Introduction

Stroke is projected to remain a major cause of death and disability worldwide over the next 20 years. The burden is particularly large among women, given their longer life expectancy and higher stroke rates in older age compared with men, along with worse physical functioning post-stroke. The inverse relationship between socioeconomic status (SES) and stroke is well-established, but has been studied to a lesser extent in women (especially younger women) than men. Many earlier studies included men only and examined stroke mortality rather than incidence, whereas recent studies have focused on area-based SES measures and stroke risk. Studies of individual SES measures that include women have raised questions regarding potential gender and age differences. Some studies indicate that the SES effect may be weaker in women, whereas others suggest the opposite. The SES–stroke gradient varies with age, being less strong, or for some SES measures, absent, in the elderly population. Few studies have simultaneously compared different SES indicators and stroke risk. Furthermore, homeownership, which has been inversely linked to mortality risk, has not, to our knowledge, been studied with respect to cerebrovascular risk.

The mechanism(s) by which SES affects stroke risk remains unclear. Although some studies have found that it is largely explained by traditional risk factors, others report that significant excess risk remains in the lowest-SES group. This may be due to differences in age-groups, gender and study populations, or inadequate control of confounding factors. Previous studies have relied on baseline measures of confounders only, without repeat data collection on potential explanatory risk factors. A recent study demonstrated that inclusion of time-varying covariates accounted for more of the relationship between SES and cardiovascular mortality than baseline measures only. Other potential mediating factors such as mental health and hysterectomy have generally not been included in studies of younger women. Recent evidence also suggests there are cultural differences in the extent to which conventional risk factors may explain disease risk.

We investigated the associations between individual measures of SES and incident stroke risk in a population-based longitudinal study of mid-aged women, and determined the extent to which lifestyle, biological and psychosocial factors attenuated these associations.

Methods

Study setting

We included participants from the Australian Longitudinal Study on Women’s Health (ALSWH), a national population-based study of women born in 1921–26, 1946–51 and 1973–78. Women were randomly selected from the Medicare database, which covers all citizens and permanent residents of Australia, including refugees and immigrants. Women born in 1946–51 were surveyed in 1996 (S1), 1998 (S2), 2001 (S3), 2004 (S4), 2007 (S5) and 2010 (S6). Full
details of the recruitment and response rates are reported elsewhere.\textsuperscript{17} ALSWH is linked to the national death register, allowing identification of cause of death.

**Study population**

In this study, we included women from the 1946–51 cohort. At S1, this included 13 715 women, with 12 338 (90\%) also returning at S2. For these analyses, we followed women from S2 onwards because not all variables of interest were collected at S1. We excluded women who reported a history of stroke at S1 or S2; did not return any survey subsequent to S2, or did return them but did not complete the question(s) on stroke occurrence or did not have information on any SES measure.

**Stroke**

Incident stroke was determined from self-report at S3–S6, when women were asked 'In the past 3 years have you been diagnosed or treated for stroke?', and cause of death through linkage to the National Death Index. Stroke deaths were determined using the International Statistical Classification of Diseases and Related Health Problems 10th revision codes from the principal or secondary diagnosis fields of death certificate data: I60–I60.9, I61.0–I61.9, I63.0–I63.9 and I64.

**Socioeconomic status**

From S1, we included education level (university degree or higher, certificate/diploma, trades and apprentice, high school certificate, school certificate or no formal qualifications); age at leaving school (≥17; 15–16 or ≤14) and own occupation and head of household occupation (manager/professional, associate professional, trades and administrative, service and sales or manual worker/no paid work). From S2, we included homeownership and how individuals manage on their income (easy/not bad, sometimes difficult, or always difficult/impossible).

**Lifestyle, biological and psychosocial risk factors for stroke**

Presence of lifestyle and biological risk factors for stroke were determined at each survey. Smoking was dichotomized into current smoker or not. Body mass index in kg/m\textsuperscript{2} was calculated from self-reported weight and height. Physical activity was assessed using questions from the Australian physical activity survey\textsuperscript{18}, and defined according to minutes of moderate activity per week: nil/sedentary (<0–10 min/wk), low (11–150), moderate (151–300) and high (>300). Alcohol intake was defined in light of the Australian defined according to minutes of moderate activity per week: nil/sedentary (CESD-10)\textsuperscript{20} score of ≥10, self-reported anti-depressant use in the past month.

**Statistical analyses**

We used generalized estimating equation regression models for binary outcome data (using an unstructured correlation structure and a logit link function) to calculate age-adjusted odds ratios (ORs) with 95\% confidence intervals (CIs) for the relationship between SES and first stroke occurrence at surveys 3–6. Women who reported a stroke did not contribute to the analysis thereafter.

We then focused on the SES measures that were statistically significantly associated with stroke occurrence, as indicated by a \(P\)-value of <0.05 from a Wald test, to examine the effect of adjusting for potential mediating factors. We performed multiple imputation using MICE commands in Stata for covariates with missing values (excluding education and homeownership), as the proportion of women with missing data on one or more covariates ranged from 6 to 14\% across surveys. We performed 20 multiple imputations, in keeping with the recommendation that the number of imputations should at least equate to the proportion of participants with missing data.\textsuperscript{21} The results of the analyses using imputed data were similar to those of the complete covariate analyses (see Supplementary table S1), but had improved statistical power through inclusion of more stroke outcomes, therefore we present the results of the former. We first adjusted for age and SES (either homeownership or education) in Model 1. To examine possible mediating pathways through which SES affects stroke risk, we separately adjusted for groups of potential mediators in Models 2–4 to determine the extent to which lifestyle, biological and psychosocial factors attenuate the effect of SES. We then adjusted for lifestyle and biological factors together in Model 5 to examine whether lifestyle factors simply operate through biological factors such as hypertension, or whether lifestyle independently affects stroke risk. We then adjusted for all groups of potential mediators in Model 6. Lifestyle and biological factors and depression were included as time-varying covariates. Time lags were used so that each factor predicted stroke occurring at the subsequent survey. Using the non-imputed data, we determined model fit at each time point using the Hosmer–Lemeshow goodness-of-fit test, which indicated that the model was well-calibrated.

We determined the contribution of mediating factors (lifestyle, biological and psychosocial factors) to explaining the relationship between SES measures and stroke by calculating the percentage attenuation in the \(\beta\) coefficient for SES after including the risk factor(s) in the model adjusted for age and other SES measures associated with stroke \(\{100 \times (\beta_{\text{SES+age+risk factor(s)}} - \beta_{\text{SES+age}}) \}/\beta_{\text{SES}}\) where \(\beta = \log(\text{OR})\).\textsuperscript{22}

Analyses were performed using Stata 12.0.

**Results**

We included 11 468 women from S2 (figure 1), who had a mean age of 49.5 (±1.46 SD) years. During follow-up, 177 first-ever strokes occurred, five of which were fatal, giving a stroke incidence and prevalence of 1.5\%.

**SES and stroke risk**

Stroke risk increased with decreasing education level (table 1). Similarly, school-leaving age was linearly associated with stroke risk, with women who left at a younger age having an increased stroke risk. This was explained by education level, as the association disappeared after adjusting for education (data not shown). Women’s occupation, head of household occupation and managing on income were not associated with stroke risk (table 1). Non-homeowners had a 2-fold increased risk of stroke compared with homeowners. This was not explained by education, adjustment for which only slightly attenuated the association (tables 1 and 2).
Adjustment for groups of mediators

Education and homeownership were strongly associated with lifestyle, biological and psychosocial factors at S2, apart from heart disease (Supplementary tables S2 and S3). However, presence of heart disease beyond S2 was statistically significantly associated with both SES measures.

After adjusting for age, homeownership and lifestyle, the overall relationship between education and stroke became statistically nonsignificant ($P = 0.098$; table 2), although a strong association remained in the lowest education group (OR: 2.03, 95% CI: 1.11–3.73). After adjusting for biological factors, the association between education and stroke remained statistically significant. Adjustment for depressive symptoms and marital status also attenuated but did not remove this association. After adjusting for all factors, there remained an increased stroke risk in those with a trade or an apprenticeship (OR: 2.33, 95% CI: 1.04–5.25), and a residual increased risk in the lowest education group in particular, although this was not statistically significant.

Adjustment for each group of lifestyle, biological and psychosocial factors attenuated, but did not remove, the association between homeownership and stroke. After adjusting for all factors, non-homeownership increased odds of stroke by 63% (OR: 1.63, 95% CI: 1.12–2.38; table 2).

Adjustment for individual and combined factors

Adjusting for all risk factors explained more than one-third of the association between education and stroke, and just less than one-third of the association between homeownership and stroke (table 3). Of the lifestyle factors, adjusting for alcohol reduced the association between the lowest education level and stroke by the highest amount (9.9%), reflecting the protective effect of moderate alcohol intake on stroke risk. Among biological factors, adjustment for history of hysterectomy or oophorectomy reduced the association by the greatest amount (12.2%).

Discussion

Education level and homeownership, but not occupation or managing on income, were associated with stroke incidence in mid-aged women. When comparing the lowest versus highest education level, there was a 2.5-fold increased stroke risk. Just more than one-third of this association was explained by lifestyle, biological and psychosocial factors. Non-homeownership was strongly associated with increased stroke risk even after adjusting for all confounders. Lifestyle and psychosocial factors were more...
important than biological factors in partially explaining the association between home ownership and stroke.

**Comparison with previous studies**

Our findings on education are consistent with a Swedish study of mid-aged women, which found an excess stroke risk in lower education groups that was largely explained by lifestyle and biological stroke risk factors, particularly smoking and alcohol intake. In our study, heart disease and hysterectomy/oophorectomy were also biological mediators of the relationship between education and stroke. Residual confounding through lack of adjustment for these factors in the Swedish study might explain why a statistically significant relationship remained between the lowest education level and stroke.

### Table 2: Associations between socioeconomic status indicators and incident stroke, adjusted for groups of potential mediators

<table>
<thead>
<tr>
<th>Socioeconomic status indicator</th>
<th>Model 1 (95% CI)</th>
<th>Model 2 (95% CI)</th>
<th>Model 3 (95% CI)</th>
<th>Model 4 (95% CI)</th>
<th>Model 5 (95% CI)</th>
<th>Model 6 (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University degree or higher</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Certificate/diploma</td>
<td>1.54 (0.81–2.92)</td>
<td>1.44 (0.76–2.73)</td>
<td>1.52 (0.80–2.87)</td>
<td>1.41 (0.75–2.68)</td>
<td>1.35 (0.71–2.57)</td>
<td>1.35 (0.71–2.56)</td>
</tr>
<tr>
<td>Trades and apprentice</td>
<td>2.72 (1.22–6.08)</td>
<td>2.45 (1.10–5.50)</td>
<td>2.68 (1.20–6.00)</td>
<td>2.49 (1.11–5.57)</td>
<td>2.32 (1.03–5.21)</td>
<td>2.33 (1.04–5.25)</td>
</tr>
<tr>
<td>High school certificate</td>
<td>1.43 (0.75–2.74)</td>
<td>1.29 (0.67–2.46)</td>
<td>1.40 (0.73–2.67)</td>
<td>1.34 (0.70–2.56)</td>
<td>1.23 (0.64–2.36)</td>
<td>1.22 (0.64–2.35)</td>
</tr>
<tr>
<td>School certificate</td>
<td>1.58 (0.89–2.82)</td>
<td>1.39 (0.78–2.50)</td>
<td>1.53 (0.86–2.74)</td>
<td>1.43 (0.80–2.55)</td>
<td>1.31 (0.73–2.35)</td>
<td>1.30 (0.72–2.34)</td>
</tr>
<tr>
<td>No formal qualifications</td>
<td>2.57 (1.42–4.65)</td>
<td>2.03 (1.11–3.73)</td>
<td>2.34 (1.29–4.26)</td>
<td>2.20 (1.21–4.01)</td>
<td>1.86 (1.01–3.42)</td>
<td>1.80 (0.97–3.34)</td>
</tr>
<tr>
<td>Owns own home</td>
<td>0.020</td>
<td>0.067</td>
<td>0.029</td>
<td>0.052</td>
<td>0.100</td>
<td>0.118</td>
</tr>
<tr>
<td><strong>P-value</strong></td>
<td>&lt;0.001</td>
<td>0.002</td>
<td>0.005</td>
<td>0.001</td>
<td>0.004</td>
<td>0.010</td>
</tr>
</tbody>
</table>

**Model 1:** Adjusted for age and home ownership or education.
**Model 2:** Model 1 + smoking, BMI, alcohol and physical activity.
**Model 3:** Model 1 + depression and marital status.
**Model 4:** Model 1 + hypertension, diabetes mellitus, heart disease and hysterectomy/oophorectomy.
**Model 5:** Model 1 + smoking, BMI, alcohol, physical activity, hypertension, diabetes mellitus, heart disease and hysterectomy/oophorectomy.
**Model 6:** Adjusted for all factors.

a: Analyses based on 10 820 women.
b: The overall statistical significance of associations between SES and stroke was determined by calculating type III P-values.
c: Owns own home outright or has a mortgage.

### Table 3: Contribution of lifestyle behaviours, biological and psychosocial in explaining the relationship between each of education and home ownership and stroke

<table>
<thead>
<tr>
<th>Model</th>
<th>Education (comparing highest versus lowest level)</th>
<th>Home ownership (no versus yes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>% difference</td>
</tr>
<tr>
<td>Baseline model&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.57 (1.42–4.65)</td>
<td></td>
</tr>
<tr>
<td>Baseline model + adjustment for</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifestyle behaviours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking</td>
<td>2.42 (1.33–4.38)</td>
<td>–6.4</td>
</tr>
<tr>
<td>Alcohol use</td>
<td>2.34 (1.28–4.26)</td>
<td>–9.9</td>
</tr>
<tr>
<td>Body mass index</td>
<td>2.46 (1.35–4.46)</td>
<td>–7.7</td>
</tr>
<tr>
<td>Physical activity</td>
<td>2.39 (1.32–4.33)</td>
<td>–4.6</td>
</tr>
<tr>
<td>Smoking + alcohol use</td>
<td>2.20 (1.20–4.01)</td>
<td>–16.5</td>
</tr>
<tr>
<td>Smoking + physical activity</td>
<td>2.27 (1.25–4.13)</td>
<td>–13.2</td>
</tr>
<tr>
<td>Smoking + alcohol + physical activity</td>
<td>2.09 (1.14–3.82)</td>
<td>–21.9</td>
</tr>
<tr>
<td>All lifestyle behaviours</td>
<td>2.03 (1.11–3.73)</td>
<td>–25.0</td>
</tr>
<tr>
<td>Psychosocial factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td>2.32 (1.28–4.20)</td>
<td>–10.8</td>
</tr>
<tr>
<td>Marital status</td>
<td>2.62 (1.44–4.75)</td>
<td>+2.0</td>
</tr>
<tr>
<td>All psychosocial factors</td>
<td>2.34 (1.29–4.26)</td>
<td>–9.9</td>
</tr>
<tr>
<td>Biological factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>2.52 (1.39–4.56)</td>
<td>–2.1</td>
</tr>
<tr>
<td>Heart disease</td>
<td>2.49 (1.38–4.51)</td>
<td>–2.9</td>
</tr>
<tr>
<td>Diabetes</td>
<td>2.50 (1.38–4.52)</td>
<td>–3.4</td>
</tr>
<tr>
<td>Hysterectomy/oophorectomy</td>
<td>2.29 (1.26–4.15)</td>
<td>–12.2</td>
</tr>
<tr>
<td>Hypertension + heart disease</td>
<td>2.42 (1.34–4.39)</td>
<td>–6.4</td>
</tr>
<tr>
<td>All biological factors</td>
<td>2.20 (1.21–4.01)</td>
<td>–16.5</td>
</tr>
<tr>
<td>All lifestyle + psychosocial factors</td>
<td>1.94 (1.05–3.58)</td>
<td>–29.8</td>
</tr>
<tr>
<td>All Lifestyle + biological factors</td>
<td>1.86 (1.01–3.42)</td>
<td>–34.3</td>
</tr>
<tr>
<td>All biological + psychosocial factors</td>
<td>2.07 (1.13–3.79)</td>
<td>–22.9</td>
</tr>
<tr>
<td>All factors</td>
<td>1.80 (0.97–3.34)</td>
<td>–37.7</td>
</tr>
</tbody>
</table>

*OR = odds ratio; CI = confidence interval.

<sup>a</sup> Percentage attenuation in log OR = 100 × βSES + age − βSES + age + risk factor(s)/βSES + age), where β = log(OR).
Although our finding that the association between education and stroke in our study is partially accounted for by conventional stroke risk factors concurs with previous findings, few studies have examined the separate contribution of different groups of risk factors. We demonstrated that lifestyle probably has a stronger mediating effect than biological factors, highlighting the important role of health behaviours on stroke risk. Our finding that history of hysterectomy or oophorectomy explains some of the relationship between education and stroke risk after accounting for other biological risk factors is novel. Hysterectomy has been shown to be associated with SES and with an increased cardiovascular disease risk. The latter remains a controversial and relatively understudied area. The risk for cardiovascular disease is likely to vary by age, menopausal age, duration and timing of hormone use. One study concluded that women with a hysterectomy have a more adverse cardiovascular risk profile, whereas others suggest that surgical menopause (hysterectomy with oophorectomy) has a direct effect on cardiovascular risk through ovarian failure and subsequent hormone-related changes in the vascular bed. Our findings do suggest that, certainly among mid-aged women, history of hysterectomy/oophorectomy may be associated with stroke independently of hypertension, diabetes and heart disease. We also found that mental health plays a role in the relationship between SES and stroke risk, which is in keeping with studies of older populations, where adjusting for depressive symptoms impacted on SES–stroke risk estimates. Estimates from previous studies that did not adjust for mental health factors are therefore likely to be residually confounded.

After controlling for various potential mediators, we still observed a residual trend for increased stroke risk among lower versus higher education groups, with effect estimates and confidence intervals not excluding the possibility of an association between SES and stroke that is independent of conventional mediating factors. The Swedish study by Kuper et al. is of a similar size to ours, in terms of number of stroke outcomes, and similarly found a residual trend for increased stroke risk among lower educational groups after controlling for mediating factors. Studies of older women also indicate that conventional stroke risk factors only partially account for the relationship between education and stroke.

We found that homeownership was associated with a decreased risk of stroke. In relation to stroke risk, homeownership has generally been studied as part of an SES index rather than as a single SES measure. Homeownership has however been shown to be associated with coronary heart disease and to be associated with broader health outcomes independent of other SES indicators. In a similar-aged UK cohort of post-war baby-boomers, homeownership by the age of 26 years was associated with decreased mortality. Homeownership is described as representing the achievement of the ‘great Australian dream’. Studies on the psychosocial benefits of home and housing indicate that homeownership is associated with a direct effect on cardiovascular risk through ovarian failure and subsequent hormone-related changes in the vascular bed. This was a community-based study that allows us to extrapolate our findings to the general female population of this age-group. Women were followed for a long period, and surveyed periodically to obtain repeated measures data. This enabled us to more effectively control for lifestyle factors as well as biological factors, such as hypertension, that developed during follow-up. To our knowledge, all previous studies of the SES–stroke gradient in women have only accounted for baseline measurements of confounders. We were able to directly compare the relationship between different individual SES measures and stroke within one study population. Existing studies have tended to focus on only one or two SES indicators, making it difficult to assess the consistency of associations between different SES measures and stroke risk across studies. Finally, to our knowledge, this is the first study to examine the effect of homeownership on chronic disease risk.

**Limitations**

Incident stroke is based largely on self-report, which may have introduced some errors. However, in a validation study of a subgroup of the ALSWH mid-aged cohort for whom we had hospital admission data, we found moderate agreement between self-report and hospital-recorded stroke. This is likely to be an underestimate, as studies that have compared self-report against a more comprehensive comparison group that identifies strokes from multiple sources of information report even greater validity of self-reported stroke. One recent study found that 89% of self-reported strokes were verified by hospital or general practitioner records. The prevalence of stroke in our study is also in keeping with the stroke prevalence in this particular age-group from population-based studies in similar high-income countries. It is possible that the accuracy of self-reporting of stroke may vary according to education level, with people in lower educational groups perhaps more likely to over-report strokes. However, this is unlikely to explain all of the observed SES–stroke gradient, as our findings are in keeping with the results of other similar studies that assessed stroke occurrence using health records. Some women may have misreported transient ischaemic attacks as strokes. However, given the aetiological similarities of these clinical conditions, we might expect associations with SES measures to be similar. We did not collect information on pathological type of stroke. The association between SES and stroke may be less marked for haemorrhagic than ischaemic stroke, and so the observed associations may be even stronger among ischaemic strokes only. Finally, we were unable to adjust for other potential confounders such as social support or work-related factors. However, recent evidence suggests these psychosocial factors may not contribute to the SES–stroke gradient in mid-aged women.

**Conclusions and Implications**

We found that education and homeownership, but not income and occupation, are associated with stroke risk in mid-aged women. Although other factors are likely to be important in explaining the observed SES–stroke gradient, particularly in the lowest educational groups, differences in lifestyle behaviours and mental health are important mediators and should be appropriately and effectively addressed if inequalities in stroke risk are to diminish. Further research is needed to investigate the impact of homeownership on stroke and the mechanism by which this occurs. It is likely to be explained by psychosocial measures other than marital status and depression, and raises the issue of the potential impact of other aspects of emotional and psychosocial well-being on physical health.

**Supplementary data**

Supplementary data are available at EURPUB online.

**Acknowledgements**

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organization had no role in the design and conduct of the study; in data collection, analysis and interpretation of results or in preparation of the manuscript. C.A.J. designed the study, carried out the statistical analyses, drafted the manuscript and is guarantor, G.D.M. and M.I. advised on the statistical analyses and critically reviewed the manuscript. All authors were involved in the interpretation of the data and approved the final version.

All authors had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Conflicts of interest: None declared.

Key points

- Lower education level is associated with a substantially increased stroke risk in mid-age women, but is partially explained by lifestyle, biological and psychosocial factors.
- Lifestyle and mental health are important mediators of this association and should be effectively addressed if inequalities in stroke risk are to diminish.
- Non-homeownership in these post-war baby-boomers is associated with a 63% increased risk of stroke after adjusting for confounders.
- The association between homeownership and stroke is not fully explained by lifestyle or biological factors, or depression and marital status, and highlights the potential impact of other aspects of emotional and psychosocial well-being on physical health.

References