Title (122 characters / 125 max): **Older adults' marital status and excess all-cause mortality during COVID-19: investigating heterogeneity by place of death**

Running Title (42 characters / 45 max): **Older adults' marital status and mortality**
Alternative (39 characters / 45 max): **Mortality, marriage, and place of death**

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Limits:	Structured Abstract:	299 words / 300 max
	Text-only word count:	3011 words / 3500 max
	Key points box:	124 words / 300 max
	Number of references:	___ refs / 50 max
	Number of tables/figures:	___ tables & figures / 5 max
	Graphical abstract encouraged (as supplement)	

Key Points (3 bullets max)

- Marriage was associated with lower excess all-cause mortality among older adults during the COVID-19 pandemic compared to widowed, divorced, and never-married counterparts.
- In analyses stratified by place of death, married individuals had the most advantage in nursing homes.
- Relative differences in mortality risk were less pronounced for those who died in hospitals or at home.

Why does this paper matter? (1-2 sentences)
This study highlights the protective effects of marriage against excess all-cause mortality among older adults during the COVID-19 pandemic, particularly in nursing homes, where spousal advocacy may mitigate institutional care limitations. Identifying disparities in mortality risk among unmarried individuals, this work underscores critical gaps in social and healthcare safety nets, with implications for equitable care strategies in aging populations.

ABSTRACT

Background

Despite extensive research on social factors affecting health outcomes during the COVID-19 pandemic, the role of marital status in influencing older adults' mortality remains underexplored.

This study aimed to fill this gap by examining the relationship between marital status and excess mortality among older Californians during the pandemic, assessing potential heterogeneity by place of death.

Methods

Using California death records for decedents aged 65+, we estimated the expected number of deaths during the pandemic (Mar. 2020–Jul. 2023) based on pre-pandemic trends (Jan. 2015–Feb. 2020). ARIMA time series models stratified by marital status (married, widowed, divorced, never married) and place of death (home, hospital, nursing home/long-term care, other) yielded monthly and cumulative estimates of absolute pandemic-era excess mortality overall and by subgroup, per 100,000 using American Community Survey population data.

Results

Among California decedents aged 65+ (n=1,595,862), married individuals had lower excess mortality across age, sex, and education groups. In nursing homes, married individuals had a relative mortality risk ratio of 0.69 (0.65, 0.73), 31% lower than expected based on pre-pandemic trends. Never-married individuals had a ratio of 0.86 (0.83, 0.89), 14% lower than expected. The difference (0.17) between the relative risk ratios of married vs. never-married in nursing homes was nearly twice as large as that observed for home deaths (1.15 vs. 1.24) and six times larger than for hospital deaths (1.22 vs. 1.25).

Conclusions

Marriage was associated with lower excess all-cause mortality among older adults during the COVID-19 pandemic, particularly in nursing homes. These findings suggest that marital status–possibly through mechanisms such as social support and advocacy–may play a critical role in mitigating mortality risk during public health crises. This highlights the need for targeted support for unmarried older adults, especially in institutional care settings.

INTRODUCTION

Marital status is a critical social determinant of health for older adults, offering profound physical, emotional, cognitive, and social consequences. (cite) Being married has consistently been linked to better health outcomes, lower mortality, and greater longevity, likely due to the emotional support, practical assistance, and caregiving that spouses often provide. (cite)

As Americans live longer, the composition of the older adult population is rapidly changing, and the circumstances surrounding their end-of-life experiences are evolving. (cite) The COVID-19 pandemic further emphasized the importance of social bonds and support systems, especially among older adults, due to their heightened vulnerability to severe outcomes. (cite)

Prior to the pandemic, research consistently demonstrated that married individuals generally experienced better health outcomes and lower mortality rates compared to those who were unmarried (widowed, divorced, or never married). (cite) The apparent protective effect of marriage has been attributed to various factors, including enhanced social support, improved access to resources, and more preventative health behaviors. (cite) The pandemic introduced unique stressors and altered social dynamics, likely affecting the traditional health advantages associated with marriage. (cite) For instance, stay-at-home orders and social distancing measures may have intensified social isolation for unmarried individuals while potentially strengthening bonds within married households. Conversely, the increased stress of prolonged close contact and shared pandemic-related anxieties could have strained some marital relationships. Additionally, the pandemic's impact on healthcare access and utilization likely differed between married and unmarried individuals, possibly altering or exacerbating pre-existing patterns of access. The economic fallout from the pandemic may have also affected married and unmarried individuals differently, further complicating the traditional understanding of marital status as a determinant of health. Given these complex and possibly contradictory effects, the unprecedented circumstances of the COVID-19 pandemic have necessitated a re-examination of the earlier observed differences between married and unmarried individuals.

As a result, a growing body of literature has emerged to investigate the health consequences of marital status during the pandemic period. However, a critical gap remains: understanding the relationship between the marital status of older adults and their excess mortality during the COVID-19 pandemic. This research is essential because marital status plays a key role in shaping social support systems, which are vital to older adults' ability to withstand and recover from crises. (cite) Examining these patterns can help identify vulnerable populations who may lack access to these social supports, and it can highlight opportunities to strengthen the systems that serve older adults in future public health emergencies. Furthermore, focusing on excess all-cause mortality, rather than solely on recorded COVID-19 deaths, allows for a more comprehensive assessment of the pandemic's overall impact on mortality. (cite) This approach offers two key benefits. Firstly, it accounts for the significant underreporting of COVID-19 deaths, particularly in the early stages of the pandemic, due to factors such as limited testing and misdiagnosis. (cite) These underreported COVID-19 deaths likely constitute a substantial portion of the observed excess mortality. (cite) Secondly, this approach captures deaths resulting from any number of other consequences of the pandemic, such as disruptions to healthcare systems, increased social isolation, and heightened stress—factors that may disproportionately affect certain marital status groups. (cite) By examining excess all-cause mortality, we can assess both the immediate impact of COVID-19 (including unreported cases) and these broader, indirect consequences of the pandemic on mortality patterns among different marital status groups. (cite)

This study examined the relationship between marital status and excess all-cause mortality among older adults during the COVID-19 pandemic. We also investigated heterogeneity in marital-status-specific excess mortality across different places of death (home, hospital, and nursing home/long-term care facilities), which may serve as an imperfect proxy for care settings and support structures available at the end of life. (cite) While place of death does not perfectly correspond to residential status, since nursing home residents may die in hospitals, for instance, it provides insight into the care environment during the final period of life.

Older adults were particularly vulnerable to both the direct effects of SARS-CoV-2 transmission and the indirect impacts of social isolation, healthcare disruption, and reduced access to routine care. (cite)

Marital status likely played a pivotal role in mitigating the adverse repercussions of the pandemic, with potential differences across places of death, which may reflect different care environments. We hypothesized that marriage would confer the strongest protective effects in community-based settings (i.e., private homes, hospitals) and the weakest effects in institutional, long-term care settings (i.e., nursing homes), where the provision of care might depend more heavily on facility-level resources than on spousal involvement.

This research contributes to a more comprehensive understanding of how marital status may function as a key social determinant of health among older adults, particularly during the COVID-19 pandemic, when the unique social, economic, and healthcare disruptions may have intensified or attenuated the traditional protective effects of marriage.

METHODS

Study Population

Based on comprehensive statewide death certificate records from the California Department of Public Health, the study population included all California residents who died in the state between January 1, 2015, and July 31, 2023, who were age 65 or older at the time of death, and who died at home, in a hospital, or in a nursing home or other long-term care facility (NH/LTC). We excluded decedents who died in inpatient hospice facilities and those whose place of death was recorded as “Other” or “Unknown.”

To ensure adequate subgroup size and stability across the 103-month study period, we restricted the study population to individuals whose sex was recorded as either male or female on the death certificate. Individuals for whom sex was recorded as non-binary or unknown were excluded because their small numbers—13 decedents out of over 1.6 million (<0.01%)—would not support reliable modeling or rate estimation within a large number of stratified subgroups, including twelve 1-way, 2-way, and 3-way combinations of age group, marital status, sex, and place of death.

We note that California death certificates currently include a single field labeled 'sex' with options for male (M), female (F), non-binary (X), or unknown (U), rather than separate fields for sex assigned at birth and gender identity. This administrative limitation reflects current vital statistics infrastructure rather than a conceptual conflation of sex and gender.

Study Time Periods

The study included data from January 1, 2015, to July 31, 2023. For analytical purposes, this interval was divided into two primary phases: a pre-pandemic period, defined as the 62 months from January 1, 2015, through February 29, 2020, and a pandemic period, defined as the 41 months from March 1, 2020, through July 31, 2023. This partition allowed for the development of baseline time-series models using stable pre-pandemic mortality data and the subsequent assessment of changes in mortality patterns following the onset of the COVID-19 pandemic.

Within the pandemic period, we further distinguished between two sub-periods based on the timing of initial vaccine availability in California. The pre-vaccine period was defined as the first 9.5 months of the pandemic from March 1, 2020, through December 13, 2020. The post-vaccine period began on December 14, 2020, when the first COVID-19 vaccine doses were administered in California, and extended through the end of the study period. This sub-division enabled separate evaluation of excess mortality during periods with and without widespread access to vaccination, an important contextual factor in understanding mortality risk during the pandemic.

Measures

The primary outcome of interest was all-cause mortality, defined as any recorded death from any cause at home, in a hospital, or in a nursing home or other long-term care facility among California residents aged 65 and older during the study period. We chose all-cause mortality in order to capture not only deaths directly attributed to COVID-19 but also all undiagnosed COVID-19 deaths that may have gone unrecorded due to limited testing capacity, asymptomatic infection, or misattribution of cause. This approach also allowed us to capture deaths potentially arising from the pandemic's indirect effects on healthcare access, health-seeking behaviors, social determinants, and other risk pathways.

The primary exposure of interest was marital status, as recorded on the death certificate. Every decedent's marital status was classified according to the following nine groups: married, widowed, divorced, never married, state-registered domestic partnership, surviving member of state registered domestic partnership, legally married with simultaneous death of spouses, state registered domestic partnership with simultaneous death of partners, and unknown. Missing values of marital status (the unknown group) were imputed using multivariate imputation by chained equations with the classification and regression tree method, which is well-suited for imputing missing values of unordered categorical variables and robust to interactions, nonlinear relationships, and sparsity in predictor variables. Predictor variables for the imputation model were selected based on theoretical relevance, presumed temporal ordering (i.e., occurring before or at the same time as the exposure), and data completeness. The final predictor set included the decedents' age at time of death, sex, race and ethnicity, and educational attainment. Five imputed datasets were generated, each with five iterations. Following imputation, marital status was collapsed into four analytically relevant categories that we used for all analyses: married (including state-registered domestic partnerships, simultaneous death of spouses or domestic partners, and married but legally separated), widowed (including surviving domestic partners—a designation we applied because domestic partnership is a legal status in California that confers many of the same benefits as marriage), divorced, and never married. Descriptive statistics presented in Table 1 were generated using the first completed dataset (i.e., the first of five imputed datasets), a common approach for reporting baseline characteristics when multiple imputation is used for missing data.

Additional demographic and contextual covariates included sex (male or female), age at death (integer value and also categorized into four groups: 65–74, 75–84, 85–94, and 95+ for descriptive analyses of death counts, though these latter two groups were combined into 85+ for population-based rate calculations due to ACS top-coding limitations), and place of death. Age was calculated by subtracting each individual's date of birth from their date of death, expressed in years (the number of days was divided by 365.25 days per year to account for leap years). Place of death was recorded as the location where death occurred—at home, in a hospital, or in a nursing home/long-term care (NH/LTC) facility—which may differ from the decedent's primary residential address. For example, a long-term nursing home resident who died in a hospital would be classified as a hospital death in our analysis. We chose to use place of death rather than residential address as it was more consistently recorded and reflected the care environment at the time of death, though we acknowledge this approach cannot distinguish between long-term institutional residents and those who died shortly after admission. We restricted the study population to individuals who died at these three locations because they are the most common and well-defined places of death, representing the majority of decedents. Excluding deaths at places categorized as "other," "unknown," or in hospice facilities ensured data quality by avoiding less common or ambiguously classified settings.

Data Preparation and Aggregation

Following the imputation of missing marital status values in the mortality data as described in the Measures section, each of the five imputed datasets was cleaned and then aggregated into monthly death counts. These counts were stratified by marital status, age group (65–74, 75–84, 85–94, and 95+ for count-based analyses; 65–74, 75–84, 85+ for rate-based analyses), sex (male, female), and place of death (home, hospital, or NH/LTC facility). This aggregation produced five parallel time-series datasets of the number of deaths per month across all relevant subgroups.

Population denominators corresponding to these subgroups were constructed separately using data from American Community Survey (ACS) as described below. These denominators were used to calculate both crude and age-standardized mortality rates.

Because population estimates stratified by place of death do not exist in NVSR or ACS data, standard weights and population denominators could not be constructed for place-of-death-specific strata. Thus, mortality patterns by place of death are presented only in terms of raw death counts or proportions, without rate scaling or standardization.

Population Estimates and Standard Populations

To account for differences in age structure across marital status groups and permit comparisons of mortality risk across marital status groups, we applied direct age standardization. We constructed our standard population using 2019 U.S. population data from the National Vital Statistics Reports (NVSR). We chose to use the 2019 NVSR data rather than the commonly used 2000 U.S. Standard Population because we believe they better reflect the age structure of the older U.S. population immediately before the onset of the COVID-19 pandemic. Specifically, we used data from NVSR Volume 70, No. 8 (Supplemental Table I-18), which provided national estimates of the number of adults aged 65 and older by marital status and age group. These estimates were disaggregated into three age groups (65-74, 75-84, and 85+) using survival proportions from the 2019 U.S. Life Tables (NVSR Volume 70, No. 19, Table 1). This produced the full set of age- and marital status-specific weights for the four marital status categories (married, widowed, divorced, and never-married) that we applied for our age standardization procedure.

To construct population denominators for mortality rate estimates, we used ACS Public Use Microdata Sample (PUMS) data from 2015 through 2023. We filtered the ACS data to include only individuals age 65 and older, and we grouped these estimates by year, sex, marital status, and age group to match the structure of the mortality data. Each year’s ACS data produced annual midyear population estimates for that calendar year, and we treated these as representative of the average population at risk during the year to merge with the mortality counts from the imputed datasets.

We calculated two types of mortality rate estimates: crude and age-standardized mortality rates per 100,000 individuals. For descriptive and sensitivity analyses, we calculated crude (non-standardized) mortality rates by dividing the total number of deaths in each marital status × sex × age group stratum by its ACS-derived population estimate. For comparative analyses, we calculated age-standardized mortality rates using direct standardization. For each imputed dataset, we computed age-specific mortality rates within each stratum of marital status, sex, and age group, multiplied those rates by their corresponding standard weight, and summed across age groups to obtain the age-standardized mortality rate for each marital status × sex combination. Final estimates were pooled across imputations by calculating the mean rate and corresponding standard error and 95% confidence interval. All rates were scaled to reflect mortality per 100,000 individuals.

In addition to these pooled estimates, we also computed year-specific age-standardized rates using ACS denominators for each calendar year, which allowed for visualization of trends over time (e.g., Figure X).

Finally, since the 2023 mortality data were available only for January through July, we annualized death counts for 2023 by multiplying by a factor of 12/7 in order to allow for meaningful comparisons between 2023 and earlier years. This adjustment was applied only to descriptive rate calculations, not analytic models, and reflects the assumption that the first 7 months of 2023 were representative of the full year. ACS midyear population estimates were treated as representative of the average population at risk across each calendar year.

Due to the absence of place-of-death information in the ACS and NVSR data, we did not calculate population-scaled mortality rates for place-of-death subgroups. All analyses of place of death are therefore presented as raw death counts or proportions within strata.

Statistical Analysis

Mortality data are seasonally patterned year over year, so a robust modeling approach that accounts for this seasonality is required. We used Autoregressive Integrated Moving Average (ARIMA) models with harmonic terms—periodic functions that model seasonal variations—to learn pre-pandemic mortality trends and estimate the number of deaths expected to occur in subsequent periods. (cite)

Model Specification and Assumptions. The ARIMA approach assumes: 1) stationarity of the detrended time series, 2) linearity in the autoregressive and moving average relationships, 3) normally distributed residuals with constant variance (homoscedasticity), and 4) independence of residuals. The inclusion of harmonic terms assumes regular, cyclical seasonal patterns. The training set comprised monthly death counts from January 2015 through February 2020. We then used the trained ARIMA models to estimate the monthly number of deaths that would have occurred from March 2020 onward had the COVID-19 pandemic not happened.

Model Selection and Diagnostics. The best-fit model was selected using the Akaike Information Criterion corrected for small sample sizes (AICc), which balances model fit against complexity to avoid overfitting. Model adequacy was assessed through comprehensive residual diagnostics. The Ljung-Box test was performed at multiple lag values (up to 24 months) to verify the absence of significant autocorrelation in residuals, confirming the independence assumption. Autocorrelation in residuals would violate the independence assumption of ARIMA models, indicating that systematic temporal patterns remain unexplained by the model, resulting in worse accuracy of our excess mortality estimates and prediction intervals that fail to reflect true uncertainty, potentially leading to biased conclusions about marital status differences in excess mortality. Visual inspection of residual plots (residuals versus fitted values, Q-Q plots, and autocorrelation function plots) was conducted to assess normality, homoscedasticity, and remaining temporal patterns. Where visual inspection suggested potential violations, formal tests were considered, though we note that slight departures from normality have minimal impact on ARIMA forecasting performance for large samples. Models failing diagnostic checks were respecified with additional seasonal or autoregressive terms until residual diagnostics were satisfactory.

Model Performance Assessment. To evaluate goodness of fit during the training period (January 2015–February 2020), we calculated the mean absolute percentage error (MAPE) between fitted and observed monthly death counts for each marital status group. MAPE values ranged from X.X% to X.X% across subgroups, indicating [excellent/good/adequate] fit, with values below 10% generally considered acceptable for mortality forecasting. Additionally, we generated calibration plots comparing observed versus fitted values during the training period to visually assess model performance across the range of mortality counts (Supplementary Figure X).

Missing Data Handling. Marital status was missing for approximately 1% of death records (n=15,860). We employed multiple imputation by chained equations using classification and regression trees (CART), which is robust to non-linear relationships and interactions among predictors. The imputation model included age, sex, education, and race/ethnicity as predictors, assuming data were Missing at Random (MAR)—that missingness was related only to observed covariates. Five imputed datasets were generated with five iterations each, and all analyses were conducted separately on each dataset with results pooled using Rubin's rules to properly account for imputation uncertainty.

Age Standardization and Stratification. To enable meaningful comparisons of mortality risk across marital status groups, all-cause mortality rates were first age-standardized using direct standardization procedures described above. Standardized mortality rates were calculated separately for each of the five imputed datasets and then pooled to produce final age-adjusted mortality estimates. These standardized rates were subsequently used in stratified excess mortality modeling and subgroup comparisons. All rates were scaled to reflect mortality per 100,000 individuals.

Excess Mortality Estimation. Pandemic-period excess mortality was defined as the difference between the number of deaths observed during the pandemic period and the number of deaths expected to occur based on ARIMA forecasts for the same period. We estimated both monthly and cumulative excess deaths. To facilitate comparisons across subgroups, year-specific excess deaths were also divided by population size using estimates from the 2020, 2021, and 2022 ACS, resulting in per capita excess mortality rates (per 100,000 individuals). For 2023, where only partial-year data were available (January-July), we annualized death counts by multiplying by 12/7 to enable year-over-year comparisons, though this assumes the observed months were representative of the full year. Relative mortality was assessed using ratios of the observed number of deaths in a category over the expected number of deaths estimated by the ARIMA model. For example, a ratio of 1.5 would indicate that mortality was 50% higher than expected based on pre-pandemic trends.

Uncertainty Quantification. For all estimates, we calculated 95% prediction intervals (PIs) by simulating the forecast 10,000 times and selecting the 2.5th and 97.5th percentiles. These prediction intervals account for both parameter uncertainty and forecast uncertainty, providing more conservative bounds than confidence intervals alone.

Stratified and Sensitivity Analyses. Analyses were stratified by age, biological sex, and place of death to examine whether the association between marital status and mortality differed by subgroup. Notably, the sum across subgroup excess death estimates may not equal the total excess death estimate because each subgroup was modeled independently with its own ARIMA parameters and seasonal patterns. To correct for such potential discrepancies and ensure that the sum S1 + S2 + … + Sn of subgroup estimates equals the overall estimate S, we defined the ratio r = (S1 + … + Sn)/S and divided each subgroup estimate by r, thus standardizing the subgroup estimates in alignment with the overall total estimated number of excess deaths.

To evaluate the sensitivity of our findings to model choice, we repeated the analyses with an alternative modeling approach using dynamic harmonic regression with ARIMA errors. While this shares fundamental assumptions with our primary ARIMA models—both use autoregressive components and harmonic seasonal terms—it differs in how seasonality is incorporated into the model structure. We acknowledge that a more distinct modeling framework (such as generalized linear models or non-parametric approaches) would provide a stronger test of model dependency; however, the concordance between these related approaches (differences <5% across all estimates) provides reassurance about the stability of our temporal modeling."

RESULTS

Characteristics of the Study Population

A total of 1,611,776 older adults aged 65 and over who were California residents and died at home, in a hospital, or in a nursing home/long-term care (NH/LTC) facility between January 1, 2015, and July 31, 2023, were included in the analysis (Table 1). Among these decedents, 49.1% were male, and 50.9% were female (based on the sex field recorded on death certificates; California death certificates do not currently capture sex and gender as separate fields), with a median age of 83 years (inter-quartile range: 75 to 90 years). The most common place of death was the decedent's home (44%), followed by hospital (38%), and NH/LTC (18%). At their time of death, 38% decedents were married, 39% widowed, 16% divorced, and 7% never married. These proportions varied significantly by age, sex, and place of death, underscoring the need for age-standardized comparisons (Table 1, Supplementary Table 1).

Age-Standardized Mortality Rates by Marital Status

Using the 2019 U.S. population aged 65+ as the standard population, we calculated directly age-standardized mortality rates (ASMRs) for each marital status group across the five imputed datasets. The pooled ASMRs (per 100,000 individuals) revealed substantially lower mortality rates among married individuals (6,430 deaths per 100,000 (95%CI: 6,350 - 6,490)) compared to their unmarried counterparts: 7,830 deaths per 100,000 widowed individuals (95% CI: 7,710 - 7,950), 7,410 deaths per 100,000 divorced individuals (95% CI: 7,280 - 7,540), and 8,220 deaths per 100,000 never-married individuals (95% CI: 8,050 - 8,390).

Sex-stratified analyses confirmed this pattern among both men and women, although the absolute levels differed slightly (Supplementary Table 2). These findings remained consistent after applying standard population weights stratified by age group (65-74, 75-84, 85-94, and 95+) and sex.

Excess Mortality by Marital Status During the Pandemic

Between March 1, 2020, and July 31, 2023, the estimated cumulative excess mortality varied markedly across marital status groups. These estimates were derived from ARIMA models trained on pre-pandemic mortality trends from January 2015 through February 2020, and extrapolated forward to estimate counterfactual death counts during the pandemic. Married individuals had the lowest cumulative excess mortality, with an estimated 880 excess deaths per 100,000 population (95% prediction interval [PI]: 770 to 990). In comparison, widowed individuals experienced an estimated 1,130 excess deaths per 100,000 (95% PI: 900 to 1,370), and divorced individuals had a slightly higher rate of 1,200 per 100,000 (95% PI: 980 to 1,420). Never-married individuals had the highest excess mortality, at 1,750 per 100,000 (95% PI: 1,490 to 2,010). (comment1, comment 2)

When stratifying by both marital status and sex, never-married men exhibited the highest pandemic-era excess mortality, followed sequentially by divorced and widowed men. Married women, by contrast, consistently experienced the lowest excess mortality estimates across all strata, reinforcing the potential protective effects of marriage for older adults during the pandemic (Figure 2; Supplementary Table 3).

Pandemic Phase Comparisons

To explore temporal variation in mortality risk, we divided the pandemic period into two sub-periods: a pre-vaccine phase from March to December 2020, and a post-vaccine phase from January 2021 through July 2023. Although excess mortality was substantially higher during the pre-vaccine phase across all marital status groups, relative disparities in mortality between married and unmarried individuals became more pronounced during the post-vaccine period. For instance, during the pre-vaccine phase, never-married individuals experienced mortality that was approximately 1.7 times higher than expected based on pre-pandemic trends, while married individuals had a relative mortality ratio of 1.3. In the post-vaccine phase, the relative mortality ratio for never-married individuals declined to 1.4, while the ratio for married individuals decreased more sharply to 1.1. These temporal shifts suggest that differential access to, or uptake of, protective factors such as vaccination, social support, or timely healthcare may have widened the mortality gap between marital groups over time.

Place of Death and Marital Status

The association between marital status and pandemic-era mortality was strongly modified by place of death. Among NH/LTC decedents, married individuals had the lowest relative excess mortality ratio at 0.68 (95% PI: 0.65 to 0.71), suggesting that mortality was 32% lower than what would have been expected without the pandemic. This was followed by widowed individuals at 0.81, divorced individuals at 0.89, and never-married individuals at 0.92. These findings indicate that marriage was most protective in institutional settings, where spousal involvement may facilitate advocacy, timely care, and continuity of support.

Among decedents who died at home, all marital status groups experienced excess mortality above expected levels, though the magnitude varied. Married individuals had a relative risk ratio of 1.10 (95% PI: 1.02 to 1.19), while never-married individuals experienced a higher relative risk of 1.29 (95% PI: 1.18 to 1.40). This 19 percentage point difference in home-based mortality risk ratios, along with a 24 percentage point difference observed in NH/LTC settings, suggests that the protective association of marriage extended across care environments but was particularly pronounced in institutional contexts where caregiving resources are often externally managed. (comment1, comment2, comment3)

The variation in relative risk ratios across marital status groups in nursing homes (ranging from 0.68 for married to 0.92 for never-married) primarily reflects differences in pre-pandemic trends rather than differential pandemic impacts. Married and widowed groups showed declining pre-pandemic mortality that, when projected forward, resulted in lower relative ratios, while divorced and never-married groups had stable pre-pandemic trends.

Sensitivity Analysis

All primary analyses were repeated using an alternative modeling framework: dynamic harmonic regression with ARIMA errors. This sensitivity check yielded nearly identical results across all marital status groups and subgroups. Differences in cumulative excess deaths by marital group remained under 5%, and estimates of age-standardized mortality rates showed minimal variation across model specifications (Supplementary Table 3). These findings affirm the robustness of the primary results to model choice and support the validity of the observed associations.

DISCUSSION

Protective Effect of Marriage

Married decedents in nursing home settings consistently showed greater survival advantages relative to their unmarried counterparts. These differences highlight the unique protective role of spousal advocacy in nursing homes and long-term care settings, where reliance on facility-level care often limits the extent of external social support.

Contrary to our initial hypothesis that marriage would confer the weakest protective effects in nursing homes, we found that married individuals had the strongest mortality advantage in these institutional settings (relative mortality ratio 0.69), suggesting that spousal advocacy and support may be particularly crucial in navigating institutional care environments.

The apparent protective effect of marriage in nursing homes should be interpreted cautiously, as it largely reflects pre-existing declining mortality trends among married and widowed residents rather than pandemic-specific protection. The finding of lower-than-expected mortality in nursing homes (RR < 1.0 for all groups) may be an artifact of pre-existing declining mortality trends combined with survivorship bias following high mortality in 2020-2021, rather than indicating pandemic-era protection.

The findings from this study highlight the significant influence of marital status on pandemic-era excess mortality among older adults, with broader societal implications. Marriage appeared to confer significant protective effects, as evidenced by consistently lower absolute excess mortality among married individuals compared to their unmarried counterparts, though relative increases were similar across groups. This reflects the lower baseline mortality rates among married individuals, which translated to fewer excess deaths even when experiencing similar proportional increases, aligning with existing research suggesting that spousal support enhances resilience through emotional, instrumental, and healthcare-related advocacy. However, the vulnerability faced by older adults without spouses underscores structural inadequacies in social support and healthcare systems. These disparities reflect a societal failure to provide sufficiently robust safety nets for those most in need, particularly during crises.

Possible Mechanisms

Although we hypothesized that the protective effects of marriage would be weakest in institutional settings, our finding of the strongest protective effect in nursing homes (RR 0.69 for married vs. higher ratios for unmarried) highlights the potentially critical role of spousal advocacy in institutional care. The specific types of support that marriage provides likely contributed to the observed protective effects during the pandemic. Beyond companionship, spouses offer instrumental support that may have been especially crucial during the COVID-19 pandemic, including assistance with adhering to safety protocols, caregiving, and advocacy within healthcare systems. Married individuals also benefit from access to broader social networks, often including working-age children, who may not only augment their access to flexible resources but also bolster their resilience during times of crises. These mechanisms, coupled with the emotional intimacy and practical assistance intrinsic to marriage, likely mitigated the risks associated with pandemic-era disruptions. Importantly, the protective benefits of marriage are not merely a byproduct of long-standing relationships but reflect active, real-time support that was particularly critical during the pandemic.

Overall Patterns in Excess Mortality

This study revealed that married individuals consistently experienced the lowest or second-lowest relative risk ratios for excess mortality across stratifications by age, sex, education, and other demographic factors. Conversely, never-married individuals exhibited the highest or second-highest relative risk ratios. These patterns persisted even after adjusting for age, suggesting a robust association between marital status and mortality risk. Notably, while widowed individuals demonstrated wide prediction intervals, indicating significant variability in outcomes, the overall trends strongly support the protective role of marriage.

Place of Death and Contextual Factors

Place of death appears to provide important context for understanding the protective effects of marriage. In nursing home settings, married individuals had significantly lower relative risk ratios compared to their never-married counterparts, suggesting that spousal advocacy may play a key role in mitigating mortality risks in institutional environments.

Spouses likely provide oversight, emotional support, and advocacy, which could enhance care quality even in resource-constrained settings. This hypothesis aligns with prior research indicating that married individuals often benefit from more robust social support networks. Furthermore, the protective effect of marriage in nursing home settings may reflect not only spousal advocacy but also potential selection effects during the pandemic. Many nursing home residents relocated to community settings during the pandemic, often to live with adult children. Never-married individuals, who are less likely to have adult children, may have been disproportionately likely to remain in institutional care during the pandemic's peak. This differential selection could contribute to the observed mortality disparities, as those who remained in nursing homes faced elevated exposure risks while those who relocated to family homes may have benefited from enhanced protection and advocacy. However, further investigation is needed to explore how spousal involvement specifically influences outcomes in nursing homes, including variations in care quality, resource access, and advocacy practices.

Interestingly, nursing homes demonstrated overall lower-than-expected mortality rates during the pandemic. However, this finding should be interpreted cautiously given potential selection effects. During the early pandemic, many nursing home residents relocated to community settings. Married individuals may have been particularly likely to leave institutions, as spouses could provide alternative housing and care, while never-married individuals—who are less likely to have adult children or spousal homes—may have disproportionately remained in institutional care. This differential exodus could create substantial selection bias, as those who remained in nursing homes may have differed systematically from those who left, both in terms of marital status composition and underlying health status. The substantially reduced NH mortality observed in 2022-2023 (approximately 50% of pre-pandemic levels across all marital status groups) suggests mortality displacement rather than ongoing protection.

Several factors may also explain the lower-than-expected mortality among those who remained. Early and strict protective measures, such as visitation bans, lockdowns, and enhanced infection control protocols, likely reduced exposure to SARS-CoV-2 and other pathogens. Additionally, the highest-risk residents may have succumbed during the pandemic's early stages, leaving behind a relatively more resilient population ("survivorship bias"). Increased regulatory oversight and resource allocation during the pandemic may have further improved care quality for surviving residents. These findings highlight the complex interplay between selection effects, systemic responses, and the characteristics of nursing home populations, warranting further exploration of institutional dynamics during public health crises. Future studies using longitudinal data on residential transitions should investigate how spousal advocacy interacts with institutional care quality and whether similar protective effects are observed in other high-stress healthcare settings.

Strengths of the Study

The use of ARIMA models with harmonic regression to account for seasonality and demographic heterogeneity ensured robust estimates of pandemic-era excess mortality. Stratified analyses provide nuanced insights into subgroup-specific patterns enhancing the generalizability and applicability of the findings across diverse demographic groups. Sensitivity analyses using alternative modeling approaches confirm the robustness of the findings. However, future analyses could consider employing logistic regression or similar approaches, which could better quantify differences in relative risks between marital status groups, such as divorced versus married individuals.

Limitations

Despite its strengths, this study has limitations that warrant consideration.

Confounding by Age. Although we employed both age stratification (analyzing 10-year age groups separately) and direct age standardization using 2019 US population weights, some residual age confounding may persist. Our age categories span 10 years, and mortality risk varies substantially within these intervals—for instance, individuals aged 65 and 74 are grouped together despite having markedly different baseline mortality risks. Additionally, the age distribution within each marital status category may differ even within our age strata. For example, never-married individuals might cluster toward the younger end of the 65-74 age group compared to married individuals. While our dual approach of stratification and standardization minimizes these concerns, finer age categories or continuous age modeling could further reduce potential residual confounding.

Temporal Model Validity. Our analysis assumes that the ARIMA models trained on pre-pandemic mortality patterns (2015-2020) remain valid for projecting expected mortality throughout the entire pandemic period (March 2020-July 2023). This assumption may not fully account for fundamental shifts in population health dynamics that emerged during the pandemic. Healthcare utilization patterns changed substantially, with delayed preventive care, postponed elective procedures, and altered emergency department usage potentially affecting baseline mortality risks independent of COVID-19. Additionally, the pandemic induced significant behavioral changes—including reduced physical activity, altered dietary patterns, and increased substance use—as well as widespread mental health impacts such as increased depression, anxiety, and social isolation. These factors may have fundamentally altered the underlying mortality risk landscape in ways that pre-pandemic models cannot capture. As a result, our excess mortality estimates may be conservative if these pandemic-era changes increased baseline mortality risk, or inflated if protective behaviors (such as reduced exposure to other infectious diseases due to masking and social distancing) decreased baseline risk. Future research could address this limitation by incorporating time-varying baseline models or conducting sensitivity analyses that adjust for documented changes in healthcare utilization and population health behaviors during the pandemic period.

Model Sensitivity Testing: Our sensitivity analyses were limited to variations within the ARIMA framework rather than fundamentally different statistical approaches, though the consistency of results provides some reassurance about the robustness of our temporal modeling approach.

Family Structure and Housing Circumstances. This study lacked detailed information about family structure and housing arrangements, such as whether married decedents were cohabitating with their spouses or receiving care from other family members. Future research that incorporates more granular data would better characterize the role of family structure and household environments in mitigating mortality risks.

Measurement of Sex and Gender in Death Certificate Data. A small number of individuals (<0.01%) whose sex was recorded as non-binary or unknown were excluded from the analysis due to insufficient subgroup size for time-series modeling. While this exclusion had negligible impact on aggregate estimates, it underscores the limitations of current administrative datasets in capturing sex and gender diversity and the challenges of conducting population-level analyses that are inclusive of sex and gender minorities. This decision was made in light of our analytic approach, which involved aggregating monthly death counts across a large number of stratified subgroups, including twelve 1-way, 2-way, and 3-way combinations of age group, marital status, sex, and place of death. We acknowledge that this limits the inclusivity of the study population and reflects broader limitations in population-level data systems, which often lack adequate representation and recording practices for non-binary individuals.

COVID-19-Specific Mortality. While this study focused on all-cause mortality to capture both direct and indirect pandemic effects, future analyses could examine COVID-19-specific mortality (based on underlying and contributing causes from death certificates) to distinguish patterns of protection conferred by marital status for COVID-specific versus other causes of death. Such analyses could help clarify whether the protective effects of marriage operate primarily through reducing COVID-19 exposure and severity, or through broader mechanisms such as improved healthcare access and management of chronic conditions during the pandemic period.

Implications for Policy and Practice

The findings from this study have important implications for healthcare professionals, policymakers, and researchers. Tailored interventions to address the unmet needs of unmarried older adults could mitigate the disparities observed in mortality risks. For example, expanding access to social support services, enhancing caregiver programs, and implementing advocacy training in institutional settings may help offset the advantages typically conferred by marriage. For policymakers, these findings highlight the importance of bolstering social support services for unmarried older adults, while institutions should prioritize training and resources that compensate for the absence of spousal advocacy. Recognizing the critical role of social support systems is especially important as the older adult population in the U.S. continues to grow. A collective effort to strengthen these systems will ensure that all older adults—regardless of marital status—can experience improved health and well-being. Understanding these dynamics can also inform strategies for future public health emergencies, ensuring equitable support for older adults regardless of marital status.

Conclusion

Marriage appears to have conferred significant protective effects against excess mortality during the pandemic among older Californians, particularly in nursing home settings. This study highlights the critical role of social and emotional support, instrumental caregiving, and spousal advocacy in mitigating health risks during crises. As the U.S. population ages, developing robust social systems to meet the needs of unmarried older adults will be critical for fostering equity and resilience in health outcomes during future crises.

TABLES & FIGURES

Table 1. Summary characteristics for California decedents who died at home, in a hospital, or in a nursing home/long-term care facility at age 65 or older between January 1, 2016 and July 31, 2023 (n=1,432,924).

	Overall n = 1,432,924	**Married** n = 550,201	**Widowed** n = 552,551	**Divorced** n = 227,472	**Never married** n = 102,700
Age (median (IQR))	83 (75, 90)	80 (73, 86)	89 (82, 94)	78 (72, 85)	75 (70, 84)
Sex					
Female	729,137 (51%)	163,956 (30%)	396,967 (72%)	122,441 (54%)	45,773 (45%)
Male	703,787 (49%)	386,245 (70%)	155,584 (28%)	105,031 (46%)	56,927 (55%)
Race and Ethnicity					
Asian	167,795 (12%)	77,369 (14%)	70,952 (13%)	11,817 (5.2%)	7,657 (7.5%)
Black	95,435 (6.7%)	26,326 (4.8%)	32,878 (6.0%)	23,727 (10%)	12,504 (12%)
Hispanic	261,039 (18%)	105,897 (19%)	96,572 (17%)	35,019 (15%)	23,551 (23%)
White	880,376 (61%)	330,366 (60%)	342,088 (62%)	151,150 (66%)	56,772 (55%)
Multi-race	13,827 (1.0%)	4,935 (0.9%)	4,750 (0.9%)	3,169 (1.4%)	973 (0.9%)
Other	14,452 (1.0%)	5,308 (1.0%)	5,311 (1.0%)	2,590 (1.1%)	1,243 (1.2%)
Place of Death					
Home	629,160 (44%)	256,914 (47%)	243,185 (44%)	92,211 (41%)	36,850 (36%)
Hospital	550,946 (38%)	234,708 (43%)	183,612 (33%)	89,298 (39%)	43,328 (42%)
Nursing Home/ Long-Term Care	252,818 (18%)	58,579 (11%)	125,754 (23%)	45,963 (20%)	22,522 (22%)

Table 2 (one option, see alternative on next page)

Table 2. Cumulative excess deaths during the COVID-19 pandemic among California decedents who died at home, in a hospital, or in a nursing home/long-term care facility at age 65 or older between January 1, 2016 and July 31, 2023 (n=1,432,924)

	Overall		
	Excess	**Risk Ratio**	**Per 100,000**
Entire state			
Age			
65-74 years old	25,615 (20767, 30554)	1.17 (1.13, 1.20)	783 (634, 934)
75-84 years old	24,532 (19796, 29385)	1.13 (1.10, 1.16)	1,524 (1230, 1825)
85-94 years old	5,760 (-334, 11848)	1.03 (1.00, 1.06)	755 (-44, 1553)
95+ years old	3,032 (-3631, 9799)	1.05 (0.94, 1.20)	-- --
Sex		0.00	
Female	29,193 (13259, 45500)	1.10 (1.04, 1.16)	932 (423, 1452)
Male	35,342 (27545, 43324)	1.12 (1.09, 1.15)	1,407 (1097, 1725)
Place of Death		0.00	
Home	46,903 (41907, 52025)	1.18 (1.16, 1.20)	-- --
Hospital	47,023 (35656, 58587)	1.22 (1.16, 1.28)	-- --
Nursing Home/ Long-Term Care	-32,814 (-42246, -23235)	0.73 (0.68, 0.79)	-- --

	Married			Widowed		
	Excess	**Risk Ratio**	**Per 100,000**	**Excess**	**Risk Ratio**	**Per 100,000**
Entire state	27573 (24336, 30933)	1.12 (1.10, 1.14)	866 (764, 971)	14621 (398, 29155)	1.06 (1.00, 1.14)	1194 (33, 2381)
Age						
65-74 years old	12,310 (10207, 14462)	1.17 (1.14, 1.20)	597 (495, 701)	4,215 (3139, 5314)	1.21 (1.15, 1.28)	1,089 (811, 1373)
75-84 years old	10,898 (9628, 12225)	1.12 (1.11, 1.14)	1,250 (1104, 1402)	6,683 (4353, 9084)	1.12 (1.08, 1.17)	1,547 (1007, 2102)
85-94 years old	5,247 (3915, 6640)	1.09 (1.06, 1.11)	2,090 (1559, 2645)	8,071 (1191, 15077)	1.08 (1.01, 1.16)	1,991 (294, 3719)
95+ years old	-260 (-897, 397)	0.97 (0.90, 1.05)	-- --	2,367 (-2215, 7018)	1.05 (0.95, 1.18)	-- --
Sex						
Female	10,046 (8889, 11297)	1.15 (1.13, 1.17)	709 (628, 798)	8,540 (-1665, 18993)	1.05 (0.99, 1.12)	875 (-171, 1946)
Male	19,467 (17162, 21858)	1.12 (1.10, 1.14)	1,101 (970, 1236)	5,892 (2652, 9184)	1.09 (1.04, 1.15)	2,373 (1068, 3699)
Place of Death						
Home	16,339 (14303, 18415)	1.15 (1.13, 1.17)	-- --	29,730 (7258, 52896)	1.33 (1.07, 1.80)	-- --
Hospital	20,691 (17625, 23833)	1.22 (1.18, 1.27)	-- --	8,331 (5601, 10669)	1.11 (1.07, 1.15)	-- --
Nursing Home/ Long-Term Care	-9,223 (-10905, -7490)	0.69 (0.65, 0.73)	-- --	-19,251 (-25622, -12781)	0.68 (0.62, 0.77)	-- --

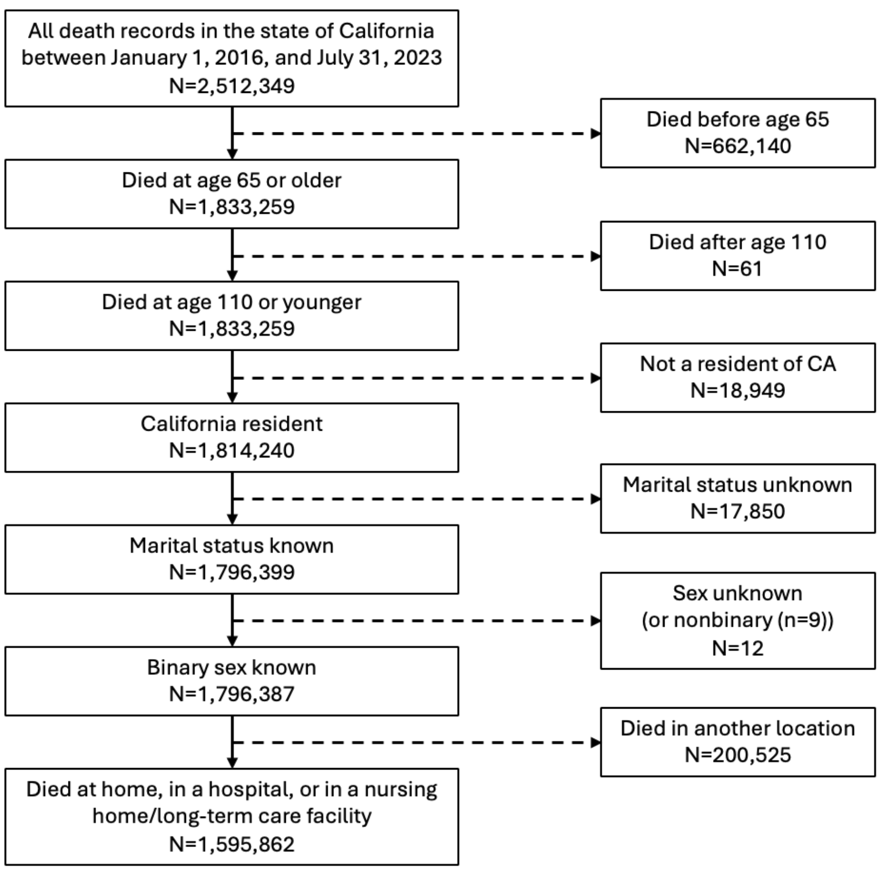
	Divorced			Never Married		
	Excess	**Risk Ratio**	**Per 100,000**	**Excess**	**Risk Ratio**	**Per 100,000**
Entire state	9505 (5531, 13547)	1.10 (1.05, 1.14)	1132 (659, 1613)	7010 (5953, 8086)	1.15 (1.13, 1.18)	1767 (1500, 2038)
Age						
65-74 years old	5,649 (4669, 6655)	1.15 (1.12, 1.18)	1,029 (850, 1212)	4,004 (3363, 4660)	1.17 (1.14, 1.21)	1,455 (1222, 1693)
75-84 years old	3,355 (2492, 4250)	1.09 (1.07, 1.12)	1,536 (1140, 1945)	2,398 (2108, 2697)	1.19 (1.16, 1.21)	2,745 (2413, 3087)
85-94 years old	2,286 (775, 3826)	1.11 (1.03, 1.20)	3,163 (1072, 5293)	714 (183, 1258)	1.09 (1.02, 1.17)	2,088 (535, 3677)
95+ years old	2 (-371, 384)	1.00 (0.92, 1.10)	-- --	244 (96, 397)	1.14 (1.05, 1.25)	-- --
Sex						
Female	3,675 (786, 6627)	1.07 (1.01, 1.13)	690 (148, 1245)	3,340 (2431, 4276)	1.17 (1.12, 1.23)	1,597 (1162, 2044)
Male	5,515 (3522, 7544)	1.12 (1.07, 1.17)	1,794 (1146, 2454)	3,669 (3175, 4177)	1.14 (1.12, 1.16)	1,956 (1693, 2227)
Place of Death						
Home	6,722 (5920, 7544)	1.17 (1.14, 1.19)	-- --	3,894 (3487, 4303)	1.24 (1.21, 1.27)	-- --
Hospital	9,343 (7729, 11085)	1.27 (1.21, 1.34)	-- --	4,673 (3907, 5457)	1.25 (1.20, 1.31)	-- --
Nursing Home/ Long-Term Care	-3,617 (-4840, -2356)	0.83 (0.79, 0.88)	-- --	-1,601 (-2036, -1157)	0.86 (0.83, 0.89)	-- --

Alternative Table 2:

Table 2. Cumulative excess deaths during the COVID-19 pandemic among California decedents who died at home, in a hospital, or in a nursing home/long-term care facility at age 65 or older between January 1, 2016 and July 31, 2023 (n=1,432,924)

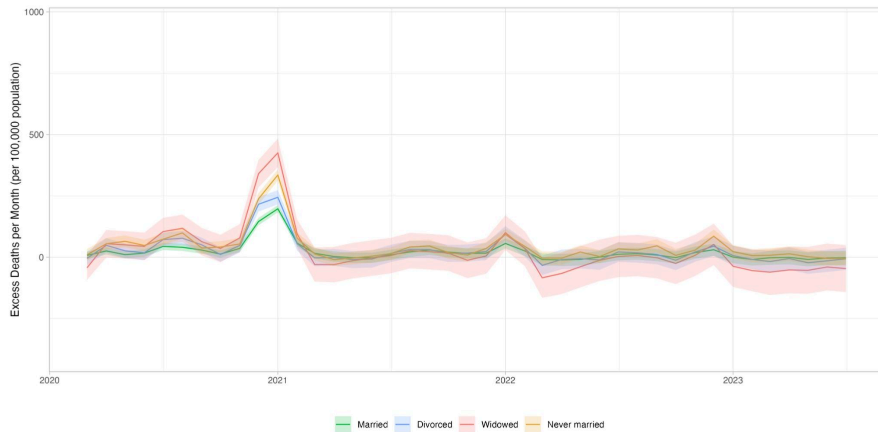
	Overall	Married	Widowed	Divorced	Never Married
	Risk Ratio	Risk Ratio	Risk Ratio	Risk Ratio	Risk Ratio
Entire state		1.12 (1.10, 1.14)	1.06 (1.00, 1.14)	1.10 (1.05, 1.14)	1.15 (1.13, 1.18)
Age					
65-74 years old	1.17 (1.13, 1.20)	1.17 (1.14, 1.20)	1.21 (1.15, 1.28)	1.15 (1.12, 1.18)	1.17 (1.14, 1.21)
75-84 years old	1.13 (1.10, 1.16)	1.12 (1.11, 1.14)	1.12 (1.08, 1.17)	1.09 (1.07, 1.12)	1.19 (1.16, 1.21)
85-94 years old	1.03 (1.00, 1.06)	1.09 (1.06, 1.11)	1.08 (1.01, 1.16)	1.11 (1.03, 1.20)	1.09 (1.02, 1.17)
95+ years old	1.05 (0.94, 1.20)	0.97 (0.90, 1.05)	1.05 (0.95, 1.18)	1.00 (0.92, 1.10)	1.14 (1.05, 1.25)
Sex	0.00				
Female	1.10 (1.04, 1.16)	1.15 (1.13, 1.17)	1.05 (0.99, 1.12)	1.07 (1.01, 1.13)	1.17 (1.12, 1.23)
Male	1.12 (1.09, 1.15)	1.12 (1.10, 1.14)	1.09 (1.04, 1.15)	1.12 (1.07, 1.17)	1.14 (1.12, 1.16)
Place of Death	0.00				
Home	1.18 (1.16, 1.20)	1.15 (1.13, 1.17)	1.33 (1.07, 1.80)	1.17 (1.14, 1.19)	1.24 (1.21, 1.27)
Hospital	1.22 (1.16, 1.28)	1.22 (1.18, 1.27)	1.11 (1.07, 1.15)	1.27 (1.21, 1.34)	1.25 (1.20, 1.31)
Nursing Home/ Long-Term Care	0.73 (0.68, 0.79)	0.69 (0.65, 0.73)	0.68 (0.62, 0.77)	0.83 (0.79, 0.88)	0.86 (0.83, 0.89)

Figure 1: Flowchart depicting exclusion criteria for study population

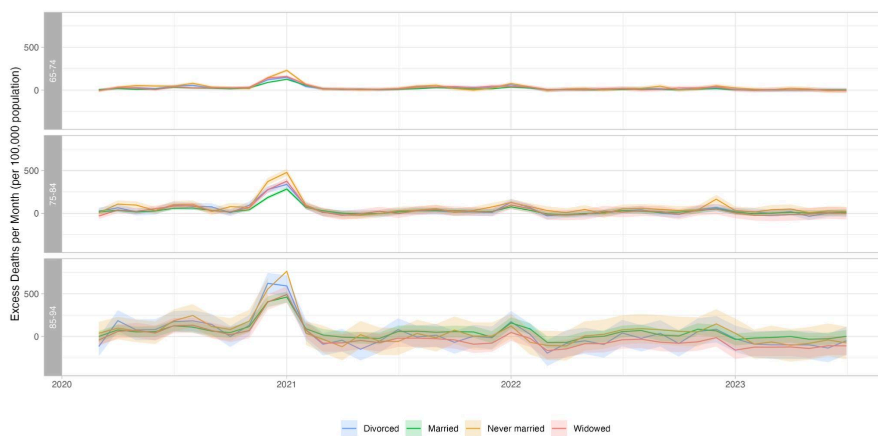


Figures 2 - 4b show monthly estimates of excess deaths per 100,000 population per month for marital status (fig 2), marital status by age group (figs 3a and 3b – need to decide which layout), and marital status by sex (figs 4a and 4b – need to decide which layout). Age group note: Per-capita estimates do not exist for place of death nor for those age 95 and older.

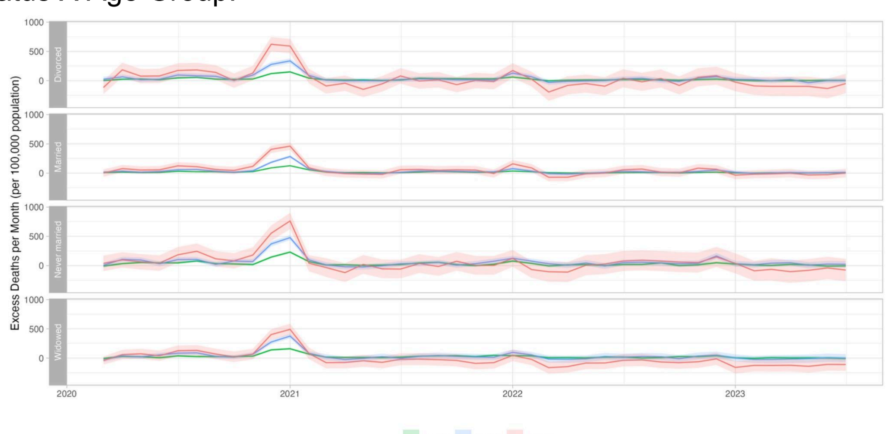
2. Marital Status only:



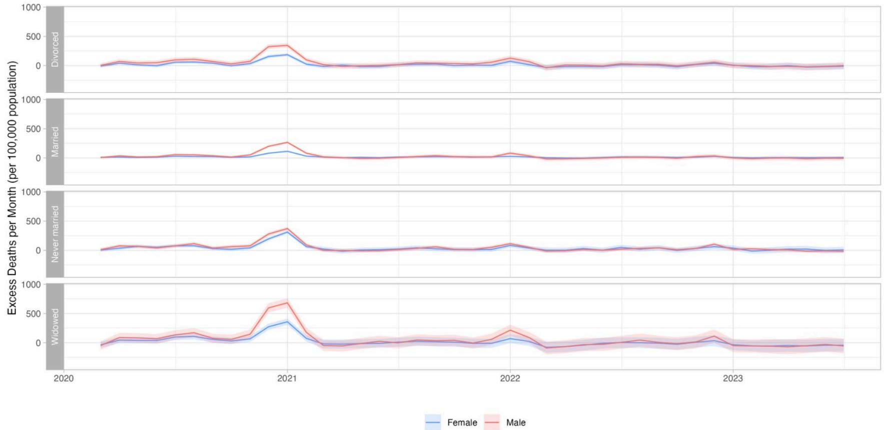
3a. Age Group X Marital Status:



3b. Marital Status X Age Group:



4a. Martial Status X Sex



4b. Sex X Marital Status