Evidence on the Robustness of the Links between Social Relationships and Mortality

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Abstract

Despite a substantial literature on the links between social relationships and mortality, the size of the relative risks from loneliness, social isolation, and living alone, remain controversial. Further research is therefore important given demographic changes meaning that more people are living alone, for longer, and with chronic health conditions. Using 19 waves of high-quality Australian longitudinal data we provide new evidence using multiple measures of social relationships, model specifications, and adjustments for confounding. We focus on chronic measures of (poor) social relationships and provide separate estimates by gender. We find that both functional and structural aspects of social relationships are independently strongly associated with all-cause mortality. We estimate a hazard ratio for loneliness of 1.41, which is greater for males (1.55) than females (1.24). These hazard ratios are larger than found for social isolation (1.19). We also find a strong relationship between being an active member of a club and reduced mortality risk, but no evidence that living alone is an independent risk factor. We provide useful comparisons with the mortality risks associated with smoking and household income. Overall, our findings suggest that interventions should focus on reducing both loneliness and social isolation, as well as encouraging active social participation.

Keywords*:* Mortality, Social Relationships, Loneliness, Social Support, Social Isolation, Club Membership, Living Alone, Smoking, Income, Survival Analysis

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Introduction

Social relationships are central to the human experience and wellbeing (e.g. Cacioppo and Patrick, 2008; Hawkley and Cacioppo, 2003, 2010; Cacioppo et al., 2014; Holt-Lunstad, 2017). However, modern societies face a major problem: the prevalence of loneliness and social isolation are high in many countries (Surkalim et al., 2022; Teo et al., 2022), with some commentators suggesting that there is an epidemic of loneliness (e.g. Murthy, 2017; Ninivaggi, 2019; US Surgeon General, 2023).[1] It is a striking paradox that loneliness and social isolation have become such prominent health, social and economic concerns at a time when advances in technology have increased the ease, and reduced the costs, of communicating with family, friends and others (e.g. Buecker et al., 2021).

Loneliness is a subjective discrepancy between what an individual perceives as their current situation relative to the desired combination of the quantity and quality of their social connections (Perlman and Peplau, 1981). In contrast, social isolation is a lack of social contact with others, and can often be more objectively measured (National Academies of Sciences, Engineering, and Medicine, 2020). The high prevalence of loneliness is of great concern given that it is a distressing and pervasive experience (Matthews et al., 2018; Holt-Lunstad, 2022), and has been described as social pain (Cacioppo et al., 2006). Moreover, loneliness is a major issue for all age groups, being a common experience from childhood to old age (e.g. Patterson and Veenstra, 2010; Yang and Victor, 2011; Cacioppo et al., 2015; Qualter et al., 2013, 2015; Hawkley et al., 2020; Eccles and Qualter, 2021; Kung et al., 2023).

Importantly, demographic changes mean that loneliness and social isolation are increasing, with more people living alone, living longer and with chronic health conditions (e.g. Cacioppo and Cacioppo, 2018). In the US, for example, the share of adults living alone has nearly doubled over the last 50 years, and this trend is becoming increasingly common in many countries, leading to new challenges in how to connect and provide support (Ortiz-Ospina, 2020). Concerns about loneliness have been further exacerbated by the COVID-19 lockdowns and social distancing policies (e.g. Banerjee and Rai, 2020; Kung et al., 2023), and large socioeconomic disparities exist in the prevalence of loneliness and social isolation (e.g. Niedzwiedz et al., 2016; Kung et al., 2021, 2022), with loneliness being linked to a rise in "deaths of despair" in the USA (Case and Deaton, 2020).

Loneliness and social isolation have both been found to be strong risk factors for mortality, with the often cited comparison that loneliness is as detrimental to health as smoking 15 cigarettes

[1] However, Hawkley (2022, p. 1) suggests that, "Contrary to some reports, there is currently little evidence for a loneliness epidemic." Also see Buecker et al. (2021) and Luhmann et al. (2023).

per day (House et al., 1988; Holt-Lunstad et al., 2010, 2015).[2] This benchmark against smoking[3] has helped to raise awareness of the strong link between social relationships and health outcomes (Smith et al., 2023), and a good example that uses this comparison to make a strong causal statement is the recent US Surgeon General Advisory (2023). From their meta-analysis, Lunstad et al. (2015) report that loneliness and social isolation are associated with increased likelihoods of mortality of 26% and 29%, respectively, with the increase associated with living alone being 32%. Discussions of potential pathways linking loneliness and social isolation to poor health including the buffering hypothesis where social relationships act to provide resources that protect against acute and chronic stressors, can be found, for example, in Hawkley and Cacioppo (2003), Cacioppo et al. (2015), Lunstad et al. (2015), Newall and Menec (2019), Smith and Victor (2019), and Kanbay et al. (2023).[4]

Despite a substantial body of literature, and the widely cited comparison with smoking, the nature of these relationships still remains uncertain. A recent systematic review and meta-analysis of 90 cohort studies notes that, "The associations between social isolation, loneliness and the risk of mortality from all-causes, cardiovascular disease (CVD) and cancer are controversial" (Wang et al., 2023, p. 1307). There is considerable heterogeneity with estimates varying with the measures of loneliness and social isolation used, differences in the length of the mortality follow-up, and differences in the extent of adjustments for confounders (Holt-Lunstad et al., 2010, 2015; Naito et al., 2023; Wang et al., 2023). For example, across 70 studies Holt-Lunstad et al. (2015) note exceptional high heterogeneity with odds ratios ranging from 0.64 to 3.85. Moreover, even the findings of recent meta-analyses that aim to obtain the best 'average weighted' estimate of the association between loneliness and/or social isolation, and mortality, differ considerably. For example, Rico-Uribe et al. (2018) report a hazard ratio (HR) of 1.22 (95% CI, 1.10 – 1.35) for loneliness and all-cause mortality, which is larger for males (1.44; 1.19 – 1.76) than females (1.26; 1.07 – 1.48). Schutter et al. (2022) report a smaller HR of 1.10 (1.06 – 1.14) for loneliness, and a HR of close to unity (0.96; 0.93 – 0.99) for having a larger social network. Similarly, Zhou et al. (2023) find a smaller HR for loneliness for older adults of 1.09 (1.06 – 1.12). Naito et al. (2023) report a HR for social isolation of 1.33 (1.26 – 1.41), while Wang et al. (2023) also find a larger HR for social isolation (1.32; 1.26 – 1.39) than loneliness (1.14; 1.08 – 1.20).

[2] The meta-analytic studies by Lunstad et al. (2010, 2015) are particularly influential having 8,700 and 5,900 citations, respectively, as measured by Google Scholar (April, 2024).
[3] In the US for example, Lariscy et al. (2018) calculated the smoking accounts for nearly 50,000 excess death each year.
[4] However, findings regarding the links between loneliness, social isolation, and health care utilisation are mixed (e.g. Bremer et al., 2017; Valtorta et al., 2018; Christiansen et al., 2023).

Overall, this evidence suggests that health and policy interventions might be more effectively focused on tackling social isolation than loneliness, and it is important to note that the correlation between measures of loneliness and social isolation (and other measures of social relationships) has been found to be modest (Holt-Lunstad et al., 2010; Kung et al., 2021, 2022; Foster et al., 2023). This is also supported by a growing number of recent individual studies that find no relationship between loneliness and mortality after adjusting for potential confounders (e.g. Steptoe et al., 2013; Elovaninio et al., 2017; Hakulinen et al., 2018; Lara et al., 2020; Stokes et al., 2021; Yu et al., 2022; Kammar-García et al., 2023), suggesting that the often cited comparison with the impact of smoking might be overstated (Batty et al., 2021). Relatedly, Raymo and Wang (2022) find little evidence of an important role for loneliness in understanding disparities in mortality for older Americans, net of several established correlates of health disparities.

Further research is therefore valuable because, as noted by Elovaninio et al. (2017, p. e260), having a better understanding of these relationships, "might facilitate the design of interventions to reduce excess health risk in socially isolated, lonely people". In this paper we test the robustness of the impact on mortality hazard rates of different measures of social relationships, model specifications, and covariate adjustments. We apply survival analysis to 19 waves of high-quality Australian household panel data that uniquely collect measures of the social relationships of respondents every year (wave), as well as capturing mortality through matched death records and survey fieldwork.

We make several contributions. Firstly, social isolation is often measured in studies as an index summing diverse aspects ranging from marital status, living alone, or number of people in the household, the frequency of contacts with family and friends, and membership of clubs, groups or associations (e.g. Steptoe et al., 2013; Elovainio et al., 2017; Crowe et al., 2021; Barnes et al., 2022).[5] However, such an index might cloud salient differences in the links to mortality, which could be important when identifying potential interventions and policy responses. It is likely that policies aimed at reducing the number of people living alone, for example, would be different to those that encourage individuals to socialise outside of their household, such as becoming active members of clubs or social groups. Obtaining estimates of the independent association with mortality of each aspect might then be valuable, and Foster et al. (2023) note the importance of examining both functional and structural aspects of social connections. In our analysis we distinguish between five different aspects of social relationships, namely, loneliness, low social (emotional) support (functional aspects); and infrequent contact with family and friends, being an active member of a club or association, and living alone (structural aspects) (Holt-Lunstad, 2018).

[5] The Supplementary Table 4 in Wang et al. (2023) provides a detailed breakdown of the measures of social isolation and loneliness used in 90 cohort studies.

Secondly, we focus on chronic measures of social relationships, rather than on situational or acute spells of loneliness or social isolation (e.g. Shiovitz-Ezra and Ayalon, 2010; Crowe et al., 2021). We do this in two ways. Given that we observe an individual's social relationships every year (each panel survey wave), we define chronic loneliness or social isolation when an individual reports the same situation in two (or three) consequent years. We focus on chronic measures because we might not expect an association with mortality for short spells of poor social connections, particularly if the length of the follow-up from the baseline observation is a long period of time (e.g. 10, or 20-years). Kung et al. (2022), for example, find that the conditional probability of an individual reporting loneliness again around 10-years later is around 0.5. Mund et al. (2019, p. 20) note that in terms of stability, loneliness seems to be "situated right in between the poles of stability and change". Moreover, while most studies in the literature model mortality as a function of baseline (when an individual is first observed in the data) observations of social relationships (and other covariates), we allow the measures to be time-varying in our main specification. However, we also provide comparison estimates when all social relationship measures and covariates are fixed at baseline, but also at the other extreme, where all relationship measures, as well as covariates, are allowed to be time-varying. Thirdly, we provide separate estimates by gender. Rico-Uribe et al. (2018, p. 2/21) state that, "There is a lack of research on the gendered aspects of the association of loneliness with all-cause mortality." Wang et al. (2023, p. 1313) note that, "Identifying and understanding gender differences in the relationship between SI (*social isolation)* or loneliness and all-cause mortality may help in improving gender equity and promoting population health status".

Fourthly, we test the robustness of the estimates to the inclusion of a wide set of potential confounder/adjustment variables, including the Big-5 personality traits (e.g. Stokes et al., 2021; Hong et al., 2023) that have been found to be important stable factors in explaining individual differences in loneliness (Buecker et al., 2020). Additionally, we control for locus of control (Kammar-García et al., 2023) that is a powerful predictor of many life outcomes including health behaviours (e.g. Cobb-Clark et al., 2014), and risk and time preferences that are drivers of decision-making and behaviours (Starmer, 2000; Frederick et al., 2002). Fifthly, our household panel data allows us to examine if spousal/partner social connections are related to own mortality risk. Sixthly, we not only provide new benchmark evidence about how the mortality risks from loneliness compare with those from smoking, but also highlight useful benchmarks with respect to household income and wealth. Finally, compared to US and UK studies, there is a scarcity of studies using

Australian data (Barr et al., 2021; Freak-Poli et al., 2021), and we can identify no Australian studies included in the recent meta-analysis by Wang et al. (2023).[6]

Data, Measures and Methods

Data

We analyse data from 19 waves (Release 19) of the Household, Income and Labour Dynamics in Australia (Department of Social Services / Melbourne Institute of Applied Economic and Social Research, 2020). HILDA is a nationally representative annual household-based longitudinal study that began in 2001. As the sampling unit, the household is broadly defined as "a group of people who usually reside and eat together" (Watson and Wooden, 2021). Each year (wave), the study collects detailed information on demographic, health, social relationships, finances, work, and family circumstances from each household member aged 15 and above. In wave one, interviews were obtained from 13,969 individuals from 7,682 households. A further 2,153 households were added in wave 11 (in 2011, providing an additional 4,009 respondents) to retain its cross-sectional representativeness. The sample also gradually extends each wave to include new household members when original household compositions change. Response rates are high, especially the annual re-interview rates, which over the period covered by this study have averaged over 95% (Summerfield et al., 2021).

We focus our analysis of mortality risks on a sample of respondents aged 50 or more. Death before age 50 is relatively rare in Australia (and in our data). Moreover, this selection makes the sample age composition similar to studies that have used data from the US Health Retirement Study (HRS) or the English Longitudinal Study of Aging (ELSA).[7] This provides a sample of 6,551 individuals who are observed on average of around 11 years (a minimum of 1 year, and a maximum of 19 years). For our survival analysis, this provides around 770,000 individual-month observations. The age in which individuals enter the sample is shown in Figure 1 (in months).

Importantly, we identify and verify those who have died (and the month of death) using two sources: (1) through matching to the National Death Index (currently available to 2014; for more information, see Watson and Summerfield, 2014); and (2) through fieldwork interviews at each survey wave. In total we observe 1,529 deaths, accounting for 23.3% of respondents.[8]

[6] In the influential meta-analysis by Holt-Lunstad (2010) five Australian studies were included. This compares to 66 included US studies. Barr et al. (2021) note that there were only 3 Australian studies included in the meta-analysis of Holt-Lunstad et al. (2015) and they provided estimates only for living alone. Barr et al. (2021) find using Australian data a 9% higher mortality rate ratio for social isolation, but living alone was not found to be linked with mortality. The study does not look at loneliness.

[7] However, we will also provide estimates when no age restriction on the sample is imposed.

[8] In cases where the respondent was known to be deceased but the month of death was unknown, we code it as June of the survey year (this applies to 11.4% deaths). In this paper we focus on all-cause mortality, although the main cause

Measuring Social Relationships

Following Holt-Lunstad (2018) and Foster et al. (2023) we distinguish between 'functional' and 'structural' aspects of social relationships. Functional aspects relate to "functions provided by, or perceived to be available because of, social relationships", with key examples being perceived loneliness, and perceptions of social support. In contrast, structural components relate to the "existence of and inter-connections among difference social relationships and roles", most often measured by social isolation, social networks, living alone and marital status (Foster et al., 2023, p. 2/17).

In each wave of HILDA individuals are asked the extent to which they agree with the following statement: "I often feel very lonely", which they answer on a 7-point Likert scale ranging from "Strongly disagree" (1) to "Strongly agree" (7). For our main estimates we define "being lonely" as reporting a value of 5, 6 or 7 (i.e. agree) on this scale. We want to focus on chronic loneliness rather than acute spells, so we define an individual as experiencing "chronic loneliness" if they report to being lonely in two consecutive years (similar to Crowe et al., 2021). Using this definition 10% of respondents report experiencing chronic loneliness (see Table 1). We also test the sensitivity of the estimates to defining loneliness as 6 or 7 (i.e. strongly agree), and to defining chronic loneliness over three consecutive years.[9] Our second 'functional' aspect is a lack of (emotional) social support, which is defined in the equivalent way as chronic loneliness using responses to the statement, "I don't have anyone that I can confide in". Using this definition 8.4% of respondents report to have a chronic lack of social support.[10]

In terms of structural aspects of social relations, we distinguish between social isolation, being an active member of a club or association, and living alone (note that we also adjust for marital status in our models). We measure social isolation using answers to the question, "In general, about how often do you get together socially with friends or relatives not living with you?", with responses being able to range on a frequency scale from 1 (every day) to 7 (less often than

of deaths is available in the National Death Index records (up to 2014). Among the sampled deaths, the common causes include heart disease (16.29%), cerebrovascular disease (7.42%), and lung cancer (6.29%).

[9] A variety of measure of loneliness have been used in the literature (see, for example, Supplementary Table 6 in Wang et al., 2023). They range from direct one-item measures such as, "How often do you feel lonely" answered on a Likert scale (e.g. Yu et al., 2022), to binary responses to the question (e.g. asked in the UK Biobank), "Do you often feel lonely?" (Elovaninio et al., 2017; Hakulinin et al., 2018; Foster et al., 2023). The Revised 3-item UCLA Loneliness scale is based on summing the responses (and imposing a binary cut-off) to three questions (e.g. asked in the US HRS and UK ELSA): "How often do you feel that you lack companionship?", "How often do you feel left out?", and "How often do you feel isolated from others" (e.g. Steptoe et al., 2013; Crowe et al., 20210; Barnes et al., 2022). Evidence suggests that direct measures of loneliness are highly correlated with the three-item UCLA measure (around 0.88) (Office for National Statistics, 2018). Another measure of loneliness used in the literature is the De Jong Gierveld Loneliness Scale (e.g. Beller, 2022)

[10] Other forms of social support that we do not capture in our measures are physical support (e.g. having someone to care for you if needed) and financial support (e.g. having someone to turn to if you need access to funds).

once every 3 months). We define respondents as "being social isolated" if they report not getting together at least on a weekly basis with friends or relatives, and being chronically socially isolated if this is reported for two consecutive years. This applies to nearly one-third (31.4%) of respondents.[11] As with loneliness and a lack of social support, we also examine the sensitivity of the estimates to a more severe measure, defined as not getting together with friends of relatives at least on a monthly basis. Respondents are also asked, "Are you currently an active member of a sporting, hobby, or community-based club or association", of which they can answer "Yes" or "No". Around one-third (33.4%) of respondents report such membership in two consecutive years. Finally, living alone is defined as living in a single household or a household size of one person at the time of the interview, and this applies to 23% of respondents over two consecutive years. For each of these measures of social relationships, using household identifiers, we can define the same measures for spouses/partners.

Control Variables

Previous research has used a wide range of adjustments for potential confounding. The meta-analysis of Wang et al. (2023, Appendix) identifies nearly 100 covariates that have been used. As with many previous studies (e.g. Steptoe et al., 2013; Elovaninio et al., 2017; Yu et al., 2022) we define a minimally adjusted ("Basic") set of controls and a more comprehensively adjusted set ("Extended"). The basic controls are gender, being born overseas, non-English-speaking as main language (to capture any differences in perceptions/interpretation of the social relationships questions), and State (e.g. New South Wales) of residence controls. Our extended controls aimed at capturing well-established mortality risk factors are similar to those used in previous studies: marital status, educational attainment, (log) of equivalent household income, physical health index (0–100 scale), SF36 mental health score (0–100), long-term health conditions, level of residential urbanisation (e.g. city, urban, rural), and decile group of local area deprivation (based on SEIFA score for postcodes).[12]

In robustness tests we test the sensitivity of the estimates to additional plausible controls: namely, employment status; (log) household wealth; smoking, drinking and BMI (obese, underweight); Big-5 personality (scales for extroversion, agreeableness, conscientiousness, emotional stability, openness to experience), locus of control, and proxy measures of economic

[11] We expect that our measure of social isolation will capture not physically "getting together" regularly with friends or relatives, but some respondents might interpret the question more broadly to include, for example, getting together on a video call. We do not have a separate measure of the frequency of contacts through technology (e.g. phones, e-mails, social media etc.).

[12] SEIFA (Socio-Economic Indexes for Areas) scores combine Census data by postcode on income, education, employment, occupations, housing and family structure to provide a measure of relative disadvantage.

risk and time preferences; and spouses/partner's social relationships.[13] The inclusion of smoking as a mortality risk factor, as well as income and wealth, provides important benchmarks to compare the estimates for social relationships in the Australian setting. Sample means for the covariates are provided in Appendix Table A1.

Statistical Methods

We follow previous research in using the Cox proportional hazard regression to model the relationships between mortality hazard rates (and thence longevity), social relationships, and other covariates. Most previous studies (e.g. Steptoe et al., 2013; Fawaz and Mira, 2023) model survival since the date of the baseline survey interview while including respondent age as a confounder. By contrast, we model longevity per se (time since birth) because a respondent's age is an integral part of the outcome variable. There is significant variation in age across respondents at the baseline survey and yet mortality hazard rates increase with age during adulthood. Consequently, previous research has allocated individuals of different ages (and hence different mortality hazards) the same time at which they are first at risk of death (the zero point on the 'time since baseline' scale). Since mortality rates per se are the fundamental outcome of interest, we prefer to consider 'time at risk' of death as defined since birth. At the same time, to account for the fact that individuals are of different ages when first observed, we fit models conditioning on survival until a specific age, 50 years. In other words, we treat our data as not only potentially right-censored but also left-truncated (also known as delayed entry data). Consequently, our estimated mortality hazard and survival functions refer to ages 50 and older.

In sum, our statistical model is a Cox proportional hazards model in which the log of each individual's mortality hazard at a specific age is represented as the log of an arbitrary (unidentified) log baseline hazard function plus a linear index summarising the impact of individual differences in characteristics including social relationships. That is, for each individual,

$$\log[h(t \mid Z_t, X_t)] = \log[h_0(t)] + \gamma' Z_t + \beta' X_t \qquad (1)$$

where $h(.)$ is the mortality hazard rate at age t, $h_0(.)$ is the common baseline mortality hazard rate, Z_t is a vector of measures of social relations and X_t is a vector of personal characteristics (controls)

[13] Time preference is measured with the question: 'In planning your savings and spending, which time period is most important to you?' (options range from 'next week' to 'more than ten years ahead'). A higher index indicates a longer planning horizon, representing a lower time preference. Risk preference is determined by the question: 'Which statement best describes your willingness to take financial risks with your spare cash?' (options range from 'substantial risk' to 'not willing to take risk'). We code this variable such that one indicates the highest risk preference (risk-loving) and four the lowest (risk-averse). Finally, locus of control is measured by a composite indicator ranging from 7 (external LoC) to 49 (internal LoC), following Cobb-Clark and Schurer (2013).

some of which are age (and calendar-time) dependent. In our main set of estimates, Z_t is time-varying, but we also present estimates for models in which $Z_t = Z_0$, the respondent's values when first observed. We present estimates for models using either "basic" or "extended" sets of control variables in X_t.

Our specific interest is in the estimates of the γ parameters or, rather, the hazard ratios implied by them, i.e., $r_k = \exp(\gamma_k)$ for each social relations variable k. We characterise social relations using binary variables (see below), and so r_k summarises the proportionate difference in mortality hazard rate by social relationship status, adjusting for differences in characteristics summarised by X_t. We benchmark the magnitude of the estimated effects of social relations variables by considering their "equivalent effect" (in terms of longevity) in terms of control variables such as (log) income. For example, estimating that being lonely rather than not lonely is associated with T fewer months of life, we calculate the increase in (log) income required to reduce longevity by the same T months, holding all other regressors constant at their sample mean values.

We fit our Cox models using the *stcox* command in Stata 17.0 (StataCorp, 2021) with likelihood functions appropriately adjusted to account for left-truncation using the *enter()* option to *stset*. Age is measured in months (as in previous research). We re-estimated all our statistical models using discrete-time proportional hazards models with non-parametric baseline hazard rates. Reassuringly, estimated hazard rates were virtually identical to the corresponding estimates from our Cox models. Therefore, we focus on the continuous time model estimates. To calculate equivalent effects of social relations variables, we used *stcurve* to predict longevity conditional on covariate values.

Main Results

The main hazard ratio (HR) estimates relating to social relationships, together with 95% confidence intervals, are presented in Table 2. To provide useful comparison points we also include the estimates for the physical health index (0-100; increasing in good health), and the log of equivalised disposable household income. The corresponding full set of estimates is provided in Appendix Table A2. As previously mentioned, our main model allows for the (chronic) social relationship measures to be time-varying, while holding all other measures constant at their baseline values (i.e. when the respondent is first observed in the data; aged 50+). We later test the sensitivity of the estimates to two alternative specifications: (1) as with most of the literature we define social relationships measures as fixed at baseline; (2) we allow both social relationship measures and all other covariates to be time-varying.

Model 1 (All) and Model 2 (All) show estimates when we control for "basic" and "extended" controls/adjustments, respectively, using the pooled sample of males and females. In the models we have included each social relationship measure jointly, because they will be correlated to various extents, and we are aiming to obtain independent associations that might be useful when thinking of the design of interventions aimed at reducing mortality risk. From Model 1 we find that all measures of social relationships, both functional and structural, are significantly related to all-cause mortality. However, the largest positive HR is found for loneliness (1.576; 95% CI 1.369 – 1.814), followed by social isolation (1.216; 95% CI 1.090 – 1.356), then living alone (1.178; 95% CI 1.051 – 1.320). While we also find a positive HR associated with having a lack of (emotional) social support, the estimate is not statistically significantly different from unity (1.134; 95% CI 0.967 – 1.330). In contrast, we find a strong relationship between being an active member of a club or association and mortality, with a HR of 0.604 (95% CI 0.536 – 0.680), or inversed for comparability 1.656 (95% CI 1.471 – 1.866).

After adjusting for a wide-range of potential confounders in Model 2, we find similar, but as expected smaller, estimates for loneliness (1.413; 95% CI 1.219 – 1.637), social isolation (1.194; 95% CI 1.068 – 1.336) and active club or association membership (0.687; 95% CI 0.607 – 0.778). However, we no longer find a significant HR for living alone (1.027; 95% CI 0.858 – 1.230). Importantly, in contrast to a number of recent studies (e.g. Steptoe et al., 2013; Elovaninio et al., 2017; Hakulinen et al., 2018; Lara et al., 2020; Yu et al., 2022; Kammar-García et al., 2023), we find that the association between loneliness and mortality is only modestly reduced after adjusting for confounders.[14] Our result is then more in line with those found in other recent studies by, for example, Crowe et al. (2021), Hajek and Konig (2021), Ward et al. (2021), Barnes et al. (2022), Lennartsson et al. (2022), and Novak et al. (2023).

The HR estimates presented for physical health and household income, both in the model measured at baseline, provide some salient points of comparison with the estimates for social relationships. As expected, being in better physical health (0-100 scale) is negatively associated with mortality risk with a HR of 0.992 (95% CI 0.989 – 0.994), suggesting that there would have to be an increase in health of around 50-points to be 'equivalent' in terms of 'off-setting' the hazard ratio for loneliness. Similarly, having greater (log) household income is associated with reduced risk, with a HR of 0.896 (95% CI 0.842 – 0.953). To calibrate the importance of loneliness for predicting mortality, we derive its equivalent effect in terms of (log) household income using

[14] If we include each aspect of social relations in separate models (see Appendix Table A3) with the same set of extended controls (Model 2), we would conclude that there was a stronger association for a lack of social support and mortality (1.225; 95% CI 1.046 – 1.435), which is the other aspect of social relationships that is most strongly correlated with loneliness in the data.

Model 2.[15] Figure 2 shows (predicted) survivor functions by loneliness status and two values of log household income (9 and 10), with all other covariates set equal to their sample means. The figure shows that the mortality-increasing effect of being lonely, rather than not lonely, is equivalent to a reduction of at least one log-point for household income, which corresponds to around one standard deviation (i.e., 1.001) around the mean (9.978).

As a further example, for those who experience chronic loneliness, a one-log point increase (9 to 10) in household income increases the probability of survival at age 80 by 2.8 percentage points (0.712 compared to 0.684), while the corresponding difference for those not experiencing chronic loneliness is 2.2 percentage points (0.786 compared to 0.764).

Separate HR estimates for males and females are presented in Table 2, based on the model with the extended set of controls/adjustments (Model 2). Overall, we find a general consistency across gender in the importance of social relationships for mortality, with loneliness, social isolation, and being an active member of a club or association, being associated with mortality for both males and females. However, the HR for loneliness and social isolation are, respectively, larger for males at (1.552; 95% CI 1.267 – 1.901) and (1.240; 95% CI 1.068 – 1.439), than females (1.241; 95% CI 0.999 – 1.542) and (1.165; 95% CI 0.980 – 1.387). Conversely, the association between being an active club/association membership and mortality is larger for females (0.640; 95% CI 0.529 – 0.775) than males (0.724; 95% CI 0.614 – 0.854). Importantly, for both males and females we find no evidence of strong links to mortality for either a lack of social support, or living alone, although the HR point estimate for living is larger for males (1.239) compared to females (0.894). For both genders we find that better physical health and higher household income are associated with reduced mortality risk.

Robustness

The first set of robustness tests are based on including additional covariates that might capture confounding because they are likely to be independent risk factors for mortality. Each of these tests is based on Model 2 including the extended set of controls, and the results are presented in Table 3.[16] For brevity, given the same general results found by gender, we use the pooled sample for these tests. First, adding employment status only leads to very small changes in the HR's, but we note that being employed at baseline is strongly associated with reduced mortality risk (0.521; 95% CI

[15] How we calculate equivalent effects is explained in the Methods section and the notes to Figure 2.

[16] The sample size differs across the models presented in Table 3 as a result of missing data. Personality data has been collected in 4 waves of HILDA so has not been collected for some individuals with shorter spells in the panel. The partner social health requires respondents to be married or cohabiting. The large drop in the sample used for the model that includes smoking, drinking and obesity/underweight, is due to a significant number of missing smoking data, primarily from unrecorded responses. Since our smoking variable combines the number of cigarettes with smoking frequency, the absence of either detail leads to the variable being omitted.

0.402 – 0.675). While we already adjust for household income, we see that including a measure of household wealth (e.g. Steptoe et al., 2013) does not change our main results. Importantly, the HR for (log) household income remains roughly the same (0.914; 95% CI 0.856 - 0.976), and the HR for (log) household wealth is also significant at 0.979 (95% CI 0.964 – 0.995).

Personality traits, locus of control, and economic preferences with respect to how individuals view time and risk, have all been shown to be important in explaining individuals' choices, decisions and outcomes (e.g. Dohmen at al., 2011; Golsteyn et al., 2014; Etilé et al., 2021). As previously noted, studies have found that personality is an important stable factor in explaining individual differences in loneliness (Buecker et al., 2020). We are unaware of any previous studies that have adjusted for proxies of economic preferences. Since social relationships are to some extent a choice by individuals (e.g. whether to get together regularly with friends and family, or be an active member in a club), it is hoped that the inclusion of these "stable" traits will more fully control for selection. Importantly, we see little change in the HR's associated with any of the social relationship measures. An advantage of the HILDA data is that each adult member of the household provides their equivalent information on social relationships. Again, we find that the results are robust, and interestingly also that spouse/partner's social relationships do not significantly predict own mortality. This result also suggests that there are no unobserved household-level confounders that we are not capturing in our models, that would act to jointly determine the social relationships of all household members.

Many studies in the literature (See Supplementary Tables 5 and 6 in Wang et al., 2023) adjust for smoking, BMI and drinking. We distinguish between being a past and current smoker, being a heavy drinker (defined separately by gender at the 80th percentile; equal or greater than 19.25 units per week for males, and equal or greater than 8.25 units for females), and being obese (BMI≥30) and underweight (BMI<18.5). We note that height and weight are self-reported in HILDA.[17] Most importantly, given the frequent comparison that loneliness is as bad for mortality as smoking, we find a HR for being a past smoker of 1.270 (95% CI 1.088 – 1.481) and being a current smoker of 2.312 (95% CI 1.810 – 2.951). Adjusting for these factors does not change our results for social relationships. However, it is clear that the risks associated with loneliness and social isolation are a little larger than being a past smoker, but considerably smaller than being a current smoker (similar to the conclusion of Batty et al., 2021).[18]

[17] Consistent with allowing the measure of social relationship to be time-varying, we also allow these health-related behaviours to be time-varying. However, we note that the conclusions are not change if we fix these measures at baseline as done in previous studies.

[18] However, a caveat should apply to this interpretation as we are assuming that smoking is an independent risk factor fort mortality, but this does not allow for the possibility that loneliness could lead to increased smoking, and thus increased mortality risk. Moreover, our broad measures of smoking may not well capture lifetime exposure at the individual-level, so some caution should be applied to the comparison with social relationships.

Our focus has been on the links between chronic (rather than acute) measures of social relationships and mortality, and to do this we defined "chronic" as having reported loneliness, a lack of (emotional) social support, social isolation, being an active member of a club or association, and living alone, in two-consecutive years (waves). As shown in Table 3 if we expanded this definition to three-consecutive years the findings for social relationships hold. Additionally, for loneliness, a lack of social support, and social isolation, we based the cut-offs on the Likert scales as "agree" (answered 5, 6 or 7) to the statements, "I often feel very lonely", and "I don't have anyone that I can confide in", and we defined being social isolated as not getting together with friends or relatives at least once a week. If we increase the severity of the cut-offs to responding 6 or 7 (i.e. strongly agree) to the loneliness and lack of social support statement, and not getting together with friends or relatives at least on a monthly basis, we see, perhaps as expected, larger HR's for loneliness (1.511; 95% CU 1.269 – 1.799) and social isolation (1.385; 95% CI 1.173 – 1.634), suggesting 'dose-type' relationships with mortality. Notably, these risks are still lower than from current smoking.

Finally, in terms of modelling, as discussed, our main specification allows the social relationship measures to be time-varying, to address the issues that loneliness measured once, for example, may not be predictive of mortality some 10 or 20-years later, particularly if the initial observation captured an acute spell of loneliness, rather than chronic loneliness. However, to provide a more direct comparison for previous studies that fix social relationship at baseline, we have estimated the HR's doing the same. We find some salient differences to the results, with the HR's for loneliness (1.219; 95% CI 1.031 – 1.442), social isolation (1.088; 95% CI 0.967 – 1.225), and active club or association membership (0.845; 95% CI 0.751 – 0.950), now being smaller. We can also take the opposite approach of allowing both the social relationship measures and all the other covariates to be time-varying, but this does more explicitly raise the issue of causality. However, again the HR estimates are smaller than in our preferred specification, but loneliness, social isolation, and active club or association membership, remain statistically significant. Finally, we have used continuous time Cox proportional hazard models, but show that using a discrete-time equivalent makes no substantive differences to the estimates.[19]

[19] In Appendix Table A4 we also provide the main estimates when we exclude deaths that were identified only through fieldwork (the National Death Index has only been matched to HILDA respondents to 2014), when we expand our sample to include all respondents from age 40 at first interview (rather than age 50), or drop all age restrictions on the sample. The main estimates are robust to each of these.

Conclusions

Despite a large literature there remains uncertainty around the links between loneliness, social isolation, and other measures of social relationships, and mortality risk (Wang et al., 2023). In particular, while it is widely cited that loneliness is as bad as smoking 15 cigarettes per day for mortality (e.g. US Surgeon General, 2023), evidence from a number of recent studies places doubt on this benchmark, after controlling for confounding (e.g. Steptoe et al., 2013; Elovaninio et al., 2017; Hakulinen et al., 2018; Lara et al., 2020; Yu et al., 2022; Kammar-García et al., 2023). Rather, these studies find that social isolation remains a strong risk factor for mortality, implying that public health or policy interventions might be better targeted towards reducing social isolation rather than loneliness (remembering that they are only modestly correlated). However, other studies find that loneliness remains a significant risk factor after controlling for confounding (e.g. Crowe et al., 2021; Hajek and Konig, 2021; Ward et al., 2021; Barnes et al., 2022; Lennartsson et al., 2022; Novak et al., 2023). Even the hazard ratio estimates from recent meta-analytic studies vary considerably with respect to the importance of loneliness (Rico-Uribe et al., 2018; Schutter et al., 2022; Zhou et al., 2023; Naito et al., 2023; Wang et al., 2023).

In this paper we have sought to provide new evidence on the relative mortality risks associated with (poor) social relationships, both functional and structural aspects, using data from 19 waves of Australian longitudinal data (HILDA). Our main estimates are based on the mortality experiences of respondents aged 50 or above, providing us with a sample of 6,551 individuals observed on average for 9.8 years, of whom 1,529 (23.3%) died within our sample window. We have provided a number of contributions to the literature. In particular, we have focused on chronic and time-varying measures of social relationships, differentiating between loneliness, a lack of social support, social isolation, active membership of a club or association, and living alone. We have provided separate estimates by gender, and conducted a number of robustness tests including increasing the 'severity' of our measures, and controlling for a wide-range of potential confounders, and testing the relationship between spouse/partner's social relationships and own mortality risk. We also provide new evidence in the Australian setting, for which current information is scant (Barr et al., 2021).

Our study, however, has some limitations. Most notably, as with all the literature that has applied duration/survival analysis to study the links between measures of social relationships and mortality, we cannot make strong causal statements. This is because individuals are not randomised into loneliness, social isolation, or club membership, and even if an initial exogeneous shock to social relationships could be identified, over the long follow-up periods used to identify deaths, individuals would inevitably sort into social relationships (or not) given their characteristics, traits and preferences. However, we have adjusted in our model for "stable" characteristics that

potentially relate to sorting, including personality, locus of control, and economic time and risk preferences. Another limitation is that our measure of social isolation is based on not having regular "face-to-face" contact (i.e. "getting together") with friends and family, but we do not observe the frequency of technology-based social interactions. Yet, evidence from COVID-19 lockdowns shows that continued technology-based interactions could not prevent increased loneliness (e.g. Killgore et al., 2020; Kung et al., 2023). Finally, given our sample size, and the identification of mortality through fieldwork in later waves of the panel, we can only provide estimates for all-cause mortality.

Importantly, we have found robust evidence of a strong relationship between chronic loneliness and mortality risk with a hazard ratio (HR) of 1.413, implying a 41% higher risk for those who are lonely compared to those who are not. This dominates the risk associated with social isolation (HR = 1.194). Moreover, we identified important differences by gender, with the risk from chronic loneliness being greater for males (HR = 1.552) than females (HR = 1.241). In terms of identifying potential policy interventions, we find a strong relationship between being an active member of a club or association and mortality risk, with a hazard ratio of 0.687, and for males (HR = 0.724) and females (HR = 0.640). In contrast we find no evidence that social support or living alone are independent risk factors for mortality. In terms of the often made comparison with smoking, we find that loneliness has roughly the same mortality risk as being a past smoker (HR = 1.270), but this is considerably smaller than being a current smoker (HR = 2.312). However, we have noted that some caution should be applied to this comparison.

These results are important given that demographic changes in many countries mean that loneliness and social isolation are increasing, with more people living alone, and living longer. Overall, our findings suggest that interventions and policies should focus on reducing both loneliness and social isolation, as well as encouraging active social participation in clubs and associations.

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Table 1: Definitions and Summary Statistics for Main Social Relations Measures

Social Relations	Definition	Individuals	Mean	Min	Max
Functional					
Loneliness	Loneliness in the past 2 years (=1 if answering Yes in both of the last 2 years)	6,551	0.101	0.000	1.000
Lack of social support	Lack of social support in the past 2 years (No one to confide in, =1 if answering Yes in both the last 2 years)	6,551	0.084	0.000	1.000
Structural					
Social isolation	Social isolation in the past 2 years (get socially less than once per week, =1 if answering Yes in both the last 2 years)	6,551	0.314	0.000	1.000
Active Club/Association	Active member of a club or association (=1 if answering Yes in both the last 2 years)	6,551	0.334	0.000	1.000
Living alone	Living alone in the past 2 years (=1 if living alone in both the last 2 years)	6,551	0.232	0.000	1.000

Table 2: Main Estimates of Social Relations Measures on Mortality (Hazard Ratios)

Social Relation Measures	**Model 1 (All)**	**Model 2 (All)**	**Model 2 (Male)**	**Model 2 (Female)**
Functional				
Loneliness	1.576***	1.413***	1.552***	1.241*
	(1.369 - 1.814)	(1.219 - 1.637)	(1.267 - 1.901)	(0.999 - 1.542)
Lack of (emotional) social support	1.134	1.066	1.111	1.026
	(0.967 - 1.330)	(0.905 - 1.257)	(0.889 - 1.390)	(0.802 - 1.312)
Structural				
Social isolation	1.216***	1.194***	1.240***	1.165*
	(1.090 - 1.356)	(1.068 - 1.336)	(1.068 - 1.439)	(0.980 - 1.387)
Active Club/Association	0.604***	0.687***	0.724***	0.640***
	(0.536 - 0.680)	(0.607 - 0.778)	(0.614 - 0.854)	(0.529 - 0.775)
Living alone	1.178***	1.027	1.239	0.894
	(1.051 - 1.320)	(0.858 - 1.230)	(0.936 - 1.640)	(0.703 - 1.137)
Physical health index	-	0.992***	0.991***	0.992***
		(0.989 – 0.994)	(0.988 – 0.994)	(0.988 - 0.996)
Log household income	-	0.896***	0.921*	0.864***
		(0.842 - 0.953)	(0.837 - 1.013)	(0.795 - 0.939)
Basic controls	X	X	X	X
Extended controls	-	X	X	X
Individual/Month observations	767,804	752,946	346,500	406,446

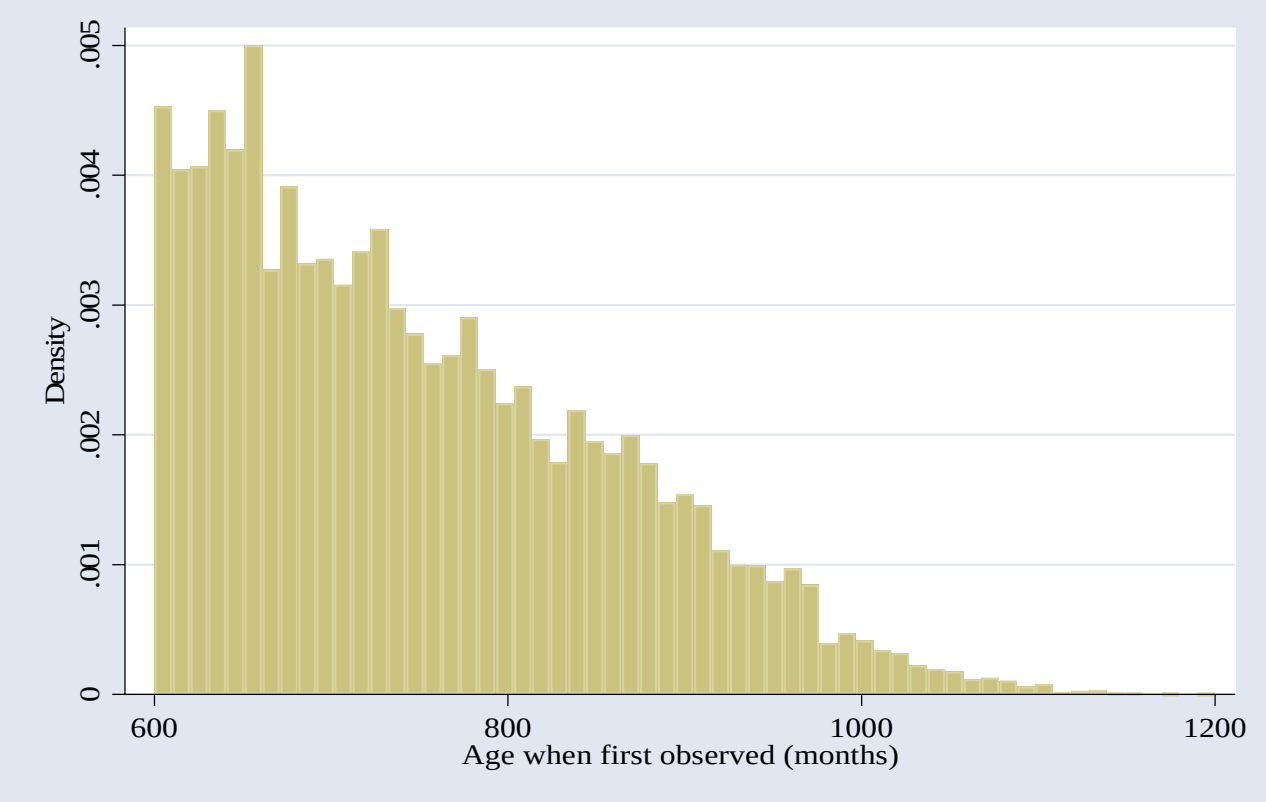
Notes: Results reported as hazard ratio; 95% CI in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Basic controls: gender; born overseas (base = born in Australia), non-English-speaking as main language (base = English as main language), State of residence controls (base = New South Wales). Additional Extended controls: marital status (base = Single), education attainment (base = Year 11 or below), log household income, dummy for non-positive household income; Mental Health SF-36 (0-100), Physical Health Index (0-100), long-terms health condition (base = no condition); degree of urbanisation (base = lives in major city), Area deprivation decile (base = SEIFA decile 1, lowest). See Appendix Table A2 for further details.

Table 3: Robustness Estimates of Social Relations Measures on Mortality (Hazard Ratios)

(1) Social Relations	**Adding Employment Status**	**Adding Household Wealth**	**Adding Personality, LOC, & Preferences**	**Adding Partner Social Health**	**Add Smoking and Obesity**
Functional					
Loneliness	1.410***	1.427***	1.364***	1.385***	1.392***
	(1.216 - 1.634)	(1.229 - 1.656)	(1.130 - 1.647)	(1.115 - 1.720)	(1.134 - 1.709)
Lack of social support	1.069	1.073	1.051	1.144	1.074
	(0.907 - 1.259)	(0.908 - 1.267)	(0.852 - 1.297)	(0.908 - 1.442)	(0.853 - 1.351)
Structural					
Social isolation	1.209***	1.197***	1.230***	1.220**	1.220***
	(1.080 - 1.352)	(1.069 - 1.341)	(1.075 - 1.408)	(1.047 - 1.422)	(1.054 - 1.412)
Active Club/Association	0.682***	0.695***	0.669***	0.702***	0.720***
	(0.603 - 0.773)	(0.613 - 0.788)	(0.577 - 0.775)	(0.593 - 0.830)	(0.616 - 0.842)
Living alone	1.035	1.019	1.007	1.066	1.153
	(0.864 - 1.240)	(0.848 - 1.223)	(0.809 - 1.254)	(0.732 - 1.552)	(0.902 - 1.474)
Observations	752,946	717,358	658,448	529,858	489,549
(2) Social Health	**Social Relations Defined Over 3-Years**	**Severe Social Relations**	**All Covariates Fixed Baseline**	**All Covariate Time-Varying**	**Discrete Time Model**
Functional					
Loneliness	1.342***	1.511***	1.219**	1.237***	1.413***
	(1.174 - 1.534)	(1.269 - 1.799)	(1.031 - 1.442)	(1.065 - 1.437)	(1.219 - 1.637)
Lack of social support	1.007	1.115	0.875	0.989	1.065
	(0.872 - 1.162)	(0.910 - 1.366)	(0.730 - 1.048)	(0.839 - 1.166)	(0.904 - 1.255)
Structural					
Social isolation	1.147**	1.385***	1.088	1.144**	1.198***
	(1.026 - 1.282)	(1.173 - 1.634)	(0.967 - 1.225)	(1.022 - 1.280)	(1.071 - 1.340)
Active Club/Association	0.724***	0.681***	0.845***	0.782***	0.687***
	(0.643 - 0.815)	(0.602 - 0.770)	(0.751 - 0.950)	(0.690 - 0.886)	(0.607 - 0.778)
Living alone	1.050	1.031	1.102	1.111	1.029
	(0.866 - 1.273)	(0.862 - 1.234)	(0.948 - 1.281)	(0.931 - 1.325)	(0.859 - 1.231)
Observations	683,924	752,946	752,946	752,946	752,927

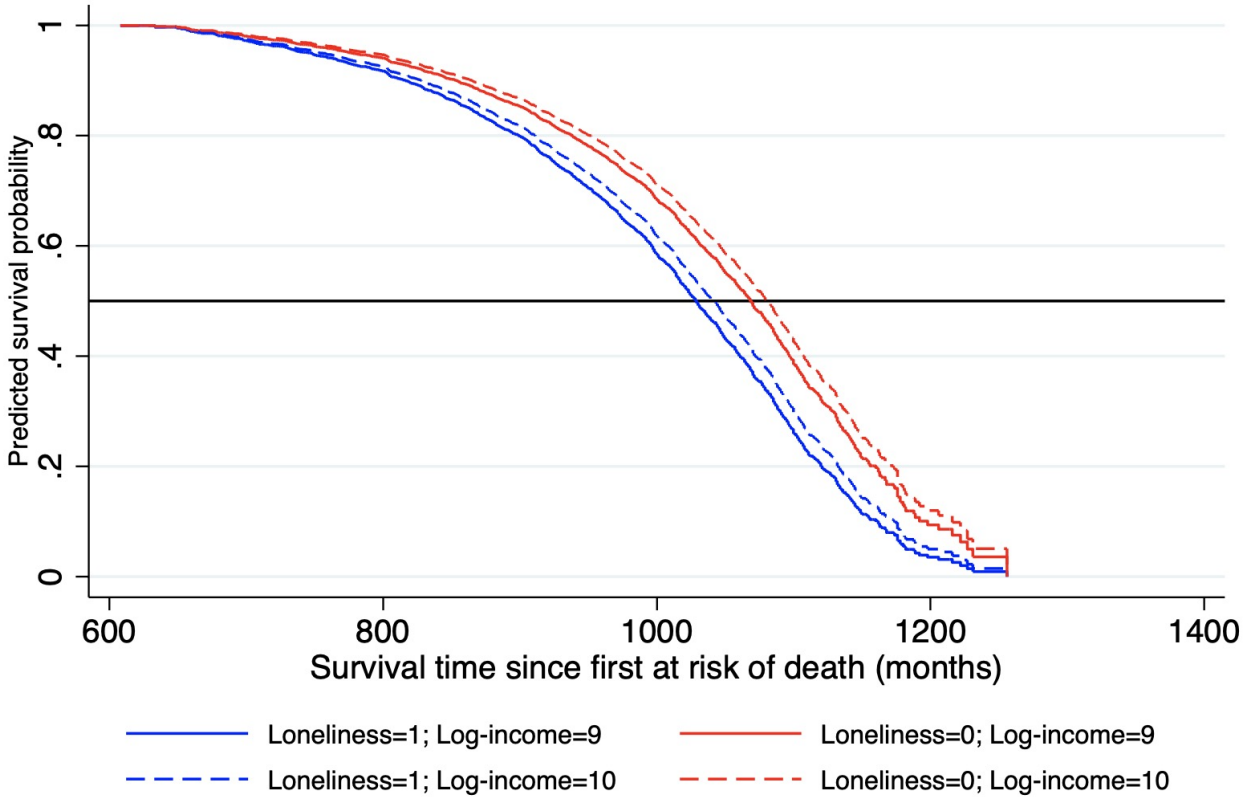
Notes: Results reported as hazard ratio; 95% CI in parentheses; *** p<0.01, ** p<0.05, * p<0.1. All models include Basic and Extended Controls (see footnote to Table 2).

Figure 1: Age First Observed in Panel (Sample 50+, in months since birth)



Notes: Our analysis conditions on survival to age 50 years (600 months): see Methods section. Individuals may be first observed in our panel after age 50.

Figure 2: The Mortality-Increasing Effect of Being Lonely is Equivalent to a Reduction in Log Household Income of about One Log-point



Notes: 'Income' refers to log(household income): see main text. The chart shows predicted survival curves from age 50 for the combinations of loneliness and log-income shown, with all other covariates set at sample mean values. Let $M(L, I)$ be the predicted median for values of loneliness L and log-income I, and define $A = M(1, 9)$, $B = M(1, 10)$, $C = M(0, 9)$, $D = M(0, 10)$. The equivalent effect of loneliness in terms of log-income is the difference between the values of log-income such that $A–C = B–D$, i.e., 9 and 10.

Appendix

Table A1: Sample Characteristics

Main Controls	Individuals	Mean	Std. dev.	Min	Max
Female	6,551	0.530	0.499	0.000	1.000
Born in Australia	6,551	0.694	0.461	0.000	1.000
Born overseas: English-speaking	6,551	0.151	0.358	0.000	1.000
Born overseas: Other	6,551	0.155	0.362	0.000	1.000
Speaks main language other than English	6,551	0.160	0.367	0.000	1.000
Single	6,551	0.293	0.455	0.000	1.000
Married	6,551	0.631	0.482	0.000	1.000
Cohabiting	6,551	0.076	0.264	0.000	1.000
Degree	6,551	0.162	0.369	0.000	1.000
Diploma / Certificate	6,551	0.282	0.450	0.000	1.000
Year 12	6,551	0.077	0.266	0.000	1.000
Year 11 or lower	6,551	0.479	0.500	0.000	1.000
Household income (log)	6,551	9.978	1.001	4.605	14.043
Non-positive income	6,551	0.003	0.051	0.000	1.000
Resides in major cities	6,551	0.623	0.485	0.000	1.000
Resides in inner/outer regional	6,551	0.360	0.480	0.000	1.000
Resides in remote area	6,551	0.018	0.132	0.000	1.000
Mental health SF36 score	6,551	75.623	17.491	0.000	100.000
Physical health index	6,551	71.751	26.489	0.000	100.000
Used in Robustness Test					
Employed	6,551	0.297	0.401	0.000	1.000
Household wealth (log)	6,348	13.206	3.258	-15.420	17.847
Extroversion	5,544	4.330	0.976	1.000	7.000
Agreeableness	5,543	5.452	0.915	1.000	7.000
Conscientiousness	5,534	5.256	0.944	1.000	7.000
Emotional stability	5,526	5.569	0.960	1.000	7.000
Openness	5,522	4.007	1.040	1.000	7.000
Locus of control	6,119	5.169	1.224	1.000	7.000
Risk preference	6,452	3.507	0.636	1.000	4.000
Time preference	6,485	2.922	1.556	1.000	6.000
Never smoke	6,497	0.495	0.482	0.000	1.000
Past smoker	6,497	0.386	0.453	0.000	1.000
Current smoker	6,497	0.120	0.300	0.000	1.000
Heavy drinker	6,503	0.204	0.346	0.000	1.000
Obese	6,503	0.212	0.367	0.000	1.000
Underweight	6,503	0.036	0.160	0.000	1.000

Note: Statistics for SEIFA decile and State of Residence not shown.

Table A2: Full Estimates of Social Relations Measures on Mortality

Covariates	Model 1 (All)	Model 2 (All)	Model 2 (Male)	Model 2 (Female)
Loneliness	1.576***	1.413***	1.552***	1.241*
	(1.369 - 1.814)	(1.219 - 1.637)	(1.267 - 1.901)	(0.999 - 1.542)
Lack of social support	1.134	1.066	1.111	1.026
	(0.967 - 1.330)	(0.905 - 1.257)	(0.889 - 1.390)	(0.802 - 1.312)
Social isolation	1.216***	1.194***	1.240***	1.165*
	(1.090 - 1.356)	(1.068 - 1.336)	(1.068 - 1.439)	(0.980 - 1.387)
Active Club/Association	0.604***	0.687***	0.724***	0.640***
	(0.536 - 0.680)	(0.607 - 0.778)	(0.614 - 0.854)	(0.529 - 0.775)
Living alone	1.178***	1.027	1.239	0.894
	(1.051 - 1.320)	(0.858 - 1.230)	(0.936 - 1.640)	(0.703 - 1.137)
Female	0.540***	0.491***	-	-
	(0.486 - 0.601)	(0.437 - 0.552)		
Born overseas: English-speaking	0.953	1.018	1.137	0.900
	(0.823 - 1.104)	(0.871 - 1.189)	(0.931 - 1.388)	(0.696 - 1.163)
Born overseas: Other	1.151	1.107	1.175	1.063
	(0.896 - 1.478)	(0.848 - 1.445)	(0.833 - 1.656)	(0.688 - 1.642)
Speak language other than English	0.752**	0.780*	0.732*	0.831
	(0.583 - 0.969)	(0.598 - 1.016)	(0.519 - 1.034)	(0.543 - 1.272)
Married	-	0.886	0.900	0.978
		(0.740 - 1.062)	(0.689 - 1.176)	(0.754 - 1.269)
Cohabiting	-	1.102	1.202	0.895
		(0.756 - 1.606)	(0.758 - 1.907)	(0.408 - 1.964)
Degree	-	1.069	1.221	0.996
		(0.871 - 1.312)	(0.915 - 1.630)	(0.738 - 1.343)
Diploma / Certificate	-	0.913	0.977	0.765*
		(0.798 - 1.046)	(0.830 - 1.150)	(0.579 - 1.010)
Year 12	-	0.925	0.893	1.053
		(0.760 - 1.126)	(0.685 - 1.166)	(0.779 - 1.422)
Household income (log)	-	0.896***	0.921*	0.864***
		(0.842 - 0.953)	(0.837 - 1.013)	(0.795 - 0.939)
Non-positive income	-	0.423*	0.402	0.741
		(0.165 - 1.085)	(0.133 - 1.219)	(0.096 - 5.717)
Mental health SF-36 score	-	1.003*	1.006**	1.001
		(1.000 - 1.007)	(1.001 - 1.010)	(0.995 - 1.006)
Physical health index	-	0.992***	0.991***	0.992***
		(0.989 - 0.994)	(0.988 - 0.994)	(0.988 - 0.996)
Sensory	-	0.903	0.872	0.957
		(0.765 - 1.066)	(0.700 - 1.086)	(0.736 - 1.246)
Mobility / Movement	-	1.035	1.114	0.964
		(0.875 - 1.225)	(0.891 - 1.392)	(0.740 - 1.256)
Respiratory	-	1.422***	1.334**	1.610***
		(1.177 - 1.719)	(1.034 - 1.723)	(1.206 - 2.151)
Mental	-	0.981	0.982	1.015
		(0.734 - 1.311)	(0.683 - 1.411)	(0.615 - 1.673)
Chronic pain	-	0.974	0.853	1.137
		(0.791 - 1.199)	(0.641 - 1.134)	(0.832 - 1.554)
Other conditions	-	1.455***	1.705***	1.210
		(1.252 - 1.691)	(1.400 - 2.076)	(0.952 - 1.537)

Inner/Outer Regional	-	0.978	0.945	1.044
		(0.864 - 1.106)	(0.801 - 1.116)	(0.865 - 1.262)
Remote areas	-	0.842	0.842	0.925
		(0.544 - 1.305)	(0.474 - 1.496)	(0.468 - 1.828)
SEIFA 2nd decile	-	1.032	0.902	1.198
		(0.849 - 1.256)	(0.690 - 1.180)	(0.893 - 1.607)
SEIFA 3rd decile	-	1.077	1.140	1.012
		(0.871 - 1.330)	(0.859 - 1.514)	(0.732 - 1.401)
SEIFA 4th decile	-	0.918	0.806	1.055
		(0.732 - 1.150)	(0.594 - 1.095)	(0.750 - 1.484)
SEIFA 5th decile	-	0.947	0.868	1.045
		(0.756 - 1.186)	(0.643 - 1.172)	(0.740 - 1.476)
SEIFA 6th decile	-	0.881	0.903	0.824
		(0.707 - 1.097)	(0.675 - 1.208)	(0.584 - 1.163)
SEIFA 7th decile	-	0.892	0.881	0.924
		(0.693 - 1.149)	(0.626 - 1.241)	(0.632 - 1.352)
SEIFA 8th decile	-	0.900	0.793	1.060
		(0.712 - 1.139)	(0.573 - 1.099)	(0.751 - 1.496)
SEIFA 9th decile	-	1.063	1.004	1.133
		(0.835 - 1.352)	(0.726 - 1.389)	(0.785 - 1.635)
SEIFA 10th decile	-	0.701**	0.592***	0.869
		(0.529 - 0.928)	(0.401 - 0.874)	(0.575 - 1.315)
Victoria	0.934	1.002	1.041	0.965
	(0.818 - 1.067)	(0.870 - 1.154)	(0.859 - 1.262)	(0.781 - 1.193)
Queensland	0.909	0.914	0.999	0.807*
	(0.783 - 1.056)	(0.782 - 1.069)	(0.812 - 1.230)	(0.632 - 1.031)
South Australia	0.936	0.880	0.917	0.850
	(0.779 - 1.124)	(0.724 - 1.068)	(0.705 - 1.192)	(0.632 - 1.142)
Western Australia	0.826*	0.876	0.827	1.002
	(0.681 - 1.002)	(0.716 - 1.072)	(0.627 - 1.091)	(0.742 - 1.352)
Tasmania	1.096	0.999	0.963	1.010
	(0.835 - 1.439)	(0.744 - 1.341)	(0.648 - 1.430)	(0.642 - 1.587)
Northern Territory	1.791	1.663	1.130	1.794
	(0.799 - 4.014)	(0.707 - 3.911)	(0.154 - 8.277)	(0.645 - 4.986)
Australian Capital Territory	0.778	0.916	1.538	0.652
	(0.471 - 1.284)	(0.531 - 1.582)	(0.744 - 3.178)	(0.283 - 1.503)
Observations (Individual-month)	767,804	752,946	346,500	406,446

Notes: Results reported as hazard ratio; 95% CI in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table A3: Estimates of Social Relations Measures (when included separately) on Mortality

Social Relations	Model 2 (All)	Model 2 (All)	Model 2 (All)	Model 2 (All)	Model 2 (All)
Functional					
Loneliness	1.474***	-	-	-	-
	(1.277 - 1.700)				
Lack of social support	-	1.220**	-	-	-
		(1.041 - 1.429)			
Structural					
Social isolation	-	-	1.291***	-	-
			(1.159 - 1.440)		
Active Club/Association	-	-	-	0.672***	-
				(0.595 - 0.758)	
Living alone	-	-	-	-	0.966
					(0.811 - 1.152)

Notes: Results reported as hazard ratio; 95% CI in parentheses; *** p<0.01, ** p<0.05, * p<0.1. All models include Basic and Extended Controls (see footnote to Table 2).

Table A4: Robustness Estimates of Social Health Measures on Mortality Risk (Hazard Ratios)

Social Relations	Excluding Waves 15-19	Sample 40+	No Age Restrictions
Functional			
Loneliness	1.325***	1.415***	1.475***
	(1.119 - 1.570)	(1.228 - 1.632)	(1.288 - 1.688)
Lack of social support	1.088	1.036	1.044
	(0.903 - 1.310)	(0.883 - 1.216)	(0.895 - 1.218)
Structural			
Social isolation	1.193***	1.185***	1.144**
	(1.048 - 1.359)	(1.064 - 1.320)	(1.031 - 1.269)
Active Club/Association	0.702***	0.691***	0.688***
	(0.609 - 0.810)	(0.613 - 0.778)	(0.612 - 0.772)
Living alone	0.996	1.003	0.979
	(0.809 - 1.227)	(0.846 - 1.189)	(0.834 - 1.149)

Notes: Results reported as hazard ratio; 95% CI in parentheses; *** p<0.01, ** p<0.05, * p<0.1. All models include Basic and Extended Controls (see footnote to Table 2).