Atrial fibrillation as risk factor for cardiovascular disease and death in women compared with men: systematic review and meta-analysis of cohort studies

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Atrial fibrillation as risk factor for cardiovascular disease and death in women compared with men: systematic review and meta-analysis of cohort studies

Connor A Emdin, Christopher X Wong, Allan J Hsiao, Douglas G Altman, Sanne AE Peters, Mark Woodward, Ayodele A Odutayo

ABSTRACT
OBJECTIVE
To determine whether atrial fibrillation is a stronger risk factor for cardiovascular disease and death in women compared with men.

DESIGN
Meta-analysis of cohort studies.

DATA SOURCES
Studies published between January 1966 and March 2015, identified through a systematic search of Medline and Embase and review of references.

ELIGIBILITY FOR SELECTING STUDIES
Cohort studies with a minimum of 50 participants with and 50 without atrial fibrillation that reported sex specific associations between atrial fibrillation and all cause mortality, cardiovascular mortality, stroke, cardiac events (cardiac death and non-fatal myocardial infarction), and heart failure.

DATA EXTRACTION
Two independent reviewers extracted study characteristics and maximally adjusted sex specific relative risks. Inverse variance weighted random effects meta-analysis was used to pool sex specific relative risks and their ratio.

RESULTS
30 studies with 4 371 714 participants were identified. Atrial fibrillation was associated with a higher risk of all cause mortality in women (ratio of relative risks for women compared with men 1.12, 95% confidence interval 1.07 to 1.17) and a significantly stronger risk of stroke (1.99, 1.46 to 2.71), cardiovascular mortality (1.93, 1.44 to 2.60), cardiac events (1.55, 1.15 to 2.08), and heart failure (1.16, 1.07 to 1.27). Results were broadly consistent in sensitivity analyses.

WHAT IS ALREADY KNOWN ON THIS TOPIC
Atrial fibrillation (AF) is associated with an increased risk of stroke and death in men and women.
A growing body of literature suggests that women and men experience risk factors for cardiovascular disease differently, including diabetes, smoking, and body mass index.

WHAT THIS PAPER ADDS
AF is associated with a stronger relative risk of all cause mortality, cardiovascular mortality, stroke, ischaemic heart disease, and heart failure in women than in men.
Whether the differential association of AF with death and cardiovascular disease in women relative to men is causal is unclear.

CONCLUSION
Atrial fibrillation is a stronger risk factor for cardiovascular disease and death in women compared with men, though further research would be needed to determine any causality.

Introduction
Atrial fibrillation (AF) is a leading cause of cardiovascular disease worldwide, with an estimated 33.5 million people affected in 2010. Recent estimates from the Global Burden of Disease study indicated that AF was associated with an age adjusted mortality rate of 1.7 per 100 000 people (95% uncertainty interval 1.4 to 2.1) in 2010 and that the prevalence is increasing in both developed and developing countries.

Although AF is associated with an increased risk of stroke and death in men and women, a growing body of literature suggests that women and men experience risk factors for cardiovascular disease differently. Previous analyses have shown that smoking and diabetes are associated with greater proportional risks of coronary heart disease in women than in men. Diabetes is also associated with a greater relative risk of stroke in women. It is currently unclear, however, whether such sex differences exist for AF. While being female is a risk factor for stroke among individuals with AF, this could reflect differences in the multivariable adjusted risk of stroke by sex in the general population rather than differential effects of AF by sex. To explore sex differences in the effect of AF, it is necessary to compare sex specific estimates of the effect of AF on risk of death and cardiovascular disease.

Accordingly, we conducted a meta-analysis of cohort studies to estimate the association between AF and cardiovascular disease and death in women and men and to compare the sexes.

Methods
Search strategy and selection criteria
We conducted a systematic review of cohort studies that reported associations between AF and death or cardiovascular events in men and women. This was
done in accordance with the MOOSE (meta-analysis of observational studies in epidemiology) guidelines. An experienced research librarian designed and conducted the search strategy. Medline and Embase were searched from 1966 to March 2015 with a combined text and MeSH subheading search with the following terms: “atrial fibrillation”, “mortality”, “death”, “cardiovascular disease”, “heart failure”, “myocardial infarction”, “death, sudden, cardiac”, “stroke”, “kidney”, “renal”, “peripheral”, and “risk factors”. We conducted a review of the references of identified studies.

We included any study that reported sex specific associations between AF and any of the following outcomes: all cause mortality, cardiovascular mortality, stroke (fatal and non-fatal), cardiac events (a composite of cardiac death and non-fatal myocardial infarction, excluding heart failure), heart failure, peripheral arterial disease, and chronic kidney disease. For inclusion in the analysis, studies were required to have a minimum of 50 participants with AF, a minimum of 50 participants without AF, and a median follow-up of at least six months. Importantly, we included only studies that reported associations for both men and women to restrict our analysis to comparisons of men and women within studies and to reduce the risk of heterogeneity between studies influencing our results. Additionally, we required all studies to adjust for, at a minimum, age and the presence of cardiovascular disease at baseline. We excluded studies that examined postoperative atrial fibrillation because the differing epidemiology and duration of postoperative atrial fibrillation relative to chronic atrial fibrillation. There were no language restrictions, and an investigator with extensive experience in epidemiological study translation (AJH) translated non-English studies. We contacted authors of studies that did not report separate associations for women and men to provide any unpublished data on adjusted sex specific associations.

Data extraction
Data were extracted, in duplicate, from studies deemed to meet the eligibility criteria. These included details on general study characteristics (study name, duration of follow-up, year of publication), information about the studied population (number of participants with and without AF, mean age, number of men and women, number of participants with a history of coronary heart disease, stroke, and heart failure), and information on the outcomes in the study (all cause mortality, cardiovascular mortality, stroke, cardiac events, heart failure, peripheral arterial disease, and chronic kidney disease). We extracted sex specific adjusted measures of relative risk (hazard ratios, relative risks, and odds ratio) and 95% confidence intervals. We used the maximally adjusted relative risk that was available and risk estimates corresponding to the longest period of follow-up. For cohorts that had multiple reports of the same outcome, we used the report with the largest number of events. Study quality was assessed with the Newcastle-Ottawa scale for cohort studies.

Statistical analysis
For the primary analysis, we derived a ratio of relative risks with 95% confidence intervals of AF for each outcome in women compared with men, as previously described. This relative risk ratio for each study was then pooled with inverse variance weighted random effects meta-analysis. We also pooled relative risks for men and women separately. For one study, which reported separate hazard ratios for men and women in different age groups, we first used inverse variance weighted fixed effects meta-analysis to generate a summary hazard ratio for men and for women. We used funnel plots to examine if publication bias seemed to be present for outcomes that had at least 10 studies present (all cause mortality and stroke). If publication bias was present, we used the trim and fill method to adjust for publication bias. Heterogeneity was quantified with the I^2 statistic and the Q test. P≤0.05 was considered significant.

To estimate the difference in absolute risks associated with AF between women and men, we multiplied estimated sex specific excess incidence rates for all cause mortality, cardiovascular mortality, coronary heart disease, coronary heart disease mortality as an incidence rate for the composite of coronary heart disease death and non-fatal myocardial infarction could not be obtained), stroke, and heart failure in the United Kingdom general population by sex specific associations of each outcome with AF. The relative risk associated with each outcome in women was calculated by multiplying the pooled ratio of relative risks by the relative risk in men. We then subtracted the excess risk in men from the excess risk in women to estimate the difference in absolute risks associated with AF between men and women. Confidence intervals were derived through simulation with 10 000 draws from the distribution of the men’s relative risk and ratio of relative risks performed.

Sensitivity analyses
We undertook seven sensitivity analyses to determine if the ratio of relative risks in women versus men for mortality and stroke differed by methodological and study characteristics. Firstly, we stratified studies by whether AF was ascertained through electrocardiography at baseline or through medical records. Secondly, we stratified by region (Europe versus non-Europe). For these two stratified analyses (which stratified on categorical variables), we performed tests for interactions between subgroups. Thirdly, we stratified by size of the study (>100 000 versus <100 000 participants) to examine whether the results were consistent we included two large studies (each with more than 100 000 participants). Fourthly, we stratified by baseline year of enrollment of each cohort (1990 and before versus 1991 or later). Fifthly, we stratified by length of follow-up (<10 versus >10 years). Sixthly, we stratified by median age (≤65 versus >65 at baseline). Finally, we stratified studies...
by the ratio of the event rate in women to men to examine whether our results were influenced by potentially lower absolute risk of outcomes in women than men. For the five analyses that stratified on continuous variables we performed tests for trend using meta-regression. The seven sensitivity analyses were restricted to stroke and all cause mortality because there were too few studies to conduct sensitivity analyses for other outcomes. All statistical analyses were conducted with R version 3.0.

Patient involvement
No patients were involved in setting the research question or the outcome measures, nor were they involved in the design and implementation of the study. There are no plans to involve patients in dissemination.

Results
The systematic search identified 3635 studies, of which 268 were examined in the full text review (fig 1) and 238 were excluded. Accordingly, we included 30 cohort studies. None of these studies reported sex specific associations for either peripheral arterial disease or chronic kidney disease. Twenty studies provided published sex specific associations, while 10 studies provided unpublished associations.

Table 1 shows the characteristics of the included studies. Ascertainment of AF status was through electrocardiography or continuous monitoring in 15 studies, medical records in eight studies, and a combination in six studies. One study did not report the method of ascertainment. Quality of included studies, as assessed by the Newcastle-Ottawa Scale, was high (appendix table A).

Studies included a total of 4 371 714 participants, 66 511 with AF (not counting one study34 with an overlapping cohort as a second study24). Twenty six studies reported the number of events. Of these, 14 studies reported on all cause mortality (18 563 events), four studies on cardiovascular mortality (7702 events), 11 studies reported on stroke (83 030 events), six studies on cardiac events (3583 events), and three studies on heart failure (27 468 events). Four additional studies reported relative risks for all cause mortality, cardiovascular mortality, and stroke associated with AF but did not report the number of events. Appendix table B shows pooled incidence rates for studies that reported number of events for men and women separately are provided.

Risk of cardiovascular disease and all cause mortality in women versus men
The pooled relative risk of all cause mortality for individuals with AF compared with those without AF was higher in women than in men (relative risk 1.69 (95% confidence interval 1.50 to 1.90) v 1.47 (1.32 to 1.65); fig 2). The pooled ratio of relative risks for women versus men showed a 12% greater risk of all cause mortality associated with AF in women than in men (relative risk ratio 1.12, 95% confidence interval 1.07 to 1.17; fig 3). Although heterogeneity was observed in the relative risk of all cause mortality associated with AF in both women and men (P=0.001 and P=0.001, respectively, P<0.001; fig 2), no significant heterogeneity was observed in the pooled ratio of relative risks (P=0.2%, P=0.43; fig 3).

The relative risk of stroke was also greater in women than in men (relative risk 4.05 (95% confidence interval 2.52 to 6.50) v 1.77 (1.40 to 2.24); fig 4). When we pooled the ratios of relative risks, AF was observed to be associated with twice the relative risk of stroke in women than in men (relative risk ratio 1.99, 95% confidence interval 1.46 to 2.71; fig 5). There was significant heterogeneity between studies (I²=73%, P<0.001).

AF was associated with a higher relative risk of cardiovascular mortality in women than in men (relative risk ratio 1.93, 95% confidence interval 1.44 to 2.60; fig 6; appendix fig A), with little heterogeneity observed between studies (I²=8%), and was associated with a 55% higher relative risk of cardiac events (cardiac death or non-fatal myocardial infarction) in women versus men (1.55, 1.15 to 2.08; fig 6; appendix fig B). This was consistent when we restricted our analysis to three studies that reported only myocardial infarction, excluding the one study that reported sudden cardiac death30 (1.64, 1.15 to 2.34). AF was also associated with an increased risk of heart failure in women compared with men (1.16, 1.07 to 1.27; appendix fig C).

When we looked at events per 1000 patient years, corresponding absolute risk increases in outcomes associated with AF in women compared with men were 1.8 (95% confidence interval 1.1 to 2.6) for all cause
### Table 1: Characteristics of included cohort studies that reported associations between atrial fibrillation (AF) and death or cardiovascular events in men and women

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Baseline year(s)</th>
<th>AF ascertainment</th>
<th>Total No (with AF)</th>
<th>No of women</th>
<th>Age (years)</th>
<th>Follow-up (years)</th>
<th>No of individuals at baseline with</th>
<th>Maximum adjustment available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andersson 2016</td>
<td>Sweden</td>
<td>1995-2008</td>
<td>Medical records</td>
<td>21987 (9519)</td>
<td>6816</td>
<td>59</td>
<td>NA</td>
<td>NA</td>
<td>Matched by sex, adjusted for age, comorbidities excluded</td>
</tr>
<tr>
<td>Bejot et al, 2009</td>
<td>France</td>
<td>1985-2006</td>
<td>ECG</td>
<td>3064 (572)</td>
<td>1615</td>
<td>75</td>
<td>2.0</td>
<td>620</td>
<td>3064 NA Age, hypertension, smoking, diabetes, ECG left ventricular hypertrophy, vascular disease</td>
</tr>
<tr>
<td>Benjamin 1998</td>
<td>US</td>
<td>1948</td>
<td>ECG</td>
<td>1863 (621)</td>
<td>975</td>
<td>75</td>
<td>25.6</td>
<td>252</td>
<td>213 201 Age, diabetes mellitus, hypertension, hypercholesterolemia, smoking habit, family history of CAD, MI, PCI, CABG, angina, LBBB, medication, chest pain, exercise ECG, METs, peak SBP, heart rate</td>
</tr>
<tr>
<td>Bouzas-Mosquera et al, 2010</td>
<td>Spain</td>
<td>1995-2008</td>
<td>ECG</td>
<td>17 100 (619)</td>
<td>6999</td>
<td>64</td>
<td>6.5</td>
<td>2963</td>
<td>NA Age, diabetes mellitus, hypertension, hypercholesterolemia, smoking habit, family history of CAD, MI, PCI, CABG, angina, LBBB, medication, chest pain, exercise ECG, METs, peak SBP, heart rate</td>
</tr>
<tr>
<td>Chamberlain et al, 2011</td>
<td>US</td>
<td>1983-2006</td>
<td>ECG and medical records</td>
<td>1664 (553)</td>
<td>905</td>
<td>76</td>
<td>4.0</td>
<td>353 NA</td>
<td>1664 Age, BMI, year of heart failure diagnosis, smoking status, derived NYHA class, estimated glomerular filtration rate, anaemia, hypertension, diabetes mellitus, COPD, MI, medication</td>
</tr>
<tr>
<td>Chao 2012</td>
<td>Taiwan</td>
<td>2000-09</td>
<td>Medical records</td>
<td>9119 (829)</td>
<td>3520</td>
<td>45</td>
<td>4.8</td>
<td>NA NA 201</td>
<td>Age, dyslipidaemia, CKD, asthma, malignancy, liver cirrhosis, autoimmune diseases (stepwise regression)</td>
</tr>
<tr>
<td>Chen 2013</td>
<td>US</td>
<td>1989</td>
<td>ECG and medical records</td>
<td>20 918 (2352)</td>
<td>11 713</td>
<td>59</td>
<td>13.1</td>
<td>1786 NA</td>
<td>927 Age, race, field centre, heart rate, smoking status, BMI, hypertension, diabetes mellitus, coronary heart disease</td>
</tr>
<tr>
<td>D’Agostino 1994</td>
<td>US</td>
<td>1948</td>
<td>ECG</td>
<td>5734 (140)</td>
<td>3362</td>
<td>66</td>
<td>10</td>
<td>NA 0 NA 201</td>
<td>Age, systolic blood pressure, antihypertensive therapy, cardiovascular disease, left ventricular hypertrophy, smoking, diabetes, ischemic heart disease, obesity</td>
</tr>
<tr>
<td>Friberg 2004</td>
<td>Denmark</td>
<td>1976-78</td>
<td>ECG</td>
<td>29 310 (276)</td>
<td>16 314</td>
<td>58</td>
<td>4.70</td>
<td>763 0 NA 201</td>
<td>Age, arterial hypertension, SBP, diabetes, myocardial infarction, left ventricular hypertrophy, smoking, FEV1, smoking, alcohol</td>
</tr>
<tr>
<td>Genovesi et al, 2009</td>
<td>Italy</td>
<td>2003-06</td>
<td>ECG</td>
<td>476 (127)</td>
<td>199</td>
<td>NA</td>
<td>3.0</td>
<td>112 NA 45</td>
<td>Age, ischaemic heart disease, diabetes</td>
</tr>
<tr>
<td>Guize 2007</td>
<td>France</td>
<td>1972-1988</td>
<td>ECG</td>
<td>154 070 (298)</td>
<td>55 109</td>
<td>51</td>
<td>15.2</td>
<td>NA NA 201</td>
<td>Age, cardiomyopathy, left ventricular hypertrophy, blood pressure, cholesterol, glycaemia, BMI, smoking, alcohol, vital capacity</td>
</tr>
<tr>
<td>Hamaguchi 2009</td>
<td>Japan</td>
<td>2004-05</td>
<td>ECG</td>
<td>2659 (937)</td>
<td>1069</td>
<td>71</td>
<td>2.4</td>
<td>851 399 2659</td>
<td>Age, cause of heart failure, medical history, serum creatinine, haemoglobin and BNP levels, LVEF, medication use</td>
</tr>
<tr>
<td>Hermann et al, 2013</td>
<td>Germany</td>
<td>2000-03</td>
<td>ECG</td>
<td>4180 (52)</td>
<td>2212</td>
<td>59.2</td>
<td>7.9</td>
<td>0 0 0 201</td>
<td>Age, systolic blood pressure, LDL and HDL cholesterol, diabetes mellitus, and smoking</td>
</tr>
<tr>
<td>Hippisley-Cox et al, 2010</td>
<td>UK</td>
<td>1994-2010</td>
<td>Medical records</td>
<td>2 343 759 (12 031)</td>
<td>1 189 845</td>
<td>48.1</td>
<td>7.0</td>
<td>0 0 0 201</td>
<td>BMI, SBP, cholesterol, deprivation, ethnicity group, family history of coronary heart disease, type 2 diabetes, treated hypertension, rheumatoid arthritis, atrial fibrillation, chronic renal disease (age used as underlying time variable)</td>
</tr>
<tr>
<td>Hippisley-Cox 2013</td>
<td>England and Wales</td>
<td>1998-2012</td>
<td>Medical records</td>
<td>3 549 478 (15 371)</td>
<td>1 801 370</td>
<td>45</td>
<td>7 9 9 5 6 2 4 9 201</td>
<td>Age, BMI, BP, cholesterol, deprivation, smoking, ethnicity, vascular disease, other comorbidities</td>
<td></td>
</tr>
<tr>
<td>Hippisley-Cox et al, 2015</td>
<td>UK</td>
<td>1998-2014</td>
<td>Medical records</td>
<td>4 378 06 (13 953)</td>
<td>192 896</td>
<td>60</td>
<td>NA</td>
<td>NA NA 201</td>
<td>Age, cholesterol/HDL ratio, deprivation, duration of diabetes, smoking status, ethnicity, type 1 diabetes, cardiovascular disease, chronic renal disease</td>
</tr>
</tbody>
</table>

(Continued)
## Table 1 | Characteristics of included cohort studies that reported associations between atrial fibrillation (AF) and death or cardiovascular events in men and women

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Baseline year(s)</th>
<th>AF ascertainment</th>
<th>Total No (with AF)</th>
<th>No of women</th>
<th>Age (years)</th>
<th>Follow-up (years)</th>
<th>No of individuals at baseline with</th>
<th>Maximum adjustment available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iwahana 2011&lt;sup&gt;36&lt;/sup&gt;</td>
<td>Japan</td>
<td>1992-95</td>
<td>ECG</td>
<td>10929 (54)</td>
<td>6782</td>
<td>56</td>
<td>10.7</td>
<td>NA</td>
<td>0 NA</td>
</tr>
<tr>
<td>Kaarisalo 1997&lt;sup&gt;37&lt;/sup&gt;</td>
<td>Finland</td>
<td>1983-92</td>
<td>ECG and medical records</td>
<td>2635 (767)</td>
<td>1880</td>
<td>82</td>
<td>1</td>
<td>457</td>
<td>2635</td>
</tr>
<tr>
<td>Nakayama 1997&lt;sup&gt;38&lt;/sup&gt;</td>
<td>Japan</td>
<td>1977</td>
<td>ECG</td>
<td>2302 (NA)</td>
<td>1341</td>
<td>NA</td>
<td>15.5</td>
<td>NA</td>
<td>0 NA</td>
</tr>
<tr>
<td>Ohsawa 2007&lt;sup&gt;39&lt;/sup&gt;</td>
<td>Japan</td>
<td>1980</td>
<td>ECG</td>
<td>9483 (60)</td>
<td>5329</td>
<td>51</td>
<td>19</td>
<td>NA</td>
<td>0 NA</td>
</tr>
<tr>
<td>Rukizoke et al. 2002&lt;sup&gt;40&lt;/sup&gt;</td>
<td>UK</td>
<td>1996</td>
<td>Medical records</td>
<td>6035 (1035)</td>
<td>NA</td>
<td>NA</td>
<td>2</td>
<td>NA</td>
<td>NA NA</td>
</tr>
<tr>
<td>Saposnik et al., 2011&lt;sup&gt;41&lt;/sup&gt;</td>
<td>US</td>
<td>2002-04</td>
<td>Medical records</td>
<td>8223 (1405)</td>
<td>3901</td>
<td>72</td>
<td>1</td>
<td>1936</td>
<td>8223</td>
</tr>
<tr>
<td>Soliman et al., 2014&lt;sup&gt;42&lt;/sup&gt;</td>
<td>US</td>
<td>2003-07</td>
<td>ECG and self-reported history</td>
<td>23928 (1631)</td>
<td>13937</td>
<td>64</td>
<td>4.5</td>
<td>O</td>
<td>NA</td>
</tr>
<tr>
<td>Soliman et al., 2015&lt;sup&gt;43&lt;/sup&gt;</td>
<td>US</td>
<td>1987-89</td>
<td>ECG and medical records</td>
<td>14462 (1545)</td>
<td>8172</td>
<td>54</td>
<td>21.6</td>
<td>0</td>
<td>249</td>
</tr>
<tr>
<td>Stewart et al., 2002&lt;sup&gt;44&lt;/sup&gt;</td>
<td>Scotland</td>
<td>1972-76</td>
<td>ECG</td>
<td>15406 (100)</td>
<td>8354</td>
<td>54</td>
<td>20</td>
<td>NA</td>
<td>197</td>
</tr>
<tr>
<td>Strotecky et al., 2013&lt;sup&gt;45&lt;/sup&gt;</td>
<td>Switzerland</td>
<td>2007-11</td>
<td>Continuous monitor</td>
<td>389 (131)</td>
<td>224</td>
<td>83</td>
<td>1</td>
<td>238</td>
<td>30</td>
</tr>
<tr>
<td>van Wijk et al., 2007&lt;sup&gt;46&lt;/sup&gt;</td>
<td>Netherlands</td>
<td>1986-93</td>
<td>ECG</td>
<td>2659 (186)</td>
<td>946</td>
<td>66</td>
<td>101</td>
<td>277</td>
<td>2659</td>
</tr>
<tr>
<td>Wolf et al., 1998&lt;sup&gt;47&lt;/sup&gt;</td>
<td>US</td>
<td>1989</td>
<td>Medical records</td>
<td>26753 (13558)</td>
<td>14416</td>
<td>NA</td>
<td>3</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Wolle et al., 2006&lt;sup&gt;48&lt;/sup&gt;</td>
<td>UK and Barbados</td>
<td>1995-2003</td>
<td>NA</td>
<td>848 (64)</td>
<td>464</td>
<td>69.6</td>
<td>1.7</td>
<td>94</td>
<td>848</td>
</tr>
</tbody>
</table>

NA= not available, ECG= electrocardiogram, CKD= chronic kidney disease, BP= blood pressure, BMI= body mass index, SBP= systolic blood pressure, DBP= diastolic blood pressure, eGFR= estimated glomerular filtration rate, CRP= C reactive protein, LBBB= left bundle branch block, AMI= acute myocardial infarction, COPD= chronic obstructive pulmonary disease, FEV= forced expiratory volume, LVEF= left ventricular ejection fraction, BNP= B type natriuretic peptide, NYHA= New York Heart Association, IHD= ischaemic heart disease.
mortality, 4.3 (1.9 to 7.5) for cardiovascular mortality, 3.1 (1.1 to 6.1) for stroke, 0.6 (0.03 to 1.3) for cardiac events, and 6.1 (2.1 to 12.7) for heart failure.

Sensitivity analyses
Ratios of relative risk for all cause mortality were broadly consistent in seven sensitivity analyses (appendix fig D). Results of tests of interaction were non-significant when we stratified studies by ascertainment of AF through electrocardiography versus use of medical records/self reported history and region (Europe, non-Europe; all P>0.05 for interaction). Results of tests for trend by number of participants, baseline year, and ratio of mortality rate in women to men were also non-significant. Ratios of relative risk, however, declined with increasing length of follow-up and increasing age (appendix fig D).

For ratios of relative risks for stroke, results of tests of interaction by ascertainment method and region were non-significant (appendix fig E). Results of tests for trend by number of participants, baseline year, length of follow-up, and median age were also non-significant. Relative risks were significantly higher in studies with a lower ratio of absolute rate of stroke in women compared with men (P=0.027 for trend for ratio of stroke rate in women to men). When we restricted the meta-analysis to three studies with a ratio of stroke rate in women to men greater than 1 (that is, a greater absolute rate of stroke in women than men), however, atrial fibrillation continued to be associated with a higher relative risk of stroke in women than men (1.47, 95% confidence interval 1.18 to 1.83).

We found no evidence of publication bias for all cause mortality (appendix fig F), though we observed significant publication bias for stroke (appendix fig G; P=0.002). When we used the trim and fill method to control for publication bias, AF was associated with a non-significantly higher risk of stroke in women than in men (relative risk ratio 1.28, 95% confidence interval 0.94 to 1.73).

Discussion
In this systematic review and meta-analysis of 30 studies with 4,371,714 participants, we observed atrial fibrillation (AF) to be a significantly greater risk factor for death and cardiovascular disease in women than in men. AF was associated with a higher relative risk of all cause mortality, stroke, cardiovascular mortality, cardiac events, and heart failure in women compared with men.

Comparison with previous individual studies
Previous studies have presented conflicting evidence on the effect of AF on the risk of death and cardiovascular disease in women. Of the 19 studies on the association of AF with the risk of all cause mortality (fig 2) we included in our analysis, the ratio of relative risks was greater than one but not significant for 11 studies. When we pooled these studies using random effects meta-analysis, the estimate for all cause mortality was significant, indicating that individual studies were underpowered to detect a differential effect of AF on risk of all cause mortality in women compared with men. Similarly, six of the 13 studies that reported a sex specific association of AF with stroke did not detect a significant interaction between women and men (fig 3). When we pooled these studies, however, we observed a significant ratio of relative risks, again indicating a lack of power of some previous individual studies to detect an interaction by sex.
Recent meta-analyses have shown that type 2 diabetes is a greater risk factor for coronary heart disease (ratio of relative risk 1.44, 95% confidence interval 1.27 to 1.63) and for stroke (1.27, 1.10 to 1.46) in women than in men and that type 1 diabetes is also a greater risk factor for death and cardiovascular disease in women. Evidence of an increased risk of coronary heart disease associated with type 2 diabetes in women has been cited in European Society of Cardiology guidelines for the treatment of cardiovascular disease in patients with type 2 diabetes. Similarly, evidence of an increased risk of stroke associated with type 2 diabetes in women has been included in American Heart Association/American Stroke Association guidelines for stroke prevention in women. Our results show that AF is also a greater risk factor for death and cardiovascular disease in women than in men and extend these previous works showing that women experience the effects of some key risk factors for cardiovascular disease differently to men.

It is unclear what could cause the observed differences in risk of mortality and cardiovascular disease associated with AF between women and men. One possibility is that women with AF are undertreated relative to men. The results of a cohort study of Canadian patients with AF enrolled in 1990-94 support this hypothesis. Canadian women were half as likely as Canadian men to receive warfarin. Analyses of more contemporary cohorts, including a global registry of 17 814 patients with AF and an analysis of 83 513 patients with AF in Quebec, however, showed no differences in use of anticoagulants between men and women with AF. It is therefore unlikely that broad differences in treatment between the sexes are responsible for the increased relative risks we observed in women. Physiological or psychosocial differences between women and men could result in differential effects of AF on cardiovascular risk. For example, women are at a higher risk of torsade de pointes, an often lethal adverse event of antiarrhythmic drugs prescribed for AF. Response to oral anticoagulants could also differ between the sexes, with a higher risk of bleeding observed among women. Future research is needed to distinguish if one or many of these potential mechanisms underlie the differential effects of AF observed in our analysis.

**Strengths and limitations**

This analysis has several strengths. Firstly, as a systematic review and meta-analysis of all available studies of AF and risk of death and cardiovascular disease in women compared with men, it has greater power than any of the included individual studies to detect differences. This is evident in the meta-analysis of all cause mortality, in which 16 of the included 19 studies did not detect a difference. Secondly, we included only studies that reported the effect of AF on risk of cardiovascular disease and death separately in men and women. This ensured that our primary analysis (the ratio of relative risks) was a within study comparison, minimising the effect of heterogeneity between studies. Thirdly, we included only cohort studies that were adequately adjusted (prespecified requirement to adjust by at least age and history of cardiovascular disease) and that had a minimum of 100 participants with six months’ follow-up to reduce the risk of confounding and small study effects. Fourthly, pooled ratios of relative risk for all cause mortality or stroke were broadly consistent in several different sensitivity analyses.

This analysis also has several limitations. Firstly, while we attempted to contact and acquire unpublished data from eligible cohorts, our results might be influenced by publication bias because studies that detect an interaction between AF and risk of death and cardiovascular disease by sex might be more likely to be published. While there was evidence of publication bias for stroke, however, we found no evidence of this for all cause mortality. Furthermore, use of trim and fill procedures resulted in a non-significantly increased effect of AF on risk of stroke in women compared with in men similar in magnitude to other outcomes. Secondly, as a meta-analysis of observational studies, sex differences in the association of AF with risk of death and cardiovascular disease might be caused by unobserved confounding between sexes. For example, women might have had a greater number of comorbidities at the time of diagnosis of AF, which could not be fully adjusted for. However, we required included studies to adjust for, at minimum, age and presence of cardiovascular comorbidities, and we used the maximally adjusted model available. Thirdly, many of the studies had differences in design, duration of follow-up, outcome ascertainment, and populations. Indeed, we observed a greater absolute increase in cardiovascular death than all
Maximally adjusted pooled women-to-men ratio of relative risks for all cause mortality, CVD (cardiovascular) mortality, stroke, cardiac events, and heart failure, comparing individuals with and without AF. Area of each square is proportional to inverse variance of estimate. Horizontal lines indicate 95% confidence intervals.

**Fig 4** | Maximally adjusted relative risk for stroke for individuals with and without AF by sex. Area of each of each square is proportional to inverse variance of estimate. Horizontal lines indicate 95% confidence intervals.

**Fig 5** | Maximally adjusted women-to-men ratio of relative risks for stroke for individuals with and without AF. Area of each square is proportional to inverse variance of estimate. Horizontal lines indicate 95% confidence intervals.

**Fig 6** | Maximally adjusted pooled women-to-men ratio of relative risks for all cause mortality, CVD (cardiovascular) mortality, stroke, cardiac events, and heart failure, comparing individuals with and without AF. Area of each square is proportional to inverse variance of estimate. Horizontal lines indicate 95% confidence intervals.

**Table 1** | Relative risk for stroke for individuals with and without AF.

**Table 2** | Ratio of relative risk for stroke for individuals with and without AF.

**Table 3** | Ratio of relative risk for all cause mortality, CVD (cardiovascular) mortality, stroke, cardiac events, and heart failure.

**Table 4** | Study of relative risk for stroke for individuals with and without AF.

**Table 5** | Ratio of relative risk for all cause mortality, CVD (cardiovascular) mortality, stroke, cardiac events, and heart failure.

**Table 6** | Study of ratio of relative risk for stroke for individuals with and without AF.

**Table 7** | Ratio of relative risk for all cause mortality, CVD (cardiovascular) mortality, stroke, cardiac events, and heart failure.

**Table 8** | Study of ratio of relative risk for stroke for individuals with and without AF.

**Table 9** | Ratio of relative risk for all cause mortality, CVD (cardiovascular) mortality, stroke, cardiac events, and heart failure.
of AF should also consider the differential effects of AF by sex. Future research should be encouraged to determine the underlying causes of the observed sex differences.

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Data sharing. Data and code are available from the lead author on request.

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41 Ryden L, Grant PJ, Anker SD et al. ESC Guidelines on diabetes, pre-diabetes, and cardiovascular diseases developed in collaboration with the EASD: the Task Force on diabetes, pre-diabetes, and cardiovascular diseases of the European Society of Cardiology (ESC) and developed in collaboration with the European Association for the Study of Diabetes (EASD). Eur Heart J 2013;34: 3035-80. doi:10.1093/eurheartj/eht124. 23996285


