■ SHOULDER & ELBOW

Risk factors for surgery due to rotator cuff disease in a population-based cohort

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Aims

Few risk factors for rotator cuff disease (RCD) and corresponding treatment have been firmly established. The aim of this study was to evaluate the relationship between numerous risk factors and the incidence of surgery for RCD in a large cohort.

Methods

A population-based cohort of people aged between 40 and 69 years in the UK (the UK Biobank) was studied. People who underwent surgery for RCD were identified through a link with NHS inpatient records covering a mean of eight years after enrolment. Multivariate Cox proportional hazards regression was used to calculate hazard ratios (HRs) as estimates of associations with surgery for RCD accounting for confounders. The risk factors which were considered included age, sex, race, education, Townsend deprivation index, body mass index (BMI), occupational demands, and exposure to smoking.

Results

Of the 421,894 people who were included, 47% were male. The mean age at the time of enrolment was 56 years (40 to 69). A total of 2,156 people were identified who underwent surgery for RCD. Each decade increase in age was associated with a 55% increase in the incidence of RCD surgery (95% confidence interval (CI) 46% to 64%). Male sex, non-white race, lower deprivation score, and higher BMI were significantly associated with a higher risk of surgery for RCD (all $p < 0.050$). Greater occupational physical demands were significantly associated with higher rates of RCD surgery (HR = 2.1, 1.8, and 1.4 for 'always', 'usually', and 'sometimes' doing heavy manual labour vs 'never', all $p < 0.001$). Former smokers had significantly higher rates of RCD surgery than those who had never smoked (HR 1.23 (95% CI 1.12 to 1.35), $p < 0.001$), while current smokers had similar rates to those who had never smoked (HR 0.94 (95% CI 0.80 to 1.11)). Among those who had never smoked, the risk of surgery was higher among those with more than one household member who smoked (HR 1.78 (95% CI 1.08 to 2.92)). The risk of RCD surgery was not significantly related to other measurements of secondhand smoking.

Conclusion

Many factors were independently associated with surgery for RCD, including older age, male sex, higher BMI, lower deprivation score, and higher occupational physical demands. Several of the risk factors which were identified are modifiable, suggesting that the healthcare burden of RCD might be reduced through the pursuit of public health goals, such as reducing obesity and modifying occupational demands.

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Introduction

Rotator cuff disease (RCD) is the most common cause of shoulder disability. The prevalence of rotator cuff tears is consistently reported to be more than 10% in developed countries.[1-4] However, few studies have focused on identifying risk factors for patients with symptomatic tears requiring surgery. Prevention strategies aimed at high-risk groups could dramatically influence healthcare systems given the economical burden of treating painful RCD.[5,6]

The most well-established risk factor for RCD is advanced age, with higher prevalence associated with age in many studies.[1,7,8] Smoking and obesity

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have been identified as independent risk factors in previous case-control studies, but most used clinical control groups which do not accurately represent the population from which RCD develops and could lead to biased associations.[9-11] Other important and potentially modifiable risk factors include occupational physical demands, but few epidemiological studies have evaluated associations specific to RCD.[12-14]

Knowledge of modifiable risk factors could allow the development of preventive strategies for a condition with tremendous socioeconomic burdens. Our understanding of risk factors is limited by the lack of prospective, population-based studies with the ability to capture the diagnosis and treatment of RCD. The aim of this study was to examine the relationship between many potential risk factors, including smoking history, obesity, and occupational demands, and the incidence of rotator cuff surgery in a large population-based cohort.

Methods

People were identified from the UK Biobank, a population-based prospective cohort of 502,541 people from the UK.[15] Patients aged between 40 and 69 years were recruited between 2006 and 2010 by invitations mailed to people registered with the NHS.[16] At enrolment, they gave informed consent and completed questionnaires collecting demographic information, aspects of behaviour relating to health and other characteristics, such as sources of pain. Exclusion criteria included those with tendonitis or chronic pain in the shoulder or neck, answering 'Yes' to the question, 'Have you had neck or shoulder pain for more than three months?'. The questionnaire included enquiries about occupational physical demands (job always/usually/sometimes/rarely involves heavy physical work), smoking status, smoking history, and exposure to secondhand smoke. Smoking history included age of starting to smoke and age when former smokers stopped smoking. Secondhand smoking was captured through questions about the number of household members who smoked, and the number of hours per week of secondhand smoke exposure inside and outside the home. Height and weight measurements were recorded to calculate body mass index (BMI).

The NHS Research Ethics Committee approved the UK Biobank. The Washington University Institutional Review Board determined that the study did not require ethical approval.

Hospital records from the NHS are linked to the UK Biobank, providing information on inpatient diagnoses and procedures between 2006 and 2017. These diagnoses are coded using the International Classification of Diseases, 10th revision[17] (ICD-10) and procedures are coded using the Office of Population Censuses and Surveys Classification, fourth revision.[18] People with RCD were identified based on either primary or secondary diagnosis with an ICD-10 code of M75.1 or S46.0. People were excluded from the study if a diagnosis of RCD was identified in these records before their initial visit. In order to reduce the risk of misdiagnosis, RCD diagnoses were only included if the diagnosis was made by a physician specializing in trauma and orthopaedics, and a surgical procedure was performed consistent with treatment for this condition such as shoulder arthroplasty, rotator cuff repair or subacromial decompression. We characterized the diagnosis of RCD as atraumatic if it was identified with code M75.1 (rotator cuff tear or rupture, not specified as traumatic) and did not occur concurrently with diagnoses of trauma such as dislocation of the shoulder. A full list of ICD-10 codes indicating trauma is shown in Table I.

Table I. List of International Classification of Diseases codes for diagnoses used to indicate a traumatic rotator cuff tear.

ICD-10 codes	Diagnosis
M24.31, M24.41, S43.0-S43.3	Shoulder dislocation
S41.X	Open wound of shoulder and upper arm
S42.X	Fracture of shoulder and upper arm
S47.X	Crushing injury of shoulder and upper arm
T92.1	Sequelae of fracture of arm
T92.3	Sequelae of dislocation, sprain, and strain of upper limb
T92.6	Sequelae of crushing, injury, and traumatic amputation of upper limb
V00.X-V99.X	Injury in vehicle/transport accident
W11.X-W13.X	Fall from ladder, scaffolding, or from structure/building
W17.X	Fall from one level to another
Y85.0	Sequelae of motor-vehicle accident
Y85.9	Sequelae of other and unspecified transport accidents
Y87.1	Sequelae of assault

ICD, International Classification of Diseases.

The follow-up for the incidence of RCD surgery started at the patient's initial study visit and ended at the first of: rotator cuff surgery, death, loss-to-follow-up, or March 31 2017, which was the last date with available hospital data.

Statistical analysis. Baseline characteristics were described for patients with and without rotator cuff surgery during follow-up. The risk factors which were assessed included age, sex, race, education, Townsend deprivation index, which measures socioeconomic status at the neighborhood level,[19] occupational physical demands, BMI, diabetes, smoking, and exposure to secondhand smoke. Multivariate Cox proportional hazards regression was used to calculate adjusted hazard ratios (aHRs) and corresponding 95% confidence intervals (CIs) as estimates of associations between risk factors and the incidence of rotator cuff surgery. First, bivariate models were run that included each risk factor individually. Secondly, a multivariate model was run that included age and all statistically significant ($p < 0.05$) risk factors from the initial models. Age was considered the most important potential confounder of associations with the risk of RCD due to the previously well-established relationship with cuff tears and because age is related to many of the other risk factors which were considered.

In addition to evaluating smoking based on baseline smoking status (current or former smoker, or never having smoked), the length of time that a patient had smoked was calculated from the years between each patient's reported age when starting to smoke and either their age at enrolment (current smokers) or their age when they stopped smoking (former smokers). As the intensity of secondhand smoking can be difficult to disentangle from firsthand smoking, we limited the analysis of secondhand smoke exposure to those who had never smoked.

Sensitivity analyses were conducted to explore the robustness of the results. First, associations could in part be a result of characteristics that lead to treatment-seeking behaviour, particularly

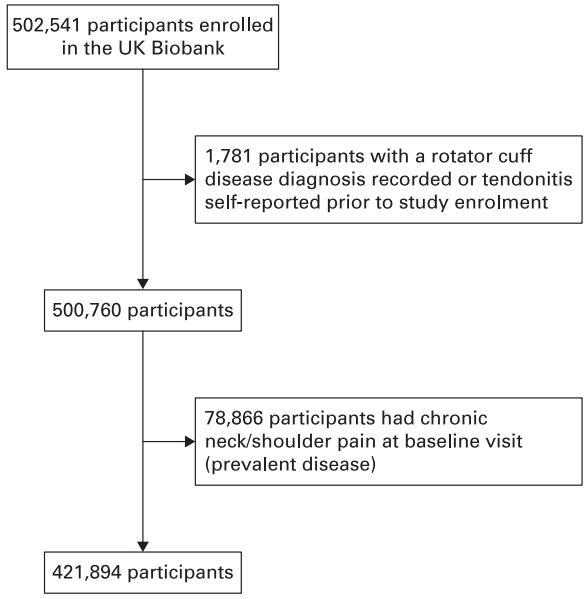

Fig. 1

A flowchart of the people in the study, who were enrolled from 21 assessment centres in the UK.

when examining rotator cuff surgery occurring shortly after measurement of the risk factors. Therefore, we estimated associations between risk factors and the risk of RCD surgery after implementing a two-year lag, where only those with RCD diagnosed more than two years after baseline were considered. Secondly, we conducted analyses estimating associations with a diagnosis of atraumatic cuff tear as some risk factors may be specific to degenerative tears. Statistical significance was defined as a two-sided p–value < 0.05. All analyses were conducted using SAS v. 9.4 (SAS Institute, Cary, North Carolina, USA).

Results

Of the initial 502,541 people who were enrolled, 1781 had a previous diagnosis of a cuff tear or reported tendonitis prior to enrolment, and 78,866 reported chronic shoulder or neck pain (Figure 1). Of the remaining 421,894, 53% were female and 94% were of white race (Table II). Their mean age at baseline was 56 years (40 to 69). About one-third had a college or university degree, and the mean Townsend deprivation index was negative (-1.35), indicating a population which was more affluent than the general population. Most had never smoked; while 10% were current smokers and 34% were former smokers. The measurements of BMI indicated that 42% were overweight and 24% were obese. A total of 5% reported diabetes at baseline. Among the 245,682 who were employed, 66% had jobs that never or rarely involved heavy manual or physical labour.

During a total mean follow-up of 8.0 years (0.03 to 11.05), diagnoses of RCD with corresponding inpatient surgical treatment were made in 2156 people. Of these, 2076 (96.3%) were identified as probably having atraumatic tears.

Associations with risk for RCD. Each decade-increase in age was associated with a 55% increase in the incidence of rotator cuff surgery (95% CI 46% to 64%, Table III). In bivariate analyses, rotator cuff surgery was significantly more frequent among men (aHR 1.32 (95% CI 1.21 to 1.44)) and those of Asian race (aHR 1.38 (95% CI 1.06 to 1.80)) compared to white race. Having a college/university degree was associated

Table II. Characteristics of the population.

Baseline characteristic	Patients
Total, n	421,894
Mean age, yrs (range)	56 (40 to 69)
Sex, n (%)	
Male	196,460 (46.6)
Female	225,434 (53.4)
Race/ethnicity, n (%)	
White/British	397,383 (94.2)
Asian	9220 (2.2)
Black	6730 (1.6)
Mixed ethnicity	2373 (0.6)
Unknown ethnicity	6188 (1.5)
Highest level of education, n (%)	
College/university	140,316 (33.3)
Other professional qualifications (e.g. nursing, teaching)	60,479 (14.3)
NVQ, HND, HNC, or equivalent	52,243 (12.4)
A levels/AS levels or equivalent	23,249 (5.5)
O levels/GCSEs/CSEs or equivalent	69,789 (16.5)
None of the above	67,368 (16.0)
Unknown	8450 (2.0)
Mean Townsend deprivation index (range)	-1.35 (-6.26 to 11.00)
Smoking status, n (%)	
Never	233,453 (55.3)
Former	143,420 (34.0)
Current	42,445 (10.1)
Unknown	2576 (0.6)
Body mass index (BMI), n (%)	
Underweight (BMI < 18.5 kg/m^2)	2243 (0.5)
Healthy (18.5 ≤ BMI < 25.0 kg/m^2)	139,049 (33.0)
Overweight (25.0 ≤ BMI < 30.0 kg/m^2)	178,730 (42.4)
Obese (30.0 kg/m^2 ≤ BMI)	99,335 (23.6)
Unknown BMI	2537 (0.6)
Diagnosed with diabetes, n (%)	
Yes	20,939 (5.0)
No	398,691 (94.5)
Unknown	2264 (0.5)
Job involves heavy manual or physical work, n (%)	
Never/rarely	161,657 (38.3)
Sometimes	52,170 (12.4)
Usually	16,311 (3.9)
Always	15,544 (3.7)
Retired/unemployed	175,919 (41.7)
Unknown	293 (0.1)
Length of follow-up, yrs (range)	8.03 (0.03 to 11.05)
Reasons for end of follow-up, n (%)	
Rotator cuff disease surgery	2156 (0.5)
Death	11,777 (2.8)
Loss to follow-up	1076 (0.3)
Administrative censoring	406,885 (96.4)

A level, Advanced level; AS level, Advanced Subsidiary level; CI, confidence interval; CSE, Certificate of SecondaryEducation; GCSE, General Certificate of Secondary Education; HNC, Higher National Certificate; HND, Higher National Diploma; N/A, not applicable; NVQ, National Vocational Qualification; O level, Ordinary level.

Table III. Associations between the characteristics of the people and the risk of rotator cuff surgery.

Characteristic	Rotator cuff disease diagnosis		Bivariate associations		Multivariate associations*	
	Yes	No	aHR (95% CI)	p-value	aHR (95% CI)	p-value
Age, modelled per decade, mean yrs (range)	59 (40 to 69)	56 (40 to 69)	1.55 (1.46 to 1.64)	< 0.001	1.55 (1.44 to 1.66)	< 0.001
Male sex, n (%)	1152 (53.4)	195,308 (46.5)	1.32 (1.21 to 1.44)	< 0.001	1.20 (1.10 to 1.32)	< 0.001
Race, n (%)						
White	2011 (93.3)	395,372 (94.2)	Referent	N/A	Referent	N/A
Black	35 (1.6)	6695 (1.6)	1.16 (0.83 to 1.63)	0.373	1.49 (1.05 to 2.11)	0.024
Asian	57 (2.6)	9163 (2.2)	1.38 (1.06 to 1.80)	0.017	1.70 (1.28 to 2.26)	< 0.001
Mixed	15 (0.7)	2358 (0.6)	1.26 (0.74 to 2.13)	0.394	1.70 (1.00 to 2.88)	0.049
Unknown	38 (1.8)	6150 (1.5)	1.20 (0.83 to 1.75)	0.333	1.49 (1.02 to 2.18)	0.042
Townsend deprivation index,†‡ modelled per 10 points, mean (range)	-1.5 (-6.3 to 8.6)	-1.4 (-6.3 to 11.0)	0.86 (0.75 to 1.00)	0.048	0.76 (0.65 to 0.89)	< 0.001
Level of education,‡ n (%)						
College/university	466 (22.4)	139,850 (34.0)	Referent	N/A	Referent	N/A
Other professional qualifications (e.g. nursing, teaching)	341 (16.4)	60,138 (14.6)	1.69 (1.47 to 1.94)	< 0.001	1.44 (1.25 to 1.66)	< 0.001
NVQ, HND, HNC, or equivalent	315 (15.1)	51,928 (12.6)	1.81 (1.57 to 2.09)	< 0.001	1.57 (1.35 to 1.82)	< 0.001
A levels/AS levels, or equivalent	106 (5.1)	23,143 (5.6)	1.38 (1.12 to 1.71)	0.003	1.33 (1.08 to 1.65)	0.010
O levels/GCSEs/CSEs, or equivalent	366 (17.6)	69,423 (16.9)	1.58 (1.37 to 1.81)	< 0.001	1.43 (1.24 to 1.64)	< 0.001
None of the above	491 (23.6)	66,877 (16.3)	2.20 (1.93 to 2.49)	< 0.001	1.57 (1.37 to 1.80)	< 0.001
Smoking status,‡ n (%)						
Never	1041 (48.4)	232,412 (55.5)	Referent	N/A	Referent	N/A
Former	909 (42.3)	142,511 (34.0)	1.50 (1.24 to 1.81)	< 0.001	1.22 (1.11 to 1.35)	< 0.001
Current	183 (8.5)	42,262 (10.1)	1.09 (0.80 to 1.49)	0.574	0.94 (0.80 to 1.11)	0.459
Body mass index,‡ modelled per 5 kg/m^2, mean (range)	28.4 (18.1 to 52.6)	27.3 (12.1 to 74.7)	2.54 (1.84 to 3.51)	< 0.001	1.19 (1.14 to 1.24)	< 0.001
Diabetes diagnosed by a doctor,‡ n (%)	161 (7.5)	20,778 (5.0)	1.61 (1.37 to 1.90)	< 0.001	1.14 (0.96 to 1.35)	0.145
Job involves heavy manual or physical work,‡ n (%)						
Never/rarely	571 (26.5)	161,086 (38.4)	Referent	N/A	Referent	N/A
Sometimes	286 (13.3)	51,884 (12.4)	1.60 (1.18 to 2.17)	0.003	1.38 (1.19 to 1.60)	< 0.001
Usually	121 (5.6)	16,190 (3.9)	2.39 (1.58 to 3.62)	< 0.001	1.81 (1.48 to 2.22)	< 0.001
Always	132 (6.1)	15,412 (3.7)	3.27 (2.25 to 4.77)	< 0.001	2.11 (1.73 to 2.58)	< 0.001
Retired/unemployed	1045 (48.5)	174,874 (41.7)	1.89 (1.53 to 2.34)	< 0.001	1.06 (0.94 to 1.20)	0.313

*Adjusted for all variables with statistically significant bivariable associations.
†A measure of neighborhood level deprivation with a higher index indicating more deprivation.
‡In total, 526 did not have information about Townsend deprivation index; 8450 did not report their level of education, 2576 did not report smoking status, 2537 did not have information about BMI, 2264 did not have information about diabetes, 293 did not have information about manual labour. Age, Townsend deprivation index, and BMI were modelled continuously with units scaled to the amounts indicated. Race, level of education, smoking status, and manual/physical work were modelled as indicator variables compared to the referring category.
aHR, adjusted hazard ratio; A level, Advanced level; AS level, Advanced Subsidiary level; CI, confidence interval; CSE, Certificate of Secondary Education; GCSE, General Certificate of Secondary Education; HNC, Higher National Certificate; HND, Higher National Diploma; N/A, not applicable; NVQ, National Vocational Qualification; O level, Ordinary level.

with significantly lower incidence of rotator cuff surgery than all other levels of education (all $p \leq 0.003$). Higher BMI was also a statistically significant predictor of surgery, with each 5 kg/m^2 increase associated with 154% higher risk of rotator cuff surgery (95% CI 84% to 251%, Table III). People with diabetes had higher rates of rotator cuff surgery (aHR 1.61 (95% CI 1.37 to 1.90), $p < 0.001$). Those with regular occupational physical demands had significantly higher rates of rotator cuff surgery than those whose jobs never or rarely involved heavy manual/physical work. This association increased consistently with increasing frequency of physical demands (aHRs of 1.60, 2.39, and 3.27, respectively for 'sometimes', 'usually' and 'always' involves heavy manual/physical work compared to 'never/rarely'; all $p \leq 0.003$).

After controlling for age and other statistically significant risk factors, all associations remained significant, with the exception of diabetes (Table III). However, some associations with RCD were attenuated, notably sex, education, BMI, and occupational demands. The association between Townsend index and rotator cuff surgery was stronger after adjustment for other factors. Patients of all non-white races also had a statistically higher risk of rotator cuff surgery than those of white race (Table III).

Table IV. Associations with smoking history. The duration of smoking was modelled continuously with units scaled by decade (i.e. 1 unit increase = 1 decade increase).

Smoking duration	Adjusted hazard ratio (95% CI)*	p-value*
Smoking duration in all people, modelled per decade	1.02 (0.99 to 1.06)	0.185
Smoking duration in former smokers, modelled per decade	1.00 (0.94 to 1.08)	0.909
Smoking duration in current smokers, modelled per decade	1.15 (0.82 to 1.62)	0.431

*Results come from a Cox regression model adjusted for age, sex, race, education, BMI, Townsend deprivation index and manual labour.

Table V. Associations between secondhand smoking among 231,510 people who had never smoked, including 994 with rotator cuff disease. Secondhand smoking characteristics with more than one category were modelled as indicator variables compared to the referring category indicated.

Measures of secondhand smoke	Rotator cuff disease, n (%)		Adjusted hazard ratio (95% CI)*	p-value
	Yes	No		
Smoking in household members				
No smokers	924 (90.0)	211,049 (91.6)	Referent	Referent
1 household smoker	87 (8.5)	17,448 (7.6)	1.04 (0.83 to 1.30)	0.743
> 1 household smokers	16 (1.6)	1986 (0.9)	1.78 (1.08 to 2.92)	0.023
Secondhand smoke exposure inside the home†				
None	946 (95.2)	214,268 (95.4)	Referent	Referent
1 to 5 hrs/week	30 (3.0)	7230 (3.2)	0.79 (0.55 to 1.15)	0.223
> 5 hrs/week	18 (1.8)	3195 (1.4)	1.10 (0.69 to 1.75)	0.700
Secondhand smoke exposure outside the home†				
None	707 (79.1)	172,079 (81.9)	Referent	Referent
1 to 5 hrs/week	171 (19.1)	35,502 (16.9)	1.10 (0.93 to 1.30)	0.287
> 5 hrs/week	16 (1.8)	2460 (1.2)	1.21 (0.73 to 2.00)	0.454
Any secondhand smoke exposure†				
None	690 (77.4)	167,550 (80.2)	Referent	Referent
1 to 5 hrs/week	174 (19.5)	36,236 (17.4)	1.08 (0.91 to 1.28)	0.372
> 5 hrs/week	28 (3.1)	5088 (2.4)	1.08 (0.74 to 1.59)	0.681

*Adjusted for age, sex, race, education, BMI, Townsend deprivation index and manual labour. Excluded: 3622 patients and 15 with RCD who were missing information on education, BMI, or manual labour.
†A total of 20,894 people did not report information about secondhand smoke exposure outside the home and 5949 did not report information about secondhand smoke exposure inside the home.

Smoking associations. Former smokers had significantly higher rates of rotator cuff surgery than those who had never smoked (Table III), while current smokers had similar rates as those who had never smoked. These results were consistent both when adjusting for age alone, and when adjusting for age and other characteristics. There was no association between the length of having smoked and the risk of surgery when examining current and former smokers collectively or separately (Table IV).

Among those who had never smoked, a minority of people (41,526; 18%) were exposed to at least one hour of secondhand smoke weekly and a much smaller percentage (5,116; 2%) were exposed to a larger number of hours of secondhand smoke. Given this non-normal distribution, this characteristic was examined categorically. Those who had never smoked living in households with more than one smoker had a higher rate of rotator cuff surgery than those living with non-smokers (Table V). However, the risk of rotator cuff surgery did not significantly differ between those reporting different durations of secondhand smoke exposure inside or outside the home.

Sensitivity analyses. Results were similar after implementing a two-year lag between the assessment of risk factors and ascertainment of rotator cuff surgery (Table VI). There were no meaningful changes in the results after excluding patients with a rotator cuff tear that was probably traumatic (Table VII).

Discussion

In this large population-based cohort, we identified many factors that were independently associated with RCD requiring surgery. The relationship between age and cuff tear is well established.[1,7,8] Unfortunately, ageing is not modifable, highlighting the importance of the identification of modifiable risk factors. We confirmed several hypothesized modifiable risk factors, such as obesity and higher occupational demands.[7,11,12] There were also associations with characteristics such as sex, race, education, and deprivation, which may be indicative of differing comorbidity profiles or other exposures.

Age is considered the most potent risk factor for degenerative RCD,[1,4,7,8,20] and our findings further support this. In elderly patients, surgical treatment may be recommended less frequently for an RCD diagnosis and thus these cases may have been less likely to have been captured in our study, but we found that the rates of rotator cuff surgery increased consistently with age. When assessing other potential risk factors it is important to control for confounding by age. In doing so, we demonstrated associations of Asian and mixed race, male sex, and lower levels of education with the risk of RCD surgery. These findings may be indicative of differential environmental exposure within these groups. For instance, associations with male sex and lower education were attenuated once we accounted for occupational physical demands. We also found that more social

Table VI. Associations between the characteristics of the people and rotator cuff surgery occurring more than two years after baseline (1894 with RCD occurring after a two-year lag, 419,404 people). Age, Townsend deprivation index, and body mass index were modelled continuously with units scaled to the amounts indicated. Race, level of education, smoking status, and manual labour were modelled as variables compared to the referent category indicated.

Characteristic	Adjusted hazard ratio (95% CI)*	p-value*
Age, modelled per decade	1.53 (1.42 to 1.65)	< 0.001
Male sex	1.19 (1.08 to 1.31)	< 0.001
Race		
White	Referent	Referent
Black	1.56 (1.08 to 2.24)	0.017
Asian	1.75 (1.30 to 2.36)	< 0.001
Mixed	1.79 (1.04 to 3.10)	0.037
Unknown	1.32 (0.86 to 2.04)	0.208
Townsend deprivation index,*† modelled per 10 points	0.76 (0.65 to 0.90)	0.001
Level of education†		
College/University	Referent	Referent
Other professional qualifications (e.g. nursing, teaching)	1.44 (1.24 to 1.68)	< 0.001
NVQ, HND, HNC, or equivalent	1.56 (1.33 to 1.82)	< 0.001
A levels/AS levels or equivalent	1.35 (1.08 to 1.69)	0.009
O levels/GCSEs/CSEs or equivalent	1.49 (1.28 to 1.72)	< 0.001
None of the above	1.50 (1.29 to 1.74)	< 0.001
Smoking status†		
Never	Referent	Referent
Former	1.24 (1.12 to 1.37)	< 0.001
Current	0.94 (0.79 to 1.12)	0.506
Body mass index,† modelled per 5 kg/m²	1.19 (1.13 to 1.24)	< 0.001
Diabetes diagnosed by a doctor†	1.16 (0.97 to 1.39)	0.109
Job involves heavy manual or physical work†		
Never/rarely	Referent	Referent
Sometimes	1.40 (1.19 to 1.63)	< 0.001
Usually	1.88 (1.52 to 2.33)	< 0.001
Always	2.05 (1.66 to 2.55)	< 0.001
Retired/unemployed	1.08 (0.95 to 1.23)	0.224
Among never smokers		
Any secondhand smoke exposure		
None	Referent	Referent
1 to 5 hrs/wk	1.11 (0.93 to 1.33)	0.262
> 5 hrs/wk	1.07 (0.71 to 1.62)	0.749

*Results come from a Cox regression model including age, sex, race, education, smoking status, BMI, Townsend index and manual labour. Models evaluating measurements of secondhand smoke did not adjust for smoking status (as only those who had never smoked were included) or diabetes (as this was not a statistically significant risk factor in the initial multivariate model).

†A total of 503 people did not have information about Townsend index, 8367 did not report their level of education, 2539 did not report smoking status, 21,627 did not have information about smoking inside and outside the home, 2226 did not have information about the diagnosis of diabetes, 2461did not have information about BMI, and 290 did not have information about manual labour.

A level, Advanced level; AS level, Advanced Subsidiary level; CI, confidence interval; CSE, Certificate of SecondaryEducation; GCSE, General Certificate of Secondary Education; HNC, Higher National Certificate; HND, Higher National Diploma; N/A, not applicable; NVQ, National Vocational Qualification; O level, Ordinary level.

Table VII. Associations between the characteristics of the people and the risk of rotator cuff surgery excluding traumatic tears (2076 remaining cases). Age, Townsend deprivation index and body mass index were modelled continuously with units scaled to the amounts indicated. Race, level of education, smoking status, and manual labour were modelled as indicator variables compared to the referent category indicated.

Characteristic	Adjusted hazard ratio* (95% CI)	p-value*
Age, modelled per decade	1.57 (1.46 to 1.69)	< 0.001
Male sex	1.20 (1.10 to 1.32)	< 0.001
Race		
White	Referent	Referent
Black	1.55 (1.09 to 2.19)	0.014
Asian	1.74 (1.30 to 2.31)	< 0.001
Mixed	1.77 (1.05 to 3.00)	0.034
Unknown	1.49 (1.01 to 2.20)	0.044
Townsend deprivation index,† modelled per 10 points	0.78 (0.67 to 0.92)	0.002
Level of education†		
College/University	Referent	Referent
Other professional qualifications (e.g. nursing, teaching)	1.45 (1.25 to 1.67)	< 0.001
NVQ, HND, HNC, or equivalent	1.58 (1.36 to 1.84)	< 0.001
A levels/AS levels or equivalent	1.34 (1.08 to 1.67)	0.009
O levels/GCSEs/CSEs or equivalent	1.44 (1.25 to 1.67)	< 0.001
None of the above	1.57 (1.36 to 1.81)	< 0.001
Smoking status†		
Never	Referent	Referent
Former	1.24 (1.13 to 1.36)	< 0.001
Current	0.92 (0.77 to 1.08)	0.304
Body mass index,† modelled per 5 kg/m²	1.18 (1.13 to 1.24)	< 0.001
Diabetes diagnosed by a doctor†	1.16 (0.97 to 1.38)	0.098
Job involves heavy manual or physical work†		
Never/rarely	Referent	Referent
Sometimes	1.37 (1.18 to 1.60)	< 0.001
Usually	1.82 (1.48 to 2.24)	< 0.001
Always	2.15 (1.76 to 2.63)	< 0.001
Retired/unemployed	1.05 (0.93 to 1.19)	0.413
Among never smokers		
Any secondhand smoke exposure		
None	Referent	Referent
1 to 5 hrs/week	1.08 (0.91 to 1.28)	0.389
> 5 hrs/week	1.09 (0.74 to 1.61)	0.673

*Results come from a Cox regression model including age, sex, race, education, smoking status, BMI, Townsend index and manual labour. Models evaluating measures of secondhand smoke did not adjust for smoking status (as only those who had never smoked were included) or diabetes (as this was not a statistically significant risk factor in the initial multivariate model).

†A total of 503 people did not have information about Townsend index, 8,367 did not report their level of education, 2,539 did not report smoking status, 21,627 did not have information about smoking inside and outside the home, 2,226 did not have information about the diagnosis of diabetes, 2,461 did not have information about BMI, and 290 did not have information about manual labour.

A level, Advanced level; AS level, Advanced Subsidiary level; CI, confidence interval; CSE, Certificate of SecondaryEducation; GCSE, General Certificate of Secondary Education; HNC, Higher National Certificate; HND, Higher National Diploma; N/A, not applicable; NVQ, National Vocational Qualification; O level, Ordinary level.

deprivation was associated with lower rates of surgery. Even though universal healthcare is available in the UK, the use of health care may differ according to socioeconomic status. For example, differential levels of the use of specialist services have been reported in Canada, despite universal healthcare.[21]

The intensity of occupational physical demands was a strong indicator of the risk of cuff surgery. A dose-response relationship was observed with more frequent manual labour being consistently associated with higher rates of surgery. Previous studies have demonstrated higher prevalence of rotator cuff tears among manual labourers,[22] high rates of shoulder pain in occupations that regularly demand labour involving loading the shoulder,[23,24] and animal models have shown early tendinopathy after repetitive stresses and fatigue-loading on the shoulder.[25,26] These findings may also be influenced by increased symptom-reporting and treatment-seeking among those who rely heavily upon their upper limbs for work-related tasks. However, even when we conducted sensitivity analyses that included a two-year lag, during which time some people would have retired or changed occupations, leading to fewer occupational demands, the associations with the incidence of cuff surgery were not attenuated. Future studies that characterize specific occupational tasks related to the upper limbs are needed to further define the relationship between occupational exposure and the risk of RCD.

Higher BMI was associated with a higher risk of rotator cuff surgery, even after accounting for other risk factors. This agrees with other studies showing associations between higher BMI levels and cuff tears specifically, and tendinopathy in general.[11,22,27] BMI is a biologically plausible risk factor as obesity is linked with chronic inflammation,[28] potentially influencing the degeneration of tendons and development of pain. Obesity is also associated with other conditions such as dyslipidemia and hypertension,[28,29] which may also increase the risk of a cuff tear.[9,30-32] One prior study did not detect a significant association between BMI and RCD, but this may have been due to statistical control of mediating factors such as dyslipidemia.[9]

Previous studies have identified smoking as a significant risk factor for RCD, and smoking has been associated with poor tendon healing in both clinical and animal studies.[9,10,33-35] When compared to non-smokers, we identified a higher risk of RCD among former but not current smokers. Current smokers may have been less likely to undergo surgery due to suboptimal outcomes associated with smoking, and thus these patients may be less likely to be captured in a hospital setting.[34,36] By contrast, exposure to secondhand smoke would be unlikely to lead to differential symptom-reporting or patterns of treatment. There was a significant association between the presence of more than one household smoker and rotator cuff surgery, but other measures of secondhand smoke were not significantly associated with the rate of rotator cuff surgery, and the importance of this exposure as a new risk factor is uncertain.

The study has important limitations. Ascertainment through inpatient hospital diagnoses accompanying surgical treatment disproportionately captures cases that are the most severe. While diagnosis within this setting helps to maximize the specificity of our definition of cases (i.e. misdiagnoses are unlikely), many individuals with rotator cuff tears will not be captured using this method. The resulting associations will be influenced by the relationship between risk factors with the probability of developing symptoms presenting clinically, and receiving inpatient (versus outpatient) surgical treatment. We also did not have radiological information, and so could not examine the characteristics of the tears. Another limitation is the determination of BMI at a single time when important changes could occur during the period of surveillance. Also, while we assessed self-reported diabetes diagnosed by a doctor, the associations which we identified could be mediated by other comorbidties which were not included. The assessment of work exposure was based on a single question about heavy manual work and did not assess more specific occupational risks, such as prolonged elevation of the arms above the level of the shoulder. Detailed data about work exposure may have shown a stronger association with the incidence of rotator cuff surgery. Finally, the Townsend deprivation index showed that the patients were slightly more affluent than the general UK population, limiting the generalizability of the findings.

Despite these limitations, there were a number of important strengths. First, the use of a population-based cohort allows comparison of patients with RCD with all others in the source population from which the cases arose, and thus is less susceptible to the selection bias common with clinic-based controls. Secondly, throughout this population there was a standardized, comprehensive assessment of potential risk factors, many of which have not been examined together previously. The longitudinal design, and exculsion of symptomatic patients at baseline, restricted the potential for biased assessments of the relevant exposures. Finally, the large sample size allowed precise estimation of associations and the concurrent consideration of a number of risk factors.

We identified a number of factors that were independently associated with the risk of rotator cuff surgery, including older age, male sex, less social deprivation, higher BMI, and higher occupational physical demands. Some of these risk factors are potentially modifiable with important implications for the burden on healthcare systems. Specifically, our findings suggest a potential for interventions that align with other public health goals to be effective in reducing the rate of surgery needed for painful rotator cuff tears. Future studies assessing specific modifiable risk factors and corresponding interventions will be needed in order to explore this further.

Take home message

- Several modifiable risk factors, such as high body mass index and high occupational physical demands, are associated with surgery for RCD.
- RCD and the accompanying healthcare burden might be reduced by addressing these factors, which could align more broadly with public health goals.

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