset of restricted mobility outside the home for older adults with osteoarthritis, both clinical and non-clinical approaches are required. Clinical approaches aimed at reducing pain, anxiety, depression and walking disability will be useful, but consideration of an individual's environment is important. Identifying older adults with osteoarthritis that live in more challenging environments can lead to a targeted approach to overcoming such barriers, within a rehabilitation programme. Approaches to reducing environmental barriers and community planning, such as improving access to public buildings, increasing mobility friendly environments where low physical and mental capacities do not prevent mobility and function, and the provision of public transport may prevent restricted mobility, improve social participation and support active ageing.

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Footnotes

Funding: NorStOp project was supported by the Medical Research Council, UK grant numbers [G9900220 and G0501798] and by the North Staffordshire Primary Care R&D Consortium. MR was supported by the Academy of Finland grant number [285747] and Finnish Ministry of Education and Culture. The study sponsors had no role in the study design; in the collection, analysis and interpretation of the data; in the writing of the report; or in the decision to submit the paper for publication.

Competing Interests: None declared.

Ethics approval: The North Staffordshire Local Research Ethics Committee granted approval and all participants gave written consent to participate.

Contributorship statement: MR and RW designed the research questions, plan of analyses, statistical analyses and interpreted the results and drafted the manuscript. MR was the main author of the manuscript.

Data sharing statement: The Research Institute for Primary Care and Health Sciences, Keele university has established data sharing arrangements to support joint publications and other research collaborations. Applications for access to anonymized data from our research databases are reviewed by the Centre's Data Custodian and Academic Proposal (DCAP) Committee and a decision regarding access to the data is made subject to the NRES ethical approval first provided for the study and to new analysis being proposed. Further information

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on our data sharing procedures can be found on the Centre's website (http://www.keele.ac.uk/pchs/publications/datasharingresources/) or by emailing the Centre's data manager (data-sharing-pcs@keele.ac.uk).

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FIGURE LEGENDS

FIGURE 1. Flow diagram of participants

NOTE: * 117 baseline were excluded at three year-follow-up having met the exclusion criteria; (i) inability to complete the questionnaire due to poor health (e.g. cognitive impairment, dementia, stroke) and (ii) had expressed a wish to their doctor that they did not want to participate further in research studies.

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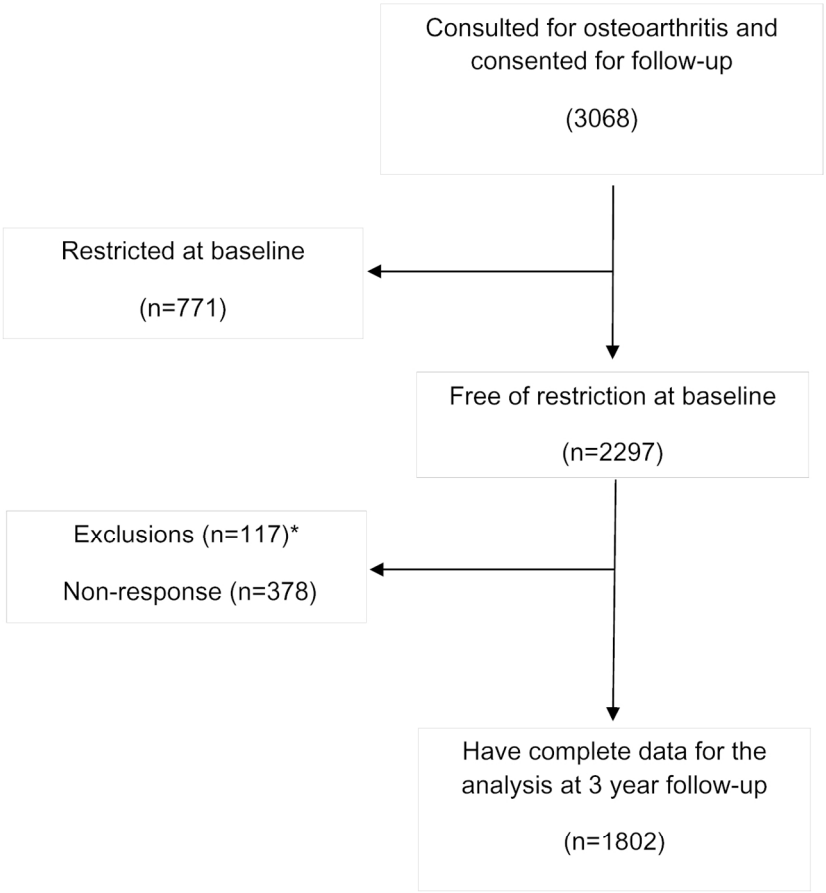

Figure 1. Flow diagram of participants.

143x142mm (300 x 300 DPI)

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APPENDIX 1. The interaction between environmental factors and morbidity on the onset of restricted mobility outside the home in older adults with osteoarthritis, adjusted odds ratios with 95% confidence intervals.

	Walking disability	Anxiety	Depression	Cognitive impairment	Obesity
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Hills	**0.47 (0.24-0.93)**	**0.45 (0.22-0.96)**	**0.25 (0.09-0.61)**	**0.46 (0.23-0.92)**	0.82 (0.36-1.84)
Public buildings	1.53 (0.50-4.71)	0.72 (0.24-2.15)	0.71 (0.20-2.57)	0.43 (0.14-1.29)	0.74 (0.20-2.67)
Pavement	0.60 (0.24-1.47)	**0.37 (0.15-0.94)**	0.52 (0.16-4.49)	0.50 (0.20-1.25)	1.56 (0.55-4.40)
Access to parks	0.91 (0.28-2.98)	0.34 (0.10-1.12)	0.47 (0.13-1.78)	0.55 (0.17-1.85)	2.19 (0.46-10.33)
Weather	0.50 (0.25-1.01)	0.79 (0.39-1.60)	1.23 (0.51-2.99)	0.54 (0.27-1.08)	0.50 (0.22-1.12)
Traffic	1.55 (0.37-6.50)	0.39 (0.09-1.60)	**0.14 (0.02-0.88)**	0.27 (0.07-1.07)	0.29 (0.05-1.56)
Crime	0.52 (0.22-1.22)	0.59 (0.25-1.39)	0.86 (0.31-2.37)	0.84 (0.35-2.03)	0.64 (0.24-1.73)

Adjusted for confounders: age and gender, socioeconomic factors, and all other health exposures.
Odds Ratio below 1 indicate less than multiplicative interaction, 95% confidence interval (CI) shows the statistical significance of the association. When 95% CI do not include 1, the association is considered as statistically significant.

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract [In the abstract, page 1]
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found [page 1]
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported [page 3-4]
Objectives	3	State specific objectives, including any prespecified hypotheses [page 4]
Methods		
Study design	4	Present key elements of study design early in the paper [page 4]
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection [page 4-5]
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up [page 4-6] *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable [page 5-7]
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group [page 5-7]
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at [page 4-6]
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why [page 7-9]
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding [page 8-9]
		(*b*) Describe any methods used to examine subgroups and interactions [page 8-9]
		(*c*) Explain how missing data were addressed [page 4-5]
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses [page 19]

Continued on next page

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Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed [page 4-6]
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram [Figure 1]
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders [page 9-10]
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time [page 10]
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included [page 10-14, appendix 1]
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses [page 12-14]
Discussion		
Key results	18	Summarise key results with reference to study objectives [page 16]
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias [page 18-19]
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence [page 16-20]
Generalisability	21	Discuss the generalisability (external validity) of the study results [page 19-20]
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based [page 21]

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-012826.R3
Article Type:	Research
Date Submitted by the Author:	18-Apr-2017
Complete List of Authors:	Rantakokko, Merja; Jyvaskylan Yliopisto, Gerontology Research Center and Department of Health Sciences Wilkie, Ross; Keele University, Research Institure for Primary Care and Health Sciences
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	Participation, Mobility, Osteoarthritis, Environment

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The role of environmental factors for the onset of restricted mobility outside the home among older adults with osteoarthritis: a prospective cohort study

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Key words: Participation, environment, older adults, mobility

Word count: 3493

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ABSTRACT

Objectives: The study examines how environmental factors contribute to the onset of restricted mobility outside the home among older adults with osteoarthritis.

Methods: Prospective cohort study of adults aged 50 years and over with osteoarthritis (N=1802). Logistic regression tested the association between the onset of restricted mobility outside the home and health, sociodemographic and perceived environmental barriers (hills and steep slopes, inaccessible public buildings, poor pavement condition, lack of access to public parks or sport facilities, heavy traffic or speeding cars, and poor weather). The potential moderating role of environmental barriers on the association between health factors and onset was examined using interaction terms and stratified analysis.

Results: Of 1802 participants, 13.5% (n=243) reported the onset of restricted mobility outside the home at three-year follow-up. Walking disability, anxiety, depression, cognitive impairment and obesity, and all environmental barriers were associated with onset after adjustment for confounders. Environmental barriers had an added contribution to the effect of the health conditions on onset of restricted mobility, which was attenuated when adjusted for confounders. The added contribution remained only for walking disability and the presence of hills and steep slopes; in the presence of both the association with onset of restricted mobility was stronger (OR 7.66, 95% CI 4.64 to 12.64) than in the presence of walking disability (3.60, 2.43 to 5.32) or the presence of hills and steep slopes alone (4.55, 2.89 to 7.16).

Conclusion: For older adults with osteoarthritis, environmental barriers are associated and add a contribution to that of morbidities and walking disability on the onset of restricted mobility outside the home. Awareness of environmental barriers is important when aiming to maintain mobility and activities outside the home despite health conditions in older adults.

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Strengths and limitations of this study

- A large population-based sample of older adults with osteoarthritis, identified using medical records, and high response rate.
- Longitudinal study on a topic that has not been widely studied.
- The generalisability of the study may be limited by the characteristics of the study sample; the area covered by this study is more deprived on health, education and employment, but with fewer barriers to housing and services than England as a whole
- A potential limitation is a use of perceived environmental barriers instead of objectively assessed features.

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INTRODUCTION

Mobility outside the home is important for maintenance of independence and good quality of life in old age.[1] Restricted mobility outside the home is the most common form of participation restriction among older people and is associated with chronic health conditions [2], physical function, socio-demographic and environmental factors.[3, 4] The International Classification of Functioning, Disability and Health (ICF) highlights the role of environmental factors as barriers or facilitators of participation.[5] A number of studies have shown the associations between environmental barriers, e.g. poor quality streets and long distances, with functional limitations [6, 7] and restricted participation among older adults [8, 9] but have not identified why. Environmental factors may moderate the relationship between impairments, such as pain, and restricted participation; that is the association between pain and restricted participation differs depending on the environment, for example, living in an area with lots of hills compared to living in an area that is flat. Identifying which environmental factors moderate the association between impairments and their impact is useful for directing interventions.

Older adults with osteoarthritis are especially vulnerable to environmental challenges due to physical limitation and symptoms such as pain and stiffness [5, 6, 9, 10]. Osteoarthritis is the most common joint condition in adults and globally is the fastest increasing major health condition.[11, 12] It is a common reason for health care consultation (one out of every twenty consultations to primary care in adults aged over 50 years is for osteoarthritis), and is also a common comorbidity in persons seen in primary care for other reasons.[13] Previous studies have identified several health factors that are associated with poor outcomes among older adults with osteoarthritis, such as pain, multimorbidity, obesity, depression and functional

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limitations.[2, 4, 14] However it is unclear if environmental factors moderate the impact of osteoarthritis on mobility outside the home in older adults.

In this study we used the ICF framework [5] to organise information and determine if features of the physical environmental moderate the association between health conditions and the onset of restricted mobility outside the home in older adults with osteoarthritis. Specifically, the study examines whether (i) pain, comorbidity (anxiety, depression, obesity, cognitive impairment, and multimorbidity) and physical disability (i.e. walking disability) at baseline are associated with an increased the risk of the onset of restricted mobility outside the home at 3 years later in older adults with osteoarthritis and (ii) these associations were moderated by environmental factors.

METHODS

Study population

The North Staffordshire Osteoarthritis project (NorStOP) is a population-based prospective cohort study.[15] The NorStOP sampling frame comprised all individuals aged 50 years and over who were registered to receive care from one of six general practices in North Staffordshire, United Kingdom (UK). In the UK general practice registers offer a convenient sampling frame for population based studies. While it is difficult to accurately state the proportion of the UK population who are registered with a general practice due to duplicate registrations of individuals and those individuals who do not register (http://www.rcgp.org.uk/pdf/ISS_INFO_02_MAY06.pdf), it has been estimated that up to 98% of UK residents are registered. For this study, potential participants were those who gave written

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consent for medical record review and who received a diagnosis of osteoarthritis during a primary care consultation between 2000 and 2008. At baseline (2005) potential participants were mailed questionnaires and at three year follow-up (2008); reminders were sent at two and four weeks after the initial mailing.

Analyses for this paper included those who (i) consulted for osteoarthritis from 2000 to 2008 (the study period of NorStOP), (ii) were free of restricted mobility outside the home at baseline and (iii) had completed the item on mobility outside the home at three year follow-up (n=1802). (Figure 1).

Identification of osteoarthritis

General practitioners in the study used the Read system to code all reasons for clinical encounters in primary care consultations.[16] The Read codes cross-map to ICD9/ICD-10 (for diseases). Morbidity data (i.e. symptoms and diseases) in this system are grouped into 18 Read chapters. Data on these diagnostic groups were aggregated starting in 2000, continuing through the time of the follow-up questionnaire in 2008. Individuals were defined as having osteoarthritis if they had at least one consultation during this period primarily for osteoarthritis based on Read codes (N05 category) for primary care consultations.[16] As osteoarthritis is a long-standing, gradually progressive chronic condition, it was assumed that a clinician-established diagnosis at any point during the study period implied that osteoarthritis was likely present at least to some degree during the entire period of observation.

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Measurements

Restricted mobility outside the home was assessed with one item from the Keele Assessment of Participation (KAP) instrument.[17] KAP is a valid and reliable measurement tool to capture perceived participation restriction in population studies. Participants were asked whether "during the past 4 weeks, have you moved around outside your home, as and when you wanted" with response options 'all the time, most of the time, some of the time, a little of the time and none of the time'. Participants were considered to be restricted for the mobility outside the home if reported being able to move outside the home 'as and when wanted' for 'some, a little or none of the time'. Onset of restricted mobility was defined as moving from no restriction at baseline to restricted mobility at three-year follow-up point.

All ***health exposures*** were assessed at baseline. *Walking disability and bodily pain* were measured using single items from the Short Form-36 physical functioning subscale.[18] For walking disability, participants were asked whether their health limited walking more than a mile; responses were categorized to walking disability (limited a lot) and no disability (limited a little and not limited at all). For *bodily pain* participants were asked "How much bodily pain have you had during the past 4 weeks?"; response options were categorized to 'none/mild' and 'moderate /severe'.

Multimorbidity was defined using general practice consultation Read code data. As defined above a count of comorbidity from the remaining 18 Read codes was then categorized using a previously validated method,[19] to identify multimorbidity (i.e. ≥4. Morbidities).

Anxiety and depression was assessed with the Hospital Anxiety and Depression scale (HADS).[20] HADS is a fourteen item scale (7 items of anxiety, 7 items for depression) and targets on how a person has felt in the past week. Each item is scored from 0 to 3 with total

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score between 0 and 21 for either anxiety or depression. Score of 8/21 is identified as cut-off point for anxiety or depression [21] and was used to dichotomize anxiety and depression as possible/probable case (scores 8-21) vs. no case (scores 0-7). *Cognitive impairment* was measured using Cognitive and Alertness behavior subscale of Functional Limitations Profile [22] and categorized into no impairment (score 0) and impairment (score ≥ 1).

Body Mass Index (BMI) was calculated based on self-reported weight and height and categorized into obese (BMI >30 kg/m^2) and other (BMI < 30 kg/m^2).[23]

Environmental barriers were assessed using a structured questionnaire at three-year follow-up. Participants were asked to indicate how much they agreed or disagreed with statements related to environment barriers to moving around outside the home; live in an area with hills and steep slopes that make it difficult to move around outside (referred to as hills and steep slopes hereafter), inaccessible public buildings make it difficult to move around, poor pavement condition stops me from going out, lack of access to public parks or sport facilities stops me from going out, heavy traffic or speeding cars stop me going out, and adverse weather stops me going out. The answers were on a 5-point scale from 'strongly disagree' to 'strongly agree'. The items measuring environmental barriers were reliable in pilot testing (weighted kappa values for test-retest (4-week period) ranged from 0.5 (moderate) to 0.9 (almost perfect)). For the analyses each environmental barrier was identified by responses of agree or strongly agree and compared to no barrier (neither disagree nor agree, disagree, strongly disagree).

Potential confounders included demographic factors (age, gender) and socio-economic factors (occupational class (professional/managerial, semi-routine, routine))[24]; and educational attainment (further education, or not)).

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Statistical analyses

Differences in distribution in health exposures, environmental barriers, and potential confounders between those with and without onset of restricted mobility outside the home were tested with Chi Square for categorical variables, and t-test for continuous variables. Univariate logistic regression analyses was used to examine for the association between baseline health exposures and environmental barriers and the onset of restricted mobility outside the home at three year follow-up, first unadjusted then adjusted for age, gender, and socioeconomic factors.

The independent effect of health and environmental factors on the onset of mobility restriction outside the home was then assessed over two stages with reference to the conceptual model of the ICF.[5] In the first stage the "health" model was derived: all health factors were entered simultaneously into the model with age, gender and socio-economic factors as potential confounders (Model 1). In the second stage all environmental factors were entered separately, adjusted for all health factors and confounders (Models 2-7). Associations are summarized by odds ratios with 95% confidence intervals. Concordance indexes (C-statistic) were calculated to evaluate model fit. A C-statistic of 0.5 indicates that model is no better than chance in making a prediction, more than 0.7 is considered reasonable and more than 0.8 indicates strong predictive ability.[25]

To examine if environmental factors moderated the association between morbidities and onset of restricted mobility outside the home interaction terms were added to the health model separately (Model 1). Health and environmental factors (Models 2-7) significant at 5% level were included in the interaction analysis. First, health*environmental barrier (e.g.

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walking difficulty*hills and steep slopes) terms were included. Where there was a significant interactions (i.e. $p<0.05$), a categorical interaction variable (e.g. no walking disability or hills and steep slopes, walking disability and no hills or steep slopes, no walking disability and hills and steep slopes, walking disability and steep slopes) was examined first in unadjusted and then in a fully adjusted model. Analyses were conducted with STATA 14.0 (StataCorp 2015, College Station, TX, StataCorp LP).

RESULTS

Of the 1802 participants free of participation restriction at baseline, 243 (13.5%) reported onset of restricted mobility outside the home three years later. Onset of restricted mobility outside the home was more common among those with walking disability, severe pain, anxiety, depression, cognitive impairment, obesity and environmental barriers. There were no differences for multimorbidity (p=.088). (Table 1)

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Table 1. Characteristics of the study population at baseline overall and stratified by the onset of restricted mobility outside the home at three-year follow-up.

	Total	Onset of restriction		P value
		Yes	No	
	n=1802	n=243	n= 1559	
	% (n)	% (n)	% (n)	
Health				
Walking disability	18.2 (328)	46.9 (114)	13.7 (214)	<.001
Multimorbidity, ≥4	83.5 (1504)	87.2 (212)	82.9 (1292)	.088
Anxiety	25.7 (463)	40.3 (98)	23.4 (365)	<.001
Depression	9.3 (167)	19.8 (48)	7.6 (119)	<.001
Pain				<.001
None / Mild	54.8 (988)	36.6 (89)	57.7 (899)	
Moderate /severe	45.2 (814)	63.4 (154)	42.3 (660)	
Cognitive impairment	39.7 (715)	57.2 (139)	37.0 (576)	<.001
BMI				.005
Obese	18.2 (328)	25.1 (61)	17.1 (267)	
Other	79.4 (1431)	71.6 (174)	80.6 (1257)	
Unknown	2.4 (43)	3.3 (8)	2.3 (35)	
Confounders				
Female	56.4 (1193)	59.3 (185)	55.9 (1008)	.270
Age, mean (SD)	65.8 (8.9)	69.9 (8.9)	65.1 (7.7)	<.001
Occupational class				.001
Managerial/professional	23.3 (493)	17.6 (55)	24.3 (438)	
Semi-routine	20.0 (423)	20.8 (65)	19.9 (358)	
Routine/manual	51.8 (1096)	52.9 (165)	51.7 (931)	
Other	4.8 (102)	8.7 (27)	4.2 (75)	
Full time education	15.6 (281)	7.8 (19)	16.8 (262)	.001
Environmental barriers				
Hills and steep slopes	12.5 (226)	34.6 (84)	9.1 (142)	<.001
Inaccessible public buildings	4.1 (73)	12.8 (31)	2.7 (42)	<.001
Poor pavement condition	6.4 (115)	16.1 (39)	4.9 (76)	<.001
Lack of access to parks	3.4 (61)	9.9 (24)	2.4 (37)	<.001
Heavy traffic or speeding cars	2.4 (44)	6.6 (16)	1.8 (28)	<.001
Adverse weather	12.7 (228)	33.7 (82)	9.4 (146)	<.001

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Associations with onset of restricted mobility outside the home

Following adjustment for confounders, walking disability (adjusted odds ratio (OR)=4.5, 95% confidence interval (95% CI) 3.4 to 6.1), anxiety (OR=2.5, 95% CI 1.9 to 3.4), depression (OR=3.4, 95% CI 2.3 to 5.0), pain (OR=2.3, 95% CI 1.8 to 3.1), cognitive impairment (OR=2.1, 95% CI 1.6 to 2.8), and obesity (OR=2.1, 95% CI 1.5 to 3.0) were associated with the onset of restricted mobility outside the home. In the multivariable health model (Model 1), pain was not significantly associated with onset of restricted mobility outside the home (OR=1.3, 95% CI 0.9 to 1.8). All environmental factors were associated with onset of restriction after adjustment for confounders and all health exposures (Table 2; models 2-7).

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TABLE 2. Associations between morbidity, walking disability and environmental factors and the onset of participation restriction in mobility outside the home in older adults with osteoarthritis; odds ratios and 95% confidence intervals.

	Crude	Associations adjusted for confounders*	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Walking disability	5.6 (4.2 to 7.4)	4.5 (3.4 to 6.1)	3.3 (2.4 to 4.6)	2.9 (2.0 to 4.0)	3.2 (2.3 to 4.4)	3.2 (2.3 to 4.5)	3.2 (2.3 to 4.5)	3.2 (2.3 to 4.5)	3.1 (2.2 to 4.4)
Anxiety	2.2 (1.7 to 2.9)	2.5 (1.9 to 3.4)	1.6 (1.1 to 2.3)	1.7 (1.2 to 2.5)	1.6 (1.1 to 2.3)	1.6 (1.1 to 2.2)	1.5 (1.1 to 2.2)	1.6 (1.1 to 2.2)	1.5 (1.0 to 2.1)
Depression	3.0 (2.1 to 4.3)	3.4 (2.3 to 5.0)	1.6 (1.0 to 2.5)	1.5 (0.9 to 2.3)	1.5 (0.98 to 2.4)	1.6 (1.0 to 2.5)	1.5 (0.96 to 2.4)	1.6 (1.0 to 2.5)	1.5 (0.9 to 2.3)
Pain									
None/Mild	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Moderate /Severe	2.4 (1.8 to 3.1)	2.3 (1.8 to 3.1)	1.3 (0.9 to 1.8)	1.2 (0.9 to 1.7)	1.3 (0.9 to 1.7)	1.2 (0.9 to 1.7)	1.3 (0.9 to 1.8)	1.3 (0.9 to 1.8)	1.2 (0.9 to 1.7)
Cognitive impairment	2.3 (1.7 to 3.0)	2.1 (1.6 to 2.8)	1.5 (1.1 to 2.0)	1.3 (0.98 to 1.9)	1.4 (1.0 to 1.9)	1.4 (1.0 to 2.0)	1.5 (1.1 to 2.0)	1.5 (1.1 to 2.0)	1.4 (1.0 to 1.9)
BMI									
Obesity (BMI > 30)	1.7 (1.2 to 2.3)	2.1 (1.5 to 3.0)	1.5 (1.0 to 2.1)	1.4 (0.99 to 2.1)	1.5 (1.0 to 2.1)	1.4 (0.99 to 2.1)	1.5 (1.0 to 2.1)	1.5 (1.0 to 2.1)	1.4 (0.9 to 2.0)
Other	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Environmental barriers									
Hills and steep slopes	5.3 (3.8 to 7.2)	4.4 (3.2 to 6.1)	-	3.3 (2.3 to 4.6)	-	-	-	-	-
Inaccessible public buildings	5.3 (3.3 to 8.6)	4.9 (3.0 to 8.2)	-	-	3.2 (1.8 to 5.5)	-	-	-	-
Poor pavement condition	3.7 (2.5 to 5.6)	3.4 (2.2 to 5.2)	-	-	-	2.4 (1.51 to 3.8)	-	-	-
Lack of access to parks	4.5 (2.6 to 7.7)	4.4 (2.5 to 7.6)	-	-	-	-	2.8 (1.5 to 5.0)	-	-
HeavyTraffic	3.9 (2.1 to 7.2)	4.2 (2.2 to 8.0)	-	-	-	-	-	2.9 (1.4 to 5.8)	-
Adverse weather	4.9 (3.6 to 6.8)	4.4 (3.2 to 6.1)	-	-	-	-	-	-	3.2 (2.2 to 4.5)
C-statistics			0.779	0.809	0.786	0.789	0.784	0.783	0.804

* The association between each exposure and the onset of restricted mobility outside the home, adjusted for confounders : age, gender, socioeconomic factors only.
Model 1 (health model): this is one multivariate model which presents the associations between each exposure and onset of restricted mobility outside the home, adjusted for all other exposure and confounders (age, gender and socioeconomic factors).
Models 2-7: each model is a multivariate model which includes the environmental factor, all morbidities, walking disability and confounders (age, gender and socioeconomic factors).
BMI, Body Mass Index
OR, Odds Ratio
95% CI, Confidence Interval

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Interactions There were significant interactions with an odds ratio and 95% confidence interval less than 1.0 between hills and steep slopes that make it difficult to move outdoors and walking disability (adjusted OR=0.47, 95% CI 0.24 to 0.93), anxiety (adjusted OR=0.45, 95% CI 0.22 to 0.96), depression (adjusted OR=0.25, 95% CI 0.09 to 0.61) and cognitive impairment (adjusted OR=0.46, 95% CI 0.23 to 0.92); between poor pavement condition and anxiety (OR=0.37, 95% CI 0.15 to 0.94), and between heavy traffic or speeding cars and depression (OR=0.14, 95% CI 0.02 to 0.88) (See Appendix 1).

For each of the significant interactions, in unadjusted analyses, the presence of the environmental barrier had an added contribution to the effect of the walking disability/anxiety/depression/cognitive impairment (Table 3), other than for heavy traffic and depression. The point estimate for the increased association of the joint presence attenuated with adjustment for confounders. The increased association for the presence of both health exposure and environmental factor remained only after adjustment for confounders for walking disability and the presence of hills and steep slopes; the presence of both walking disability and hills and slope had a stronger association with onset of restricted mobility (adjusted OR 7.66, 95% CI 4.64 to 12.64) than the presence of walking disability without hills and steep (3.60, 2.43 to 5.32) or the presence of steep slopes without walking disability (4.55, 2.89 to 7.16).

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Table 3. Associations between morbidity, walking disability and environmental factors, included as an interaction term, and the onset of participation restriction in mobility outside the home in older adults with osteoarthritis; odds ratios and 95% confidence intervals.

	Frequency of the onset of restricted mobility outside the home at 3 year-follow-up %	Crude OR (95%CI)	Associations adjusted for confounders* Adj. OR (95%CI)
Walking disability & hills and steep slopes			
No walking disability, no hills and steep slopes	6.8	1	1
Walking disability, no hills and steep slopes	29.3	5.71 (4.00 to 8.13)	3.60 (2.43 to 5.32)
No walking disability, hills and steep slopes	29.2	5.69 (3.69 to 8.78)	4.55 (2.89 to 7.16)
Walking disability, and hills and steep slopes	47.9	12.67 (8.05 to 19.94)	7.66 (4.64 to 12.64)
Anxiety & hills and steep slopes			
No anxiety, no hills and steep slopes	7.5	1	1
Anxiety no hills and steep slopes	17.9	2.71 (1.93 to 3.79)	2.09 (1.40 to 3.11)
No anxiety, hills and step slopes	35.9	6.93 (4.69 to 10.24)	4.21 (2.76 to 6.43)
Anxiety, and hills and steep slopes	40.3	8.38 (4.91 to 14.29)	4.04 (2.16 to 7.55)
Depression & hills and steep slopes			
No depression, no hills and steep slopes	8.6	1	1
Depression, no hills and steep slopes	26.2	3.74 (2.43 to 5.77)	2.18 (1.32 to 3.62)
No depression, hills and step slopes	37.0	6.22 (4.39 to 8.80)	4.14 (2.83 to 6.06)
Depression, and hills and steep slopes	37.8	6.43 (3.22 to 12.82)	2.22 (1.03 to 4.78)
Cognitive impairment & hills and steep slopes			
No cogntive impairment, no hills and steep slopes	7.0	1	1

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Cognitive impairment, no hills and steep slopes	15.3	2.40 (1.72 to 3.34)	1.64 (1.14 to 2.37)
No cognitive impairment, hills and step slopes	35.0	7.16 (4.44 to 11.56)	5.01 (3.00 to 8.38)
Cognitive impairment, and hills and steep slopes	38.9	8.47 (5.49 to 13.06)	3.81 (2.35 to 6.19)
Anxiety & poor pavement condition			
No anxiety, no poor pavements	9.5	1	1
Anxiety, no poor pavements	19.8	2.34 (1.72 to 3.18)	1.76 (1.21 to 2.55)
No anxiety, poor pavements	33.8	4.84 (2.86 to 8.19)	3.55 (2.01 to 6.27)
Anxiety, and difficult pavements	34.1	4.90 (2.56 to 9.40)	2.31 (1.09 to 4.90)
Depression & heavy traffic			
No depression, no heavy traffic	11.3	1	1
Depression, no heavy traffic	28.9	3.19 (2.19 to 4.65)	1.75 (1.11 to 2.76)
No depression, heavy traffic	38.9	4.99 (2.50 to 9.92)	4.25 (2.01 to 8.99)
Depression, and heavy traffic	25.0	2.61 (0.52 to 13.04)	1.01 (0.18 to 5.53)

* Adjusted for all morbidities, walking disability, age, gender and socioeconomic factors

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DISCUSSION

This study found that environmental barriers were associated with the onset of restricted mobility outside the home in older adults with osteoarthritis. In adults with osteoarthritis, the association between health conditions or walking disability and the onset of restricted mobility was greater when environmental barriers were present. This was particular so when older adults with osteoarthritis experienced walking disability.

Our findings support the theoretical model of the ICF by providing empirical evidence of the interaction between health and environmental factors on restricted mobility. Our findings also give support to previous studies that have emphasized importance of using comprehensive models of mobility including physical, psychosocial and environmental determinants.[26, 27] It is possible that certain health conditions that lead to walking disability, increase risk of onset of participation restriction in demanding environments because the environment no longer supports the level of functional capacity.[10] While previous cross-sectional studies have shown the association between environmental characteristics and participation in out-of-home activities,[9] and an interaction between environmental characteristics (e.g. heavy traffic) and health for participating in voting, obtaining health care and interpersonal interaction,[28] our study goes beyond previous literature by identifying how environmental factors contribute to the onset of restricted mobility and link with common consequences or comorbidities in people with osteoarthritis.

In this study the most common environmental barriers were hills and steep slopes and adverse weather. Hills and steep slopes increase requirements for physical capability, and is a particular barrier for older adults with osteoarthritis. People with difficulties in walking report

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more and different environmental barriers that affect their participation in community activities than those without difficulty.[28] This suggests that the interaction between person and the environment and the balance between these two, (i.e. person-environment fit),[10] is influential to whether a person is able to move outdoors or not. People may compensate for their impairments,[29] for example, by stopping to rest when moving outdoors or use assistive devices, but environmental barriers may make these compensations more difficult to perform, exacerbating the situation. For example, people with walking disability may be concerned for their safety when moving outdoors because of heavy traffic and speeding cars, especially when crossing the street.[30] People with depression or cognitive impairment may not encounter these barriers because they participate less or change how they participate to compensate for their impairment.[31]

Adverse weather is a common barrier for outdoor mobility among older adults and snow, ice and rainfall, increase the risk of participation restriction. [32] For example, icy conditions may increase difficulty to maintain balance leading to fear of falling despite of the health, thus restricting possibilities to participate in outdoor activities.[33] In this study adverse weather was associated with onset but there were no interactions with comorbidity or physical disability.

Older people most often go outdoors for the purposes of shopping, running daily errands and walking for exercise.[34] If public buildings for shopping or running daily errands are inaccessible, it may restrict possibilities for using these community amenities. Parks and green areas form important spaces for exercise and motivate people to go out.[35-37]. Poor access to these resources may be decisive when considering participation in outdoor activities, especially for people with osteoarthritis.[38] The considerable prevalence of

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osteoarthritis indicates that this is an issue which impacts on a large number of adults in the population.

The lack of significant interactions between some health conditions and environmental barriers suggests that some barriers have a similar impact whether a health condition/disability is present or absent (e.g. the adjusted odds ratio for walking disability if access to parks is absent is 3.23; 95% CI 2.28, 4.58) and 2.83 (0.80, 10.03) when present; interaction =3.23/2.83=0.88 (0.91 (0.28, 2.98) when adjusted (Appendix 1)). This may be because people can compensate for a barrier, for example, poor access to parks can be compensated by access to other outdoor facilities. It may also suggest that the impact of some barriers is dependent on the health condition or the presence of disability (e.g. there is only a significant interaction with heavy traffic in people that are depressed and not with any other condition or physical disability).

Strengths and limitations

The study has a number of strengths. The analysis was performed with a large population-based sample of older adults with osteoarthritis, identified using medical records. The response rate was high and was comparable to other population surveys. The sample size was sufficient to identify interactions; the sample size of 1802, had 98.6% power at the 0.05 significance level to identify an interaction between walking disability and hills and steep slopes. The available data covered a number of important factors in relation to the onset of mobility outside the home for older adults with osteoarthritis. The instruments used to identify restricted mobility outside the home, the symptoms of osteoarthritis and comorbidity, have been validated for use in population studies of older adults.[17, 18, 21, 22]

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Study limitations were: Restricted mobility outside the home was measured by self-report and focused on person-perceived participation. This is the most appropriate method for capturing an individual's social participation however it is susceptible to measurement error and it may not take account of frequency of outdoor mobility. Responders that do not mobilise outdoors may report restricted mobility but not environmental barriers that they won't experience which may lead to underestimation of associations. Perceived environmental barriers were included in this analysis as they more appropriately capture the presence of environmental barriers that an individually encounters when mobilising outdoors. Whilst objective measures identify environmental features (e.g. population density, existence of hills) individuals may not perceive these or experience them as barriers to mobility. Perceived environmental barriers may be a more valid indicator than objectively measured neighbourhood features when studying restricted mobility outside the home. There may be other predictors and confounders which may be important but were not included in this study. For example, performance based measures, such as gait speed can be used as clinical marker of decline in participation.[39] Since performance, and especially gait patterns, may also be influenced by environmental features,[40] the combined association between these in relation to participation may form an interesting target for future research. The generalisability of the study may be limited by the characteristics of the study sample; the area covered by this study is more deprived on health, education and employment, but with fewer barriers to housing and services than England as a whole. As in most prospective studies, there was some loss to follow-up and missing data; those who dropped out of the analysis were more likely to be female (p=.010), have depression (p=.046), anxiety (p<.001) and walking disability (p=.001) than those included the sample. There were no differences for pain (p=.060), obesity (p=.650), cognitive impairment (p=.106) or multimorbidity (p=.281). Data on outdoor mobility was measured three years apart and restriction in mobility may vary during this

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period; we could not measure variation between the three year time points. There may also be changes in exposure status during the follow-up period which are not accounted for in the analysis. However, this is expected to be small, for example, 93% of those who were not depressed at baseline were not depressed at follow-up. In addition, we do not have information on possible relocation during the follow-up period; this may be a reason for the onset of restricted mobility outside the home although with the mailing procedure used for this survey suggests that this will be small. Those who did not consent to medical record review were unhealthier at baseline; however the effect of this on the association between the exposures and restricted mobility is unknown.

Conclusion

The findings of this study suggest that some environmental barriers have an important role in preventing older adults with osteoarthritis mobilising outside their home, particularly when impairments and walking disability are present. To prevent the onset of restricted mobility outside the home for older adults with osteoarthritis, both clinical and non-clinical approaches are required. Clinical approaches aimed at reducing pain, anxiety, depression and walking disability will be useful, but consideration of an individual's environment is important. Identifying older adults with osteoarthritis that live in more challenging environments can lead to a targeted approach to overcoming such barriers, within a rehabilitation programme. Approaches to reducing environmental barriers and community planning, such as improving access to public buildings, increasing mobility friendly environments where low physical and mental capacities do not prevent mobility and function, and the provision of public transport may prevent restricted mobility, improve social participation and support active ageing.

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Footnotes

Funding: NorStOp project was supported by the Medical Research Council, UK grant numbers [G9900220 and G0501798] and by the North Staffordshire Primary Care R&D Consortium. MR was supported by the Academy of Finland grant number [285747] and Finnish Ministry of Education and Culture. The study sponsors had no role in the study design; in the collection, analysis and interpretation of the data; in the writing of the report; or in the decision to submit the paper for publication.

Competing Interests: None declared.

Ethics approval: The North Staffordshire Local Research Ethics Committee granted approval and all participants gave written consent to participate.

Contributorship statement: MR and RW designed the research questions, plan of analyses, statistical analyses and interpreted the results and drafted the manuscript. MR was the main author of the manuscript.

Data sharing statement: The Research Institute for Primary Care and Health Sciences, Keele university has established data sharing arrangements to support joint publications and other research collaborations. Applications for access to anonymized data from our research databases are reviewed by the Centre's Data Custodian and Academic Proposal (DCAP) Committee and a decision regarding access to the data is made subject to the NRES ethical approval first provided for the study and to new analysis being proposed. Further information on our data sharing procedures can be found on the Centre's website

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(http://www.keele.ac.uk/pchs/publications/datasharingresources/) or by emailing the Centre's data manager (data-sharing-pcs@keele.ac.uk).

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FIGURE LEGENDS

FIGURE 1. Flow diagram of participants

NOTE: * 117 baseline were excluded at three year-follow-up having met the exclusion criteria; (i) inability to complete the questionnaire due to poor health (e.g. cognitive impairment, dementia, stroke) and (ii) had expressed a wish to their doctor that they did not want to participate further in research studies.

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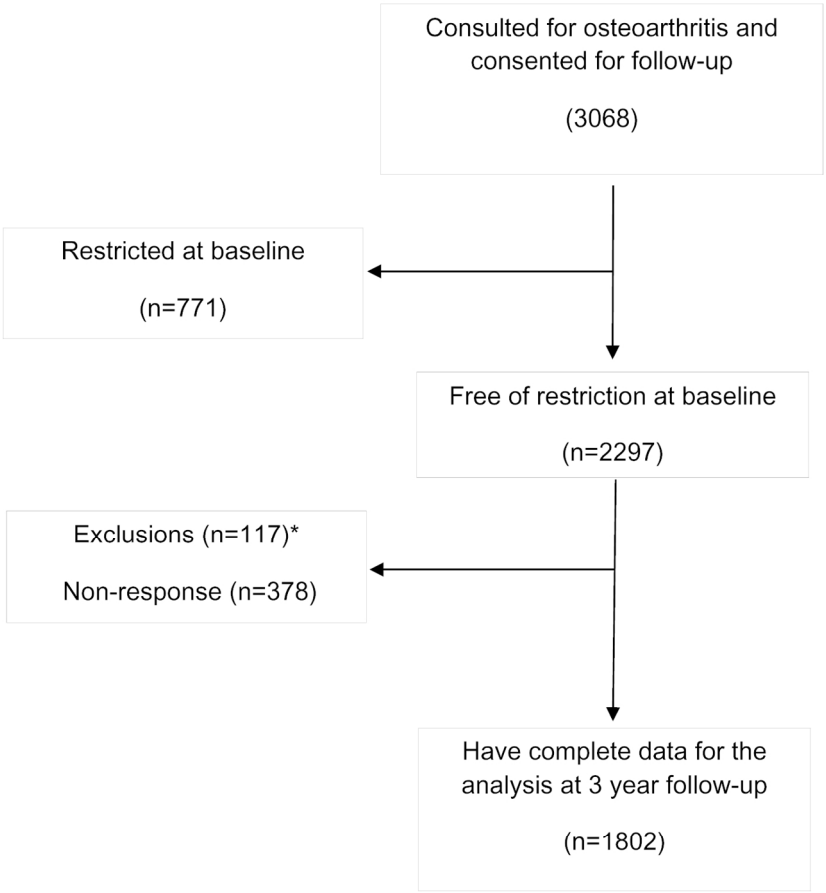

Figure 1. Flow diagram of participants.

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APPENDIX 1. The interaction between environmental factors and morbidity on the onset of restricted mobility outside the home in older adults with osteoarthritis, adjusted odds ratios with 95% confidence intervals.

	Walking disability	Anxiety	Depression	Cognitive impairment	Obesity
	Adj OR (95% CI)	Adj OR (95% CI)	Adj OR (95% CI)	Adj OR (95% CI)	Adj OR (95% CI)
Hills	**0.47 (0.24-0.93)**	**0.45 (0.22-0.96)**	**0.25 (0.09-0.61)**	**0.46 (0.23-0.92)**	0.82 (0.36-1.84)
Public buildings	1.53 (0.50-4.71)	0.72 (0.24-2.15)	0.71 (0.20-2.57)	0.43 (0.14-1.29)	0.74 (0.20-2.67)
Pavement	0.60 (0.24-1.47)	**0.37 (0.15-0.94)**	0.52 (0.16-4.49)	0.50 (0.20-1.25)	1.56 (0.55-4.40)
Access to parks	0.91 (0.28-2.98)	0.34 (0.10-1.12)	0.47 (0.13-1.78)	0.55 (0.17-1.85)	2.19 (0.46-10.33)
Weather	0.50 (0.25-1.01)	0.79 (0.39-1.60)	1.23 (0.51-2.99)	0.54 (0.27-1.08)	0.50 (0.22-1.12)
Traffic	1.55 (0.37-6.50)	0.39 (0.09-1.60)	**0.14 (0.02-0.88)**	0.27 (0.07-1.07)	0.29 (0.05-1.56)
Crime	0.52 (0.22-1.22)	0.59 (0.25-1.39)	0.86 (0.31-2.37)	0.84 (0.35-2.03)	0.64 (0.24-1.73)

Adj OR – Adjusted odds ratio for confounders: age and gender, socioeconomic factors, and all other health exposures.
The referent group for all interactions no health condition and absence of an environmental barrier.

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NOTE: The interactions were analysed using a logit model (in Stata) together with the or option, and the dependent variables are measured in the odds metric rather than in the probability metric (Buis, 2010). The interaction value indicates how much the effect of environmental factor differs between not having or having the health condition or walking disability in multiplicative terms and these multiplicative effects are relative to the baseline odds for each variable.

Taking the interaction between walking disability and the presence of hills and slopes (adj OR 0.47; 95%CI 0.24-0.93), the baseline odds of the onset of restricted mobility outside the home differ substantially between those with and without walking disability. Even though the odds of association with new onset of restricted mobility increase in those with a health condition (from 3.60 to 7.66), they do not increase as much as for those that do not have health condition/walking disability (1 to 4.55). Therefore the value for the interaction is less than 1 ((3.60/7.66:1/4.55) and hence not multiplicative) because the increase in the association is greater in those without the health condition/walking disability than for this with the health condition/walking disability. The 95% confidence interval does not include 1, and indicates that there is significant difference between the association of the health condition and onset of restricted mobility when stratified by the presence/absence of environmental barriers than when both are absent (outlined in Table 3). The marginal (Table 3) and multiplicative effects (appendix 1) are both accurate representations of the effect of environmental barriers.

Buis M, Interpretation of interactions in nonlinear models, Stata Journal 2010;10;2:305-8.

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract [In the abstract, page 1]
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found [page 1]
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported [page 3-4]
Objectives	3	State specific objectives, including any prespecified hypotheses [page 4]
Methods		
Study design	4	Present key elements of study design early in the paper [page 4]
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection [page 4-5]
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up [page 4-6] *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable [page 5-7]
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group [page 5-7]
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at [page 4-6]
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why [page 7-9]
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding [page 8-9]
		(*b*) Describe any methods used to examine subgroups and interactions [page 8-9]
		(*c*) Explain how missing data were addressed [page 4-5]
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses [page 19]

Continued on next page

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Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed [page 4-6]
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram [Figure 1]
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders [page 9-10]
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time [page 10]
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included [page 10-14, appendix 1]
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses [page 12-14]
Discussion		
Key results	18	Summarise key results with reference to study objectives [page 16]
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias [page 18-19]
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence [page 16-20]
Generalisability	21	Discuss the generalisability (external validity) of the study results [page 19-20]
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based [page 21]

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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