Living alone, loneliness and lack of emotional support as predictors of suicide and self-harm: seven-year follow up of the UK Biobank cohort

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Abstract

Background: The association between loneliness and suicide is complex, poorly understood, and there are no prior longitudinal studies. We aimed to investigate the relationship between living alone, loneliness and emotional support as predictors of death by suicide and self-harm.

Methods: Between 2006 and 2010 UK Biobank recruited over 0.5m people aged 37-73. This data was linked to prospective hospital admission and mortality records. Adjusted Cox regression models were used to investigate the relationship between self-reported measures of loneliness, emotional support and living arrangements and death by suicide and self-harm.

Results: For women, there was no evidence that living arrangements, loneliness or lack of emotional support were associated with death by suicide. However, for men, both living alone (Hazard Ratio (HR) 2.19 95%CI 1.47-3.27) and with non-partners (HR 2.17 95%CI 1.28-3.69) were associated with death by suicide, independently of loneliness, which had a modest relationship with suicide in men (HR 1.45 95%CI 0.99-2.12). Associations between living alone and self-harm were explained by health for women, and by health, loneliness and emotional support for men. In fully adjusted models, loneliness was associated with hospital admissions for self-harm in both women (HR 1.90 95%CI 1.58-2.29) and men (HR 1.75 95%CI 1.41-2.18).

Conclusions: For men -but not for women- living alone or with a non-partner increased the risk of suicide, a finding not explained by loneliness. Loneliness may be more important as a risk factor for self-harm than for suicide, and appears to mitigate against any protective effect of cohabitation.
Introduction

Loneliness, defined as the subjective perception of a lack of contact with other people (HM Government, 2018, Perlman and Peplau, 1981), is associated with premature mortality (Elovainio et al., 2017, Rico-Uribe et al., 2018), physical and mental ill-health, worse cognitive function (Hawkley and Cacioppo, 2010) and increased use of health services (Dreyer et al., 2018). Given concerns about the consequences of population ageing and greater numbers of people living alone, the UK government has made loneliness a ministerial responsibility (HM Government, 2018). However, it is currently not clear whether subjective loneliness per se is the primary reason why people living alone may be at increased risk of suicidal behaviour.

Living alone has been consistently linked with self-harm and suicide (Conejero et al., 2016, Frisch and Simonsen, 2013) but loneliness or lack of emotional support may only partly explain this relationship (Hawkley and Cacioppo, 2010). This is a complex area of research. Most studies of loneliness and suicidal behaviour have been based only on cross-sectional data using self-reported measures of suicidality, which may be prone to reporting biases (Beutel et al., 2017, Stickley and Koyanagi, 2016), and only a few (case-control) studies have investigated loneliness as a potential cause of deaths by suicide (Courtin and Knapp, 2017, Holt-Lunstad et al., 2015).

Identifying robust risk factors for suicidal behaviour is methodologically challenging for a number of reasons, not least because suicide is a rare event (Stickley and Koyanagi, 2016). Very few prospective studies have been sufficiently powered to be able to detect any statistically significant effect of factors such as living alone and subjective loneliness on outcomes such as hospitalisation for self-harm and suicide. The UK Biobank cohort represents a unique opportunity to overcome these limitations. The cohort consists of over half a million people, and the baseline questionnaire included a social questionnaire with detailed questions on living arrangements, loneliness and emotional support, in addition to key sociodemographic and health data. These data have also been linked prospectively to hospital episode statistics and mortality records (Sudlow et al., 2015).

Our primary hypothesis was that living alone may represent an independent risk factor for self-harm and suicide. We also set out to assess whether any observed association between living alone and suicidal behaviour might be explained by subjective loneliness or by perceived lack of emotional support.

Methods

Data
All adults aged between 40-70 years who were registered with the UK National Health Service (NHS) and living within 25 miles of 22 assessment centres across England, Scotland and Wales were invited to participate in UK Biobank at baseline, with a response rate of 5.5% (Sudlow et al., 2015). Baseline assessments took place between 2006 and 2010 (Sudlow et al., 2015), and consisted of a single visit lasting approximately two to three hours, including consent processes, a computerised touch screen questionnaire, nurse interviews, and physical measurements. For all participants (n = 502,616) the date and cause of death were sought from death certificates held within the National Health Service Information Centre (England and Wales), and National Health Service Central Register Scotland. At the time of analysis, mortality data were available up to the middle of February 2016. All participants who attended a Biobank assessment centre in England (n = 448,883) were linked to Hospital Episode statistics (HES) to obtain hospital admission records for self-harm up until March 2015. This study
covered by the generic ethical approval for UK Biobank studies from the National Health Service National Research Ethics Service (June 17, 2011; Ref 11/NW/0382). Participants provided electronic informed consent for the baseline assessments and the register linkage.

Outcomes

Death by suicide was defined as the act of intentionally ending one’s own life (Nock et al., 2008) and was ascertained from death records using ICD 10 codes X60-X84 (intentional self-harm), Y10-34 (undetermined cause) as used by the UK Office for National Statistics (2016). Participants dying from other causes of death were censored at time of death.

Hospital admissions for self-harm were defined as any act of intentional self-poisoning or self-injury carried out by an individual irrespective of the motivation or suicidal intent (National Collaborating Centre for Mental Health, 2012). This was assessed using the first admission for self-harm following attendance at the UK Biobank baseline assessment centre. Hospitalization for self-harm was assessed using ICD 10 codes X60 to 84 and Z91.5, for diagnosis and causes of admissions.

Main exposures of interest

Living arrangements (alone; husband, wife or partner; other) were assessed using data from the baseline touch screen questionnaire. Participants were asked how many people lived in their household. If there was more than one person, the participant was then asked how people were related to them. If any member of the household was a spouse or partner, participants were classified as living with a husband, wife or partner. The other category included both relatives and unrelated people. Participants preferring not to answer these questions were coded as missing.

Loneliness was assessed using a single question from the baseline touchscreen questionnaire: “Do you often feel lonely?” (Responses: yes, no, do not know, prefer not to answer).

Emotional Support. Participants were asked “2-4 times a week; about once a week; about once a month; once every few months; never or almost never; Do not know; prefer not answer.)

Covariates

We included sociodemographic and health variables collected during baseline data collection which might confound relationships between the key variables of interest and death by suicide and hospital admissions for self-harm.

Socio-demographic variables were: sex, age (continuous), ethnicity (derived here into white British, other) employment status, (employed, retired, other), area deprivation indicated using the Townsend Index (continuous), education (degree; professional; NVQ, HND or HND; A level; O level; CSE; none).

Health variables were: number of physical morbidities (zero, one, two, three or more), BMI (normal or underweight, overweight, obese), ever seen a GP for depression (yes, no), on psychotropic medication at baseline (yes/no based on taking medications from selected codes as baseline), alcohol consumption (categories were combined as follows; daily/almost daily, 3-4 days a week, 1-2 times a week /once a month, special occasions/never, former), smoking status (never, previous, current).

Statistical analysis

We first ran analyses using complete cases before using multiply imputed data. Preliminary analyses indicated that results for living arrangements differed by gender, so subsequent analyses were stratified by gender. Cox proportional hazards regression was used to investigate deaths by suicide.
The proportional hazards assumption was tested for using Schoenfeld residuals. Cox proportional hazard models were initially used for hospital admissions due to self-harm, however, the proportional hazards assumption was found not to be met for loneliness, so data were reanalysed using a Royston Parmar model (Royston and Lambert, 2011), with Akaike information criterion indicating that two knots to be used to model the baseline hazard and single time varying parameter for loneliness.

In total, six different stages of model were presented by gender for both deaths by suicide and hospital admissions for self-harm. The first three models are presented for each of living arrangements, loneliness, and emotional support separately. Models 1 are univariable regression models only including each of the main independent variables. Models 2 adjust for all sociodemographic variables, and Models 3 additionally adjust for the health variables. Model 4 adds loneliness and Model 5 adds emotional support to Model 3. In model 6, all variables were included.

We accounted for missing data using multiple imputation by chained equations, generating twenty imputed data sets. Given that data for hospital admissions for self-harm were constrained to people attending baseline centres in England separate sets of imputations were conducted for died by suicide and hospital admission for self-harm. Imputation models were stratified by gender and included age, living arrangements, loneliness, emotional support, all variables used in the models, the Nelson-Aalen estimate of cumulative hazard, survival status (Cleves et al., 2016), and additional variables to improve model fit including household income, same sex relationship, participation in social groups, contact with friends and family, parental depression, limiting longstanding illness and self-rated health. These variables were not included in the main models because they either had comparatively high rates of missing data which limited their utility in preliminary complete case analysis, or in the case of health variables, might mediate the relationship between our exposures of interest and outcomes. Our models were fitted to each imputed data set and combined in accordance with Rubin’s rules. All analyses were carried out using Stata 14.2.

**Results**

Sociodemographic characteristics of study participants by gender are shown in table 1. There were significant (p <0.001) gender differences for all characteristics. With respect to the main independent variables of interest, men were more likely to cohabitate, whereas women were more likely to live alone or with non-partner(s) only. Women were somewhat more likely to report often feeling lonely. While there was little difference between men and women with respect to having perceived access to emotional support on a daily basis, men were much more likely to report that they never had any emotional support. Men were much likely to have died by suicide (n=155) than women (n=59). The percentage of participants not providing answers was very low for all variables. Among potential confounders, men were more likely than woman to be in both the most and least advantaged categories of the socioeconomic measures, and women generally had poorer health (see table 1).

**Death by suicide**

The results of Cox proportional hazard models for deaths by suicide are shown in table 2. For men there was initially a strong relationship, relative to cohabitation, between living alone or with a non-partner and death by suicide, with a HR of approximately 3.5 (model 1). These associations were attenuated after adjusting for sociodemographic factors (sex, age, ethnicity, employment status, area deprivation and education; model 2) and health measures (physical morbidities, BMI, ever seen GP for depression, psychotropic medication, alcohol consumption and smoking status; model 3). Adjusting for loneliness (model 4) or emotional support (model 5) only led to a slight attenuation of
relationships, and in the final fully adjusted model (model 6) both living alone (Hazard ratio (HR) 2.19 95% CI 1.47 to 3.27) and living with a person who was not a partner (HR 2.17, 95% CI 1.28 to 3.69) were still strongly related to deaths by suicide. The relationship between loneliness and low levels of emotional support and death by suicide, although relatively strong in unadjusted models (model 1), fell after adjustment for sociodemographic factors and health. Once living arrangements were accounted for, loneliness was only modestly associated (HR 1.49, 95% CI 1.03 to 2.17) with death by suicide (model 4), and lower levels of emotional support was no longer associated within model 5.

In contrast, for women, there was limited evidence of an association between death by suicide and living arrangements, loneliness or emotional support. In unadjusted analyses, all the regression coefficients for women were much smaller than the corresponding coefficients for men. Only loneliness had a marginally significant association (p<0.10) and this would appear to be fully explained by women’s health at baseline.

Finally, using models adjusting for baseline sociodemographic and health measures, we conducted interaction tests to assess whether the relationship between living arrangements and death by suicide was modified by loneliness or emotional support. For men, a Wald test indicated a significant interaction (p=0.002) between living arrangements and loneliness, presented on the left side of Fig 1. Men who often experience loneliness or those who were not lonely and living alone, or with a non-partner only, have three times the risk of dying by suicide compared to those who cohabit and are not lonely. For women, there was no evidence of any significant interaction between living arrangements or perceived emotional support and death by suicide.

**Hospital admissions for self-harm**

The results for the Royston Parmar models for associations between hospital admissions for self-harm and living arrangements, loneliness and perceived emotional support are shown in table 3.

For men, both living alone and living with a non-partner were initially associated with increased risk of being admitted to hospital for self-harm in unadjusted analyses (model 1). The strength of these associations was reduced after adjusting for sociodemographic characteristics (model 2) and health measures (model 3). Both loneliness (model 4) and lower levels of emotional support (model 5) explained part of the relationship between living alone and self-harm, but had a more limited role in explaining the relationship between living with a non-partner and self-harm. In the final model, there was no evidence of an association between living alone and self-harm, but living with a non-partner still had a modest relationship with self-harm (HR 1.35 95%CI 1.00 to 1.82).

Women differed from men in that the two categories of living arrangements had weaker relationships with self-harm within the unadjusted model (model 1). Furthermore, the associations for women were explained by health (model 2). For both men and women, loneliness and lower levels of perceived emotional support were associated with increased risk of self-harm, independent of other factors (with the caveat that for women the relationship between lack of emotional supports and self-harm could be explained by loneliness).

For men, in models adjusting for baseline sociodemographic and health measures, we found significant (p=0.013) interactions between living arrangements and loneliness when hospitalization for self-harm was the outcome. Overall, loneliness removed any protective effects of cohabitation over living alone, such that men who were often lonely had similarly increased HRs of hospitalization of around 2.5, irrespective of their living arrangements. In contrast, among men who did not report loneliness, living alone was associated with a modest increase in risk of hospitalization for self-harm.
(HR 1.53 95% CI 10.11 to 2.10) and a greater increase was found for those living only with non-partners (HR 2.09 95% CI 1.39 to 3.14) (see right side of Fig 1). There was no evidence that either loneliness or perceived emotional support moderated the relationship between living arrangements and hospitalisation for women. Nor was there any evidence of an interaction between perceived emotional support and living arrangement in the prediction of self-harm for men.

Discussion

Our goal was to investigate the association between living arrangements, loneliness, perceived emotional support and subsequent risk of suicidal behaviours within a large general population cohort in middle-age. Overall, we identified important differences between men and women. For men, given that both living alone and living with a non-partner were both associated with an increased risk of death by suicide, it is possible that having a partner is protective against death by suicide. Subjective loneliness and perceived emotional support explained little of this relationship. For women, neither living arrangements, loneliness, nor emotional support were associated with death by suicide.

In terms of hospitalisation for self-harm as an outcome, for men the modest increased risk of self-harm among those living alone appeared to be explained by loneliness and poor emotional support. However, men who did not live with a partner had an increased risk of self-harm, independent of loneliness or emotional support. For women, any increased risk of self-harm appeared to be explained by sociodemographic characteristics or health status at baseline. Both genders were similar in that both loneliness and emotional support were associated with self-harm.

Our finding that deaths by suicide for men (and hospital admissions for self-harm for both men and women) were associated with living arrangements, is consistent with the literature for marital status that finds married or cohabiting people have lower risks of suicide compared to single people (Conejero et al., 2016, Frisch and Simonsen, 2013). Demographic factors, such as the older age of the UK Biobank sample, could explain why we did not find any associations between living arrangements and suicide for women. Kyung–Sook and colleagues found associations between marital status and suicide only among younger women (Kyung-Sook et al., 2018).

There are several additional novel findings from our analyses. Most studies of suicidal behaviour focus on the concept that it is living alone that is harmful (Turecki and Brent, 2016). However, our results indicate that both men who lived alone and with non-partners were at increased risk of dying by suicide and self-harm. Apart from Frisch and Simonsen’s (2013) study, which indicated that people living in households with more than 9 people had increased risk of suicide, the focus has generally been on living alone as a risk factor, rather than other relationships. However, this is consistent with a wider literature investigating determinants of psychological distress and depression (Joutsenniemi et al., 2006).

Another key finding relates to the importance of loneliness and perceived emotional support as a risk for hospitalisation for self-harm and deaths by suicide for men. While loneliness has been linked to suicidal ideation and attempts (Stickley and Koyanagi, 2016), including within case-control studies (Sinclair et al., 2005), our study is the first to investigate the influence of loneliness and deaths by suicide within a longitudinal population sample of adults in middle-age.

Overall, our findings suggest that social connections (or lack of social connections) may be important contributors to deaths by suicide and self-harm. To make inferences from these data we must acknowledge some potential limitations. Although we had follow-up data on deaths by suicide and
hospitalisation for self-harm, our baseline measures were only recorded at a single time point and the causal direction is impossible to determine conclusively. It is likely that the relationship between the social connection measures and baseline health is bidirectional. However, given that the peak age of onset for major depressive disorder is early adulthood (Myrna M. Weissman et al., 2016), we decided to focus on a somewhat conservative approach, prioritising relationships presented in models that have adjusted for both mental health and sociodemographic measures.

Our results add to the literature which finds that married or cohabiting people have lower risk of suicide than single people (Conejero et al., 2016, Frisch and Simonsen, 2013), by showing that men appear to actively benefit from living with a partner (not just from not living alone). Our results also suggest that the associations between self-harm and living alone might be explained by loneliness and emotional support. However, this does not appear to be the case for deaths by suicide. Men who die by suicide may be less willing to seek treatment for poor mental health and the risk of suicide is greater among those who never see a GP as opposed to those see a GP once a year (Windfuhr et al., 2016), hence there may be residual confounding due to poor health. Alternatively, the benefits of having a partner may be linked to men's sense of masculinity and their self-image (Scourfield et al., 2012), rather than emotional support or companionship. What is clear from the interactions with loneliness is that feelings of loneliness override the benefits of having a partner, and thus the focus needs to be on positive relationships, rather than simply cohabitation. Loneliness appears to be an important factor for both men and women for self-harm, independent of social-demographic factors and mental and physical health, even after adjusting for other social connection measures.

The concept of ‘thwarted belongingness’ from the Interpersonal Theory of Suicide would suggest that loneliness alongside the absence of reciprocal caring relationships could lead to self-destructive behaviour (Van Orden et al., 2010). Our results may be consistent with this, but also raise questions about the extent to which a lonely person can also feel that they do or do not have a reciprocal caring relationship.

A key strength of this work is that the large baseline population allowed us to study rare outcomes. However, despite this, there were still very few deaths by suicide events for women in this study. It has been argued that a minimum of ten outcome events should occur per predictor variable, and this would have been violated for model 3, which adjusted for multiple health factors, for deaths by suicide by women. However, simulations (Vittinghoff and McCulloch, 2007) have shown this to be too conservative and it is appropriate to include addition variables to adjust for confounding. The lack of associations with deaths by suicide for women was evident even from the simpler models with fewer independent variables. UK Biobank had an invitation response rate of only 5.5%, and compared to the general population is less economically deprived and there is some evidence of a healthy volunteer selection bias (Fry et al., 2017).

The use of administrative data has many advantages. It facilitates longitudinal follow-up of rare outcomes, and minimises potential attrition biases. However, we were limited in our analyses by only having self-harm hospital admissions for England (these data were not available for Wales or Scotland). Many who self-harm do not seek help from services or, when they do, are not admitted but reviewed at out-patients (Gunnell et al., 2005). The use of single item measures for loneliness and perceived emotional support might also be considered a weakness of the study, but single-item measures are considered valid (Stickley and Koyanagi, 2016) and are recommended for the study of loneliness (HM Government, 2018).
This study raises many questions for future exploration. Our results suggest that addressing loneliness may also reduce the risk of a person self-harming. In contrast, given that loneliness does not appear to explain the relationship between not having a partner and death by suicide, different lines of investigation are required. Future research could investigate the relationship between having a partner and health seeking behaviour, or how having a partner changes how men view themselves.

Overall, this work demonstrates that for men (but not for women) living alone or with a non-partner increases risk of suicide, a finding not explained by perceived loneliness. It appears likely that loneliness may be more important as a risk factor for self-harm than for suicide.
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| Social Connection | Women | Men | Health | Women | Men |
|-------------------|-------|-----|--------|-------|-----|
| Living arrange\(^c\) |       |     |        |       |     |
| Alone             | 53,747| 19.7| 39,192| 17.1  |     |
| Cohabitation      | 188,621| 69.0| 174,525| 76.2  |     |
| Non Partner       | 28,794| 10.5| 13,330| 5.8   |     |
| Missing           | 2,292 | 0.8 | 2,115 | 0.9   |     |
| Loneliness        |       |     |        |       |     |
| No                | 210,955| 77.1| 190,353| 83.1  |     |
| Yes               | 57,055| 20.9| 34,376| 15.0  |     |
| Missing           | 5,444 | 2.0 | 4,433 | 1.9   |     |
| Emotional Support |       |     |        |       |     |
| Almost Daily      | 140,718| 51.5| 117,896| 51.5  |     |
| 2-4 times a week  | 30,324 | 11.1| 16,463 | 7.2   |     |
| Once a Week       | 33,583 | 12.3| 19,754 | 8.6   |     |
| Monthly           | 30,284 | 11.1| 22,967 | 10.0  |     |
| Never             | 29,289 | 10.7| 42,454 | 18.5  |     |
| Missing           | 9,256  | 3.4 | 9,628  | 4.2   |     |
| Socio Demographic |       |     |        |       |     |
| Age               |       |     |        |       |     |
| 35/44             | 27,837| 10.2| 23,969 | 10.5  |     |
| 45/54             | 50,126| 29.3| 62,314 | 27.2  |     |
| 55/64             | 116,883| 42.7| 95,459 | 41.7  |     |
| 65/74             | 48,608| 17.8| 47,420 | 20.7  |     |
| Ethnicity         |       |     |        |       |     |
| White British     | 240,311| 87.9| 202,366| 88.3  |     |
| Other             | 31,876| 11.7| 25,285 | 11.0  |     |
| Missing           | 1,267 | 0.5 | 1,511 | 0.7   |     |
| Employment status |       |     |        |       |     |
| Employed          | 149,237| 54.6| 137,975| 60.2  |     |
| Retired           | 95,583| 35.0| 71,427 | 31.2  |     |
| Other             | 27,110| 9.9 | 18,326 | 8.0   |     |
| Missing           | 1,524 | 0.6 | 1,434 | 0.6   |     |
| Deprivation       |       |     |        |       |     |
| Least deprived    | 54,582| 20.0| 46,098 | 20.1  |     |
| 4\(^{th}\) Qntile  | 54,578| 20.0| 45,543 | 19.9  |     |
| 3\(^{rd}\) Qntile  | 55,338| 20.2| 45,062 | 19.7  |     |
| 2\(^{nd}\) Qntile  | 55,367| 20.3| 45,025 | 19.7  |     |
| Most deprived     | 53,258| 19.5| 47,138 | 20.6  |     |
| Missing           | 331   | 1.0 | 296   | 0.1   |     |
| Education         |       |     |        |       |     |
| Degree            | 84,555| 30.9| 76,643 | 33.4  |     |
| Professional      | 40,989| 15.0| 31,453 | 13.7  |     |
| NVQ, HND or HNC   | 28,309| 10.4| 34,687 | 15.1  |     |
| A level           | 15,759| 5.8 | 11,480 | 5.0   |     |
| O level           | 41,648| 15.2| 23,047 | 10.1  |     |
| CSE               | 10,865| 4.0 | 7,748  | 3.4   |     |
| None              | 45,979| 16.8| 39,312 | 17.2  |     |
| Missing           | 5,350 | 2.0 | 4,792 | 2.1   |     |
| Centre Country    |       |     |        |       |     |
| England           | 243,800| 89.2| 205,083| 89.5  |     |
| Wales             | 9,704 | 3.6 | 8,177 | 3.6   |     |
| Scotland          | 19,950| 7.3 | 15,902| 6.9   |     |

1. Data is only available for those reporting conditions,
2. Analyses only include those who attended a Biobank centre in England at baseline.
Table 2: Death by suicide hazard ratios for loneliness, living arrangements and perceived social support, in unadjusted and adjusted models for men and women in the UK Biobank study

|                      | Model 1           | Model 2           | Model 3           | Model 4           | Model 5           | Model 6           |
|----------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
|                      | HR 95% (CI)       | HR 95% (CI)       | HR 95% (CI)       | HR 95% (CI)       | HR 95% (CI)       | HR 95% (CI)       |
| **Men**              |                   |                   |                   |                   |                   |                   |
| **Living arrangements** |                   |                   |                   |                   |                   |                   |
| Alone                | 3.84 (2.73 to 5.39)** | 2.94 (2.04 to 4.25)** | 2.55 (1.75 to 3.71)** | 2.32 (1.57 to 3.41)** | 2.35 (1.59 to 3.47)** | 2.19 (1.47 to 3.27)** |
| Non partner          | 3.63 (2.21 to 5.96)** | 2.64 (1.58 to 4.42)** | 2.45 (1.46 to 4.10)** | 2.26 (1.34 to 3.81)** | 2.30 (1.36 to 3.88)** | 2.17 (1.28 to 3.69)** |
| **Loneliness (No)**  |                   |                   |                   |                   |                   |                   |
| Yes                  | 3.31 (2.38 to 4.60)** | 2.53 (1.78 to 3.58)** | 1.85 (1.29 to 2.67)** | 1.49 (1.03 to 2.17)* |                   | 1.45 (0.99 to 2.12)+ |
| **Emotional support (daily)** |                   |                   |                   |                   |                   |                   |
| 2-4 times a week     | 1.73 (0.95 to 3.14)+ | 1.56 (0.85 to 2.84)  | 1.39 (0.76 to 2.54)  | 1.15 (0.63 to 2.12)  | 1.12 (0.61 to 2.05)  |                   |
| Once a week          | 2.44 (1.49 to 4.00)** | 2.17 (1.32 to 3.55)** | 1.96 (1.19 to 3.22)** | 1.53 (0.92 to 2.56)  | 1.46 (0.87 to 2.44)  |                   |
| Monthly              | 1.54 (0.89 to 2.66)  | 1.40 (0.81 to 2.43)  | 1.26 (0.73 to 2.18)  | 1.02 (0.58 to 1.78)  | 0.96 (0.54 to 1.68)  |                   |
| Never                | 2.01 (1.33 to 3.02)** | 1.71 (1.12 to 2.59)* | 1.62 (1.06 to 2.46)* | 1.30 (0.84 to 2.00)  | 1.21 (0.78 to 1.87)  |                   |
| **Women**            |                   |                   |                   |                   |                   |                   |
| **Living arrangements** |                   |                   |                   |                   |                   |                   |
| Alone                | 1.33 (0.72 to 2.46)  | 1.33 (0.70 to 2.52)  | 1.06 (0.56 to 2.04)  | 1.05 (0.54 to 2.03)  | 1.10 (0.57 to 2.12)  | 1.08 (0.56 to 2.10)  |
| Non partner          | 1.23 (0.55 to 2.75)  | 0.99 (0.43 to 2.29)  | 0.82 (0.35 to 1.89)  | 0.81 (0.35 to 1.88)  | 0.84 (0.36 to 1.95)  | 0.83 (0.35 to 1.93)  |
| **Loneliness (No)**  |                   |                   |                   |                   |                   |                   |
| Yes                  | 1.74 (0.99 to 3.08)+ | 1.64 (0.92 to 2.93)+ | 1.06 (0.59 to 1.93)  | 1.07 (0.59 to 1.96)  |                   | 1.12 (0.60 to 2.09)  |
| **Emotional support (daily)** |                   |                   |                   |                   |                   |                   |
| 2-4 times a week     | 1.07 (0.47 to 2.42)  | 1.02 (0.45 to 2.33)  | 0.87 (0.38 to 1.98)  | 0.86 (0.38 to 1.98)  | 0.85 (0.37 to 1.96)  |                   |
| Once a week          | 1.23 (0.58 to 2.58)  | 1.21 (0.58 to 2.55)  | 0.98 (0.47 to 2.08)  | 0.98 (0.46 to 2.08)  | 0.96 (0.45 to 2.06)  |                   |
| Monthly              | 0.30 (0.07 to 1.24)+ | 0.30 (0.07 to 1.25)+ | 0.25 (0.06 to 1.06)+ | 0.25 (0.06 to 1.06)+ | 0.25 (0.06 to 1.04)+ |                   |
| Never                | 1.37 (0.65 to 2.89)  | 1.40 (0.66 to 2.96)  | 1.23 (0.58 to 2.62)  | 1.23 (0.58 to 2.62)  | 1.19 (0.55 to 2.59)  |                   |

*** p ≤ 0.001, ** p ≤ 0.01, * p ≤ 0.05, + p ≤ 0.1.
Model 1 univariable cox regression, model 2 adjusts for socio-demographic factors (sex, age, ethnicity, employment status, deprivation and highest qualification), model 3 is model 2 plus adjusting for health measures (number physical morbidities, ever depressed, on psychotropic medication, BMI, alcohol consumption, smoking). Model 4 is model 3 plus mutual adjustment for loneliness and living arrangements. Model 5 is model 3 plus mutual adjustment for living arrangements and perceived social support. Model 6 is model 3 plus mutual adjustment for living arrangements, loneliness and perceived social support.
Table 3: Admissions to hospital for self-harm hazard ratios for loneliness, living arrangements and perceived social support, in unadjusted and adjusted models for men and women in the UK Biobank study

|                    | Model 1 HR 95% (CI) | Model 2 HR 95% (CI) | Model 3 HR 95% (CI) | Model 4 HR 95% (CI) | Model 5 HR 95% (CI) | Model 6 HR 95% (CI) |
|--------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| **Men**            |                     |                     |                     |                     |                     |                     |
| **Living arrangements** |                    |                     |                     |                     |                     |                     |
| Alone              | 3.14 (2.57 to 3.84)***** | 1.75 (1.40 to 2.18)***** | 1.41 (1.12 to 1.76)** | 1.19 (0.95 to 1.51) | 1.20 (0.95 to 1.51) | 1.08 (0.85 to 1.37) |
| Non partner        | 3.56 (2.70 to 4.70)***** | 1.83 (1.37 to 2.45)***** | 1.68 (1.25 to 2.25)***** | 1.47 (1.09 to 1.98)** | 1.48 (1.10 to 1.99)** | 1.35 (1.00 to 1.82)** |
| Loneliness (No)    |                     |                     |                     |                     |                     |                     |
| Yes                | 5.32 (4.43 to 6.40)***** | 3.22 (2.64 to 3.92)***** | 2.03 (1.65 to 2.50)***** | 1.93 (1.56 to 2.38)***** |                     | 1.75 (1.41 to 2.18)***** |
| Per log day X Loneliness | 0.97 (0.93 to 1.01)+ | 0.97 (0.93 to 1.01)+ | 0.97 (0.93 to 1.01) | 0.97 (0.93 to 1.01) |                     | 0.97 (0.93 to 1.01)+ |
| **Emotional support (daily)** |                     |                     |                     |                     |                     |                     |
| 2-4 times a week   | 1.95 (1.37 to 2.77)***** | 1.71 (1.20 to 2.44)***** | 1.49 (1.04 to 2.12)* |                     | 1.42 (0.99 to 2.03)+ | 1.35 (0.94 to 1.93)+ |
| Once a week        | 2.46 (1.82 to 3.32)***** | 2.04 (1.50 to 2.76)***** | 1.80 (1.33 to 2.44)***** | 1.70 (1.24 to 2.32)***** | 1.56 (1.14 to 2.13)***** |                     |
| Monthly            | 2.13 (1.58 to 2.88)***** | 1.86 (1.37 to 2.51)***** | 1.61 (1.19 to 2.18)***** | 1.53 (1.12 to 2.08)***** | 1.39 (1.02 to 1.90)***** |                     |
| Never              | 2.98 (2.38 to 3.74)***** | 2.17 (1.72 to 2.73)***** | 1.96 (1.55 to 2.47)***** | 1.85 (1.46 to 2.35)***** | 1.64 (1.29 to 2.09)***** |                     |
| **Women**          |                     |                     |                     |                     |                     |                     |
| **Living arrangements** |                    |                     |                     |                     |                     |                     |
| Alone              | 1.75 (1.44 to 2.11)***** | 1.71 (1.40 to 2.09)***** | 1.19 (0.97 to 1.46)+ | 1.05 (0.86 to 1.29) | 1.16 (0.94 to 1.43) | 1.05 (0.86 to 1.30) |
| Non partner        | 2.02 (1.61 to 2.52)***** | 1.23 (0.97 to 1.56)+ | 0.95 (0.75 to 1.21) | 0.86 (0.68 to 1.09) | 0.93 (0.74 to 1.18) | 0.86 (0.68 to 1.09) |
| Loneliness (No)    |                     |                     |                     |                     |                     |                     |
| Yes                | 4.36 (3.70 to 5.15)***** | 3.28 (2.77 to 3.89)***** | 1.93 (1.62 to 2.31)***** | 1.94 (1.62 to 2.32)***** |                     | 1.90 (1.58 to 2.29)***** |
| Per log day X Loneliness | 0.95 (0.93 to 0.98)***** | 0.95 (0.93 to 0.98)***** | 0.95 (0.93 to 0.98)***** | 0.95 (0.93 to 0.98)***** |                     | 0.95 (0.93 to 0.98)***** |
| **Emotional support (daily)** |                     |                     |                     |                     |                     |                     |
| 2-4 times a week   | 1.21 (0.92 to 1.60) | 1.18 (0.90 to 1.56) | 0.99 (0.75 to 1.31) | 0.98 (0.74 to 1.29) | 0.91 (0.69 to 1.20) |                     |
| Once a week        | 1.52 (1.19 to 1.94)***** | 1.50 (1.17 to 1.92)***** | 1.20 (0.94 to 1.54) | 1.18 (0.92 to 1.51) | 1.05 (0.81 to 1.34) |                     |
| Monthly            | 1.28 (0.98 to 1.68)+ | 1.29 (0.99 to 1.69)+ | 1.04 (0.80 to 1.37) | 1.03 (0.79 to 1.35) | 0.89 (0.68 to 1.17) |                     |
| Never              | 2.20 (1.76 to 2.76)***** | 1.94 (1.55 to 2.44)***** | 1.50 (1.19 to 1.89)***** | 1.49 (1.18 to 1.88)***** | 1.24 (0.98 to 1.58)***** |                     |

*** p ≤ 0.001, ** p ≤ 0.01, * p ≤ 0.05, + p ≤ 0.1.
Model 1 Univariable Royston Parmar parametric Hazard models, model 2 adjusts for socio-demographic factors (sex, age, ethnicity, employment status, deprivation and highest qualification). Model 3 is model 2 plus adjusting for health measures (number physical morbidities, ever depressed, on psychotropic medication, BMI, alcohol consumption, smoking). Model 4 is model 3 plus mutual adjustment for loneliness and living arrangements. Model 5 is model 3 plus mutual adjustment for living arrangements and perceived social support. Model 6 is model 3 plus mutual adjustment for living arrangements, loneliness and perceived social support.
Fig 1: The interactions between living arrangements and loneliness in the prediction of deaths by suicide and hospital admissions for self-harm for men in the UK Biobank Study.