Rheumatoid arthritis is a chronic inflammatory joint disease that shows rhythmic variations in clinical symptoms depending on the biological clock.1 Susceptibility to RA is determined by both genetic and environmental factors. The disease is subclassified into two subsets based on the presence of anticitrullinated peptide antibodies (ACPA). ACPAs are specific markers of RA that occur in approximately 60% of the patients.2 3 Several reported susceptibility genes for RA including the human leukocyte antigen (HLA) DRB1 shared epitope (SE) alleles have been associated with ACPA-positive RA, but not with ACPA-negative RA.4 5 Similarly, several environmental risk factors have a more pronounced influence on ACPA-positive RA, such as smoking6 7 and exposure to silica.8

Mounting evidence indicates that shift work is associated with a wide variety of adverse health consequences. Shift work has been linked with increased risk of developing autoimmune thyroid disorders,9 multiple sclerosis,10 11 diabetes,12 cardiovascular disease13 and cancer.14 In a prospective cohort study, shift work defined as working outside regular
day shifts, was associated with an increased risk of developing RA in females (OR 1.3, 95% CI 1.0 to 1.8). We therefore hypothesise that different kinds of shift work may influence the risk of RA in different ways. Since several environmental risk factors have a more pronounced influence on ACPA-positive RA, we aimed to explore the influence of permanent night shift work, rotating shift work and day-oriented shift work on the risk of developing ACPA-positive and ACPA-negative RA.

METHOD
Design and study population
This report was based on data from the ongoing project Epidemiological Investigation of Rheumatoid Arthritis (EIRA) which is a population-based case-control study comprising the population aged 18–70 years in the middle and southern parts of Sweden. All hospital-based and most privately run rheumatology units participated in recruiting cases of RA to the study. For each potential case, one control was randomly selected from the national population register, matched by age, gender and residential area. Cases who did not fulfil the American College of Rheumatology 1987 criteria at the time of the analyses were excluded, whereas we kept the corresponding controls.

During the study period June 1996 to December 2006, completed questionnaires were obtained from 1990 cases who fulfilled the American College of Rheumatology 1987 criteria and 2230 controls; the response proportion being 92% for the cases and 75% for the controls. ACPA status was missing in 34 cases, and these were excluded. Five cases and five controls who reported shift work were excluded since they could not specify during which years they were exposed. The present study thus comprised 1951 cases and 2225 controls. All aspects of the study were approved by the ethics committee of the Karolinska Institutet.

Anticitrullinated peptide antibodies
ACPA status among cases was analysed using Immunoscan RA Mark 2 ELISA test (anti-CCP2 test). Serum samples were diluted 1/50 with dilution buffer and incubated for 1 hour at 37°C. After removing the liquid and washing three times with rinsing buffer, the conjugate solution (peroxidase conjugated anti-human IgG antibodies) was added into each well and incubated for 1 hour at 37°C. After three washing steps with rinsing buffer, the substrate solution (tetramethyl benzidine) was added and incubated for 30 min at room temperature. The stop solution (sulfuric acid, 0.5 mol/L) was added and the absorbance values were read immediately at 450 nm. An antibody level exceeding 25 AU/ml was regarded as ACPA positivity.

Data collection and definition of shift work
The questionnaire contained questions relating to demographic and reproductive factors, heredity, previous health, lifestyle factors, occupational exposures and socioeconomic circumstances. Detailed information was obtained regarding professions and work places, including whether subjects had worked outside standard working hours. Subjects could in detail specify type of shift work by answering a free text question and specify during which periods they had worked shift. Incompletely answered questionnaires were completed by mail or by telephone. For each case, the time of the initial appearance of RA symptoms was used as an estimate of the disease onset, and the year in which this occurred was defined as the index year. The corresponding control was given the same index year. Information regarding shift work was considered prior to the index year in the cases and during the same period of time in the corresponding controls.

Shift work comprises work schedules that extend beyond the typical nine-to-five workday. In the present study, shift workers were categorised based on their schedules into those who reported day-oriented shift work, rotating shift work and permanent night shift work. Subjects with morning and evening work, in which short daily rest between shifts is common, were included in the first group. Rotating shift work included those who had worked both day time and night time working hours, those who had worked rotating day and night shifts and those who worked 24 hours shifts. Permanent night shift work comprised those who exclusively had worked night shifts. In the main analysis, subjects who had been exposed to different kinds of shift work were categorised based on what kind of shift work took place closest to the index year. We also performed complementary analyses defining permanent night shift work as ever having worked permanent night shifts before the index year and defining shift work as ever having worked either day oriented or rotating shift before the index year. In order to analyse the influence of duration and intensity of the different kinds of shift work, we further categorised the subjects into subgroups based on the duration (<5, 5–10, >10 years) and intensity (≤10 or >10 nights/month) of the shift work.

Statistical analysis
By means of logistic regression, the incidence of ACPA-positive and of ACPA-negative RA, respectively, in subjects who had worked permanent night shift work, day-oriented shift work or rotating shift work at the index year were compared with those who had never worked shifts, by calculating ORs with 95% CIs. The analysis was also performed separately for men and women. Trend
test for a dose–response relationship regarding duration and intensity of permanent night shift work and risk of RA was performed by using a continuous variable for duration and intensity of permanent night shift work, in a logistic regression model.

Both matched and unmatched analyses of the data were performed. However, only the results from the unmatched analyses are presented in this report since these were in close accordance with those from the matched analyses but in general had higher precision in terms of more narrow CIs.

All analyses were adjusted for age, gender, residential area, ancestry and smoking habits. Age was adjusted for as a continuous variable. Assessment of ancestry was based on whether the subject was born in Sweden or not and whether either of the subject’s parents had immigrated to Sweden. A subject who was born in Sweden, whose parents had not immigrated, was classified as Swedish. Smoking was adjusted for as a continuous variable based on number of pack years. One pack year is equivalent to smoking 20 cigarettes daily for 1 year. Adjustments were also made for educational level (university degree or not), body mass index at inclusion in the study (underweight, normal weight, overweight or obese) and alcohol consumption (gram alcohol per week at study inclusion), but these factors did not influence on the results and were not retained in the final analyses. The complementary analyses were adjusted for shift work versus permanent shift work. All analyses were conducted using Statistical Analysis System (SAS) V.9.2.

### RESULTS

The analyses of shift work and RA risk included 1951 cases and 2225 controls. The mean age at onset was 50.5 years for ACPA-positive cases and 51.8 years for ACPA-negative subjects. The mean duration from the disease onset to inclusion in the study was less than 1 year in both subgroups (0.9 years, SD 1.3 for ACPA-positive RA and 0.9 years, SD 1.5 for ACPA-negative RA). Characteristics of cases and controls are presented in table 1.

There was a significant association between both rotating shift work and day-oriented shift work and increased incidence of ACPA-positive RA, but not ACPA-negative RA. The adjusted OR of developing ACPA-positive RA was 1.3 (95% CI 1.0 to 1.6) among those who had worked rotating shifts and 1.3 (95% CI 1.0 to 1.7) among those who had worked day-oriented shifts, compared with those who had never been exposed to any kind of shift work (table 2). There were no gender differences regarding association between different kinds of shift work and RA risk. The results were similar when we defined shift workers as ever having worked day oriented or rotating shifts and adjusted the analysis for permanent night shift work (adjusted OR of ACPA-positive RA was 1.3 (95% CI 1.1 to 1.6) and adjusted OR of ACPA-negative RA was 1.0 (95% CI 0.8 to 1.3) for those who had been exposed to day oriented

### Table 1 Characteristics of cases and controls among those who have and have not been exposed to shift work before the index year

<table>
<thead>
<tr>
<th>Kind of shift work</th>
<th>ACPA-positive cases</th>
<th>ACPA-negative cases</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (n)</td>
<td>Swedish (n, %)</td>
<td>University degree (n, %)</td>
</tr>
<tr>
<td>Rotating shift work</td>
<td>Never</td>
<td>828</td>
<td>724 (87)</td>
</tr>
<tr>
<td></td>
<td>Permanent</td>
<td>97</td>
<td>83 (86)</td>
</tr>
<tr>
<td>Day-oriented shift work</td>
<td>Never</td>
<td>97</td>
<td>83 (86)</td>
</tr>
<tr>
<td></td>
<td>Permanent</td>
<td>144</td>
<td>119 (83)</td>
</tr>
</tbody>
</table>

ACPA, anticitrullinated peptide antibodies.
Table 2  ORs with 95% CIs of developing rheumatoid arthritis (RA) for subjects who have been exposed to permanent night shift work, rotating shift work, or day oriented shift work, compared with those who have never been exposed

<table>
<thead>
<tr>
<th>Type of shift work</th>
<th>ACPA-positive RA</th>
<th>ACPA-negative RA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ca/co* (n, %)</td>
<td>OR (95% CI)†</td>
</tr>
<tr>
<td>Never</td>
<td>828 (67)/1537 (69)</td>
<td>1.0 (reference)</td>
</tr>
<tr>
<td>Day oriented shift work</td>
<td>144 (12)/244 (11)</td>
<td>1.3 (1.0 to 1.7)</td>
</tr>
<tr>
<td>Rotating shift work</td>
<td>163 (13)/252 (11)</td>
<td>1.3 (1.0 to 1.6)</td>
</tr>
<tr>
<td>Permanent night shift work</td>
<td>97 (8)/192 (9)</td>
<td>0.7 (0.6 to 0.9)</td>
</tr>
</tbody>
</table>

*Exposed cases and controls
†Adjusted for age, gender, residential area, ancestry, and smoking.
ACPA, anticitrullinated peptide antibodies.

Table 3  ORs with 95% CI of developing rheumatoid arthritis (RA) for subjects who reported past exposure to permanent night shift work compared with those who had never been exposed, by duration (years) and intensity (nights/months) of night shift work

<table>
<thead>
<tr>
<th>Duration</th>
<th>ACPA-positive RA</th>
<th>ACPA-negative RA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ca/co* (n, %)</td>
<td>OR (95% CI)†</td>
</tr>
<tr>
<td>0</td>
<td>828/1537</td>
<td>1.0 (reference)</td>
</tr>
<tr>
<td>&lt;5 years</td>
<td>149/275</td>
<td>0.8 (0.6 to 1.0)</td>
</tr>
<tr>
<td>5–10 years</td>
<td>45/89</td>
<td>0.7 (0.5 to 1.1)</td>
</tr>
<tr>
<td>&gt;10 years</td>
<td>65/152</td>
<td>0.6 (0.4 to 0.9)</td>
</tr>
<tr>
<td>p for trend</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Intensity</td>
<td>ca/co* (n, %)</td>
<td>OR (95% CI)†</td>
</tr>
<tr>
<td>0</td>
<td>828/1537</td>
<td>1.0 (reference)</td>
</tr>
<tr>
<td>≤10 nights/months</td>
<td>184/362</td>
<td>0.8 (0.6 to 1.0)</td>
</tr>
<tr>
<td>&gt;10 nights/months</td>
<td>75/154</td>
<td>0.7 (0.5 to 1.0)</td>
</tr>
<tr>
<td>p for trend</td>
<td>0.007</td>
<td></td>
</tr>
</tbody>
</table>

*Number of exposed cases and controls.
†Adjusted for age, gender, residential area, ancestry, smoking, educational level and shift work.
ACPA, anticitrullinated peptide antibodies.

There was an inverse association between permanent night shift work and risk of each subset of RA. Compared with those who had never been exposed to shift work, the adjusted OR of developing ACPA-positive RA was 0.7 (95% CI 0.6 to 0.9) and the adjusted OR of developing ACPA-negative RA was 0.8 (95% CI 0.6 to 1.0) for those who had worked permanent night shifts before the index year (table 2). There were no gender differences. The results were similar when we defined permanent night shift work as ever having worked permanent night shifts before the index year and adjusted the analysis for lifetime shift work (adjusted OR of ACPA-positive RA was 0.7 (95% CI 0.6 to 0.9) and adjusted OR of ACPA-negative RA was 0.8 (95% CI 0.6 to 1.0) for those who had been exposed to permanent night shift work compared with those who had never been exposed).

For both subsets of RA, significant trends showed a lower risk of developing RA with increasing duration of permanent night shift work (table 3). For ACPA-positive RA, there was also a significant inverse trend between intensity of permanent night shift work and RA risk.

**DISCUSSION**

In accordance with a previous prospective study on shift work and RA risk, we observed an association between shift work and increased RA risk. Compared with subjects who had never worked shifts, the risk of ACPA-positive RA was increased by 30% both among those who had worked day-oriented shift work and among those who had worked shifts including both daytime and night working hours. There was no association between risk of ACPA-negative RA and shift work.

Sleep restriction may be a possible mechanism behind the association between shift work and RA risk. All types of shift work may result in sleep restriction, and mounting evidence indicates that shift work is associated with a wide variety of adverse health consequences. Sleep deprivation has itself been shown to severely disturb the functional rhythm of regulatory T cells and CD4+ T cell and CD8+ T cell function.
A large number of studies in animal models of RA indicate high concentrations in the synovial fluid. Compared with the synovial fluid of patients with RA have specific melatonin receptors. Macrophages infiltrating the synovial fluid of patients with RA have been shown to play a crucial role in the induction of autoimmune diseases such as RA. Permanent night shift work was inversely associated with both subsets of RA. Among night shift workers, the OR of developing either of the two subsets of RA was reduced by 30% compared with those who had never worked night shifts. Sleep restriction is a consequence also of permanent night shift work. However, a possible contributing factor behind the inverse relationship between permanent night shift work and RA risk may be reduced melatonin production in night shift workers. Permanent night shift workers have lower levels and a delay in peak time of melatonin production over a 24-hours period. Melatonin production decreased progressively over consecutive days of simulated night work, both during night time and over the 24 hours. Several lines of evidence point to a disease-promoting role of melatonin in RA. Macrophages infiltrating the synovial fluid of patients with RA have specific melatonin-binding sites, and melatonin has also been found at high concentrations in the synovial fluid. Compared with healthy controls, patients with RA have altered levels of circulating melatonin with higher nocturnal serum levels of melatonin and an altered temporal profile with a more rapid increase at the start of the night and an earlier peak. The circadian serum concentrations of melatonin were also significantly higher in northern than in southern patients and the geographical distribution of RA shows a north–south gradient, with higher latitudes being associated with an increased incidence and severity of RA. Furthermore, a large number of studies in animal models of RA indicate that melatonin promotes the development or increases the severity of RA. The decreased melatonin production associated with night shift work may thus contribute to explaining the inverse relationship between night shift work and risk of developing RA.

The observation that permanent night work seems to protect against RA needs corroboration from subsequent epidemiological studies. However, there is also a need for field studies and experiments with night work, with a particular focus on the measurement of levels of melatonin across shift cycles. The experiments should also include patients with RA whose sleep is shifted to daytime, while both melatonin levels and symptoms are recorded. Finally, ways of blocking melatonin, for example, with light should be attempted. This might include optimising split sleep strategies with light exposure during melatonin peak time.

EIRA was designed as a population-based, case–control study using incident cases. Information regarding lifestyle factors and personal information was gathered retrospectively. However, we predominantly included cases of RA who had received the diagnosis within the past year in order to minimise recall bias. The questionnaire contained a wide range of questions regarding many potential environmental risk factors and no section in the questionnaire was given pre-eminent focus. Moreover, no previous reports have been conducted investigating the influence of night shift work on RA risk, and the prospective study on shift work and RA risk was only recently published. Therefore, the quality of the reported information on shift work and night shift work would probably not differ between cases and controls and hence tend to bias the studied association towards the null value when comparing exposed to unexposed.

Selection out of shift work has been observed in several occupational studies. If dropout from night shift work due to illness was a major factor, then we would expect a lower OR among current night workers than among past night workers. However, there was no significant difference between the two groups. Furthermore, the association between permanent night shift work and decreased RA risk remained unchanged when we only considered night shift work 5 years prior to the index year, indicating that the finding was not due to reverse causation.

The proportion of respondents with regard to participation in EIRA was 92% for cases and 75% for controls. A potential selection bias may result from the proportion of non-responders among the controls. However, this bias is most likely to be modest since the prevalence of shift work among the controls at different age groups was similar to what has been observed in other representative samples from Sweden. Moreover, the prevalence of smoking among the controls, seen as an indicator of life style, was in line with that of the general population at equivalent ages.

In conclusion, day-oriented shift work and rotating shift work were associated with an increased risk of ACPA-positive RA, but not ACPA-negative RA, whereas an inverse association was observed between permanent night shift work and risk of developing both subsets of RA. The mechanisms behind these observations remain to be elucidated. Sleep restriction as a consequence of shift work is associated with enhanced proinflammatory responses and may play a role in the onset of RA, whereas decreased melatonin production in night shift workers may contribute to explaining the inverse relationship between night shift work and RA risk.

Contributors AKH, LX and LA were involved in the conception and design of the study. Drafting of the manuscript and tables were done by AKH. All authors equally contributed to acquisition and analysis of the data, revised the manuscript and provided final approval of the manuscript.

Funding This work was supported by grants from the Swedish Medical Research Council, the Swedish Research Council for Health, Working Life and Welfare, King Gustaf V’s 80-year foundation, Nordforsk, the Swedish Rheumatic Foundation, steering committee, the Swedish Rheumatism Association, and a charity for patients with RA, EIRA was designed as a population-based, case–control study using incident cases. Information regarding lifestyle factors and personal information was gathered retrospectively. However, we predominantly included cases of RA who had received the diagnosis within the past year in order to minimise recall bias. The questionnaire contained a wide range of questions regarding many potential environmental risk factors and no section in the questionnaire was given pre-eminent focus. Moreover, no previous reports have been conducted investigating the influence of night shift work on RA risk, and the prospective study on shift work and RA risk was only recently published. Therefore, the quality of the reported information on shift work and night shift work would probably not differ between cases and controls and hence tend to bias the studied association towards the null value when comparing exposed to unexposed.

Selection out of shift work has been observed in several occupational studies. If dropout from night shift work due to illness was a major factor, then we would expect a lower OR among current night workers than among past night workers. However, there was no significant difference between the two groups. Furthermore, the association between permanent night shift work and decreased RA risk remained unchanged when we only considered night shift work 5 years prior to the index year, indicating that the finding was not due to reverse causation.

The proportion of respondents with regard to participation in EIRA was 92% for cases and 75% for controls. A potential selection bias may result from the proportion of non-responders among the controls. However, this bias is most likely to be modest since the prevalence of shift work among the controls at different age groups was similar to what has been observed in other representative samples from Sweden. Moreover, the prevalence of smoking among the controls, seen as an indicator of life style, was in line with that of the general population at equivalent ages.

In conclusion, day-oriented shift work and rotating shift work were associated with an increased risk of ACPA-positive RA, but not ACPA-negative RA, whereas an inverse association was observed between permanent night shift work and risk of developing both subsets of RA. The mechanisms behind these observations remain to be elucidated. Sleep restriction as a consequence of shift work is associated with enhanced proinflammatory responses and may play a role in the onset of RA, whereas decreased melatonin production in night shift workers may contribute to explaining the inverse relationship between night shift work and RA risk.

Contributors AKH, LX and LA were involved in the conception and design of the study. Drafting of the manuscript and tables were done by AKH. All authors equally contributed to acquisition and analysis of the data, revised the manuscript and provided final approval of the manuscript.

Funding This work was supported by grants from the Swedish Medical Research Council, the Swedish Research Council for Health, Working Life and Welfare, King Gustaf V’s 80-year foundation, Nordforsk, the Swedish Rheumatic Foundation, steering committee, the Swedish Rheumatism Association, and a charity for patients with RA.
the Stockholm County Council, the Insurance Company AFA and the Innovative Medicines Initiative-supported BTCure project.

Competing interests None declared.

Patient consent Obtained.

Ethics approval The ethics committee of the Karolinska Institutet.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Open Access This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

© Article author(s) (or their employer(s) unless otherwise stated in the text of the article) 2017. All rights reserved. No commercial use is permitted unless otherwise expressly granted.

REFERENCES

Relationship between shift work and the onset of rheumatoid arthritis

Anna Karin Hedström, Torbjörn Åkerstedt, Lars Klareskog and Lars Alfredsson

*RMD Open* 2017 3:
doi: 10.1136/rmdopen-2017-000475

Updated information and services can be found at:
http://rmdopen.bmj.com/content/3/2/e000475

These include:

**References**
This article cites 33 articles, 9 of which you can access for free at:
http://rmdopen.bmj.com/content/3/2/e000475#BIBL

**Open Access**
This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

**Email alerting service**
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

**Notes**

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/