in the analysis could yet have been performed to assure the reader that the presented comparisons were sound.

Furthermore, Figures 2 and 3 display gradients in the estimated hazard ratios by marital status. Given the low number of observed deaths in some of these categories (e.g. 187 deaths among women in present or previous same-sex marriage), and thereby limited statistical power, this is to be expected. Nevertheless, the hazard ratios are presented with quite narrow confidence intervals (Table 2). Is it possible that there is some kind of statistical dependency in the dataset that is not accounted for in the analysis? Many factors come into play in a dataset like this. In particular, we have not been able to locate information explaining how correlations between same-sex married individuals were accounted for. Every same-sex married individual has a close connection with at least one other individual in the same category, contributing correlations between pairs of observations. A similar problem does not occur for opposite-sex married individuals, since men and women are analysed separately.

Frisch and Simonsen have approached important health concerns, addressing how living arrangements were linked with overall cause-specific mortality, and they present alarming conclusions. This includes increased mortality rates for same-sex married individuals compared with opposite-sex married individuals. We would be eager to see results of an analysis that takes into account the methodological issues that we have raised.

## References

1. Frisch M, Simonsen J. Marriage, cohabitation and mortality in Denmark: national cohort study of 6.5 million persons followed for up to three decades (1982–2011). *Intl J Epidemiol* 2013;**42**:559–78.
2. Malterud K, Bjorkman M, Flatval M, Ohnstad A, Thesen J, Rortveit G. Epidemiological research on marginalized groups implies major validity challenges; lesbian health as an example. *J Clin Epidemiol* 2009;**62**:703–10.

# Authors' response to: Mortality rates for same-sex married individuals compared with opposite-sex married individuals

*International Journal of Epidemiology*, 2015, 369–372
doi: 10.1093/ije/dyu244
Advance Access Publication Date: 30 December 2014


From Morten Frisch[1,2]* and Jacob Simonsen[1]

[1]Statens Serum Institut, Department of Epidemiology Research, DK-2300 Copenhagen S, Denmark and [2]Center for Sexology Research, Department of Clinical Medicine, Aalborg University, DK-9000 Aalborg, Denmark

*Corresponding author. Statens Serum Institut, Department of Epidemiology Research, DK-2300 Copenhagen S, Denmark. E-mail: MFR@ssi.dk

We appreciate the thoughtful comments by Malterud *et al*. In the published paper,[1] numbers of deaths, particularly for some of the cause-specific deaths, were low in same-sex divorced or widowed persons. For power reasons, we therefore combined categories of currently and formerly same-sex married persons while keeping heterosexually married, divorced and widowed persons as separate categories.

Keeping this composition of the compared groups in mind, the published hazard ratios (HRs) provide valid estimates of the relative mortality in ever same-sex married vs currently opposite-sex married individuals. However, our HRs should not be incautiously interpreted as HRs for death associated with homosexuality per se. In addition to the uneven marital status composition of the compared categories, it should be recalled that there may well be other important differences with an impact on mortality between men and women who are, or were previously, in a same-sex marriage and the considerably larger groups of homosexual persons who never married a same-sex partner.

## Supplementary analysis: HRs of death among subgroups of ever same-sex married persons

Malterud *et al*. plausibly point out that the increased mortality seen in divorced and widowed compared with currently married individuals among heterosexual persons might also be seen when comparing divorced and widowed with currently same-sex married homosexual persons. To address this, we repeated the Cox proportional hazards regression analysis of our original article[1] to recalculate the HRs for overall mortality in our article's Table 2 and the HRs for cause-specific mortality in Table 4, this time keeping same-sex married, divorced and widowed persons in separate categories.

**Table 1.** Overall and cause-specific mortality. Hazard ratios with 95% confidence intervals according to actual marital status (with same-sex married, divorced and widowed persons in separate categories), Denmark 2000–2011[a]

| Marital status | Hazard ratio (95% confidence interval) N = No. Deaths | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Cause-specific mortality (2000–2010) | | | | | |
| | Overall mortality (2000–2011) | Cardiovascular disease mortality | Cancer mortality | Respiratory tract disease mortality | Suicide | AIDS mortality | Other causes of death |
| Women | | | | | | | |
| Unmarried persons | 1.64 (1.61–1.67) | 1.50 (1.45–1.56) | 1.17 (1.13–1.20) | 1.79 (1.70–1.89) | 2.55 (2.21–2.94) | 2.00 (0.99–4.04) | 1.83 (1.79–1.87) |
| | *N = 27,709* | *N = 4376* | *N = 5285* | *N = 2157* | *N = 397* | *N = 14* | *N = 13,943* |
| Opposite-sex married persons | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) |
| | *N = 78,062* | *N = 9279* | *N = 28,953* | *N = 5812* | *N = 575* | *N = 20* | *N = 28,875* |
| Opposite-sex divorced persons | 1.58 (1.55–1.60) | 1.54 (1.49–1.60) | 1.26 (1.23–1.29) | 2.25 (2.16–2.34) | 3.01 (2.65–3.42) | 5.64 (3.09–10.3) | 1.81 (1.78–1.85) |
| | *N = 39,638* | *N = 5336* | *N = 9722* | *N = 4054* | *N = 404* | *N = 23* | *N = 17,511* |
| Opposite-sex widowed persons | 1.38 (1.36–1.40) | 1.39 (1.36–1.43) | 1.15 (1.13–1.17) | 1.63 (1.58–1.68) | 2.19 (1.87–2.56) | 5.32 (1.61–17.6) | 1.49 (1.46–1.51) |
| | *N = 187,904* | *N = 38,617* | *N = 30,602* | *N = 17,594* | *N = 394* | *N = 4* | *N = 89,774* |
| Same-sex married persons | 1.72 (1.40–2.10) | 0.93 (0.42–2.07) | 1.75 (1.36–2.26) | NA | 4.01 (1.66–9.67) | NA | 1.18 (0.87–1.61) |
| | *N = 123* | *N = 6* | *N = 59* | *N = 0* | *N = 5* | *N = 0* | *N = 40* |
| Same-sex divorced persons | 2.64 (1.85–3.78) | 5.27 (2.19–12.7) | 1.44 (0.72–2.87) | 3.37 (0.84–13.5) | 11.3 (3.63–35.2) | NA | 3.39 (2.18–5.25) |
| | *N = 40* | *N = 5* | *N = 8* | *N = 2* | *N = 3* | *N = 0* | *N = 20* |
| Same-sex widowed persons | 1.91 (1.19–3.05) | 0.61 (0.09–4.33) | 0.77 (0.25–2.40) | 3.18 (1.03–9.87) | 40.9 (10.2–164) | *NA* | 2.51 (1.46–4.33) |
| | *N = 24* | *N = 1* | *N = 3* | *N = 3* | *N = 2* | *N = 0* | *N = 13* |
| Men | | | | | | | |
| Unmarried persons | 1.65 (1.62–1.67) | 1.80 (1.75–1.85) | 1.12 (1.09–1.15) | 2.00 (1.91–2.08) | 2.43 (2.25–2.63) | 14.2 (9.53–21.2) | 2.65 (2.60–2.71) |
| | *N = 44,276* | *N = 6429* | *N = 6835* | *N = 2701* | *N = 1661* | *N = 125* | *N = 23,734* |
| Opposite-sex married persons | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) |
| | *N = 158,137* | *N = 28,975* | *N = 47,481* | *N = 11,847* | *N = 1691* | *N = 32* | *N = 58,774* |
| Opposite-sex divorced persons | 1.66 (1.64–1.68) | 1.69 (1.64–1.73) | 1.35 (1.32–1.38) | 2.20 (2.12–2.29) | 2.73 (2.51–2.98) | 11.0 (7.18–16.8) | 2.40 (2.36–2.44) |
| | *N = 42,449* | *N = 6355* | *N = 9234* | *N = 3222* | *N = 770* | *N = 64* | *N = 19,996* |
| Opposite-sex widowed persons | 1.37 (1.35–1.38) | 1.40 (1.37–1.43) | 1.16 (1.13–1.18) | 1.60 (1.55–1.65) | 2.92 (2.61–3.28) | 3.42 (1.38–8.44) | 1.56 (1.53–1.58) |
| | *N = 73,315* | *N = 16,028* | *N = 13,604* | *N = 8010* | *N = 521* | *N = 6* | *N = 30,948* |
| Same-sex married persons | 1.26 (1.11–1.43) | 0.90 (0.63–1.28) | 1.10 (0.88–1.37) | 1.13 (0.67–1.91) | 3.54 (2.16–5.79) | 323 (195–535) | 1.33 (1.12–1.59) |
| | *N = 311* | *N = 31* | *N = 76* | *N = 14* | *N = 16* | *N = 29* | *N = 123* |
| Same-sex divorced persons | 1.67 (1.28–2.17) | 2.10 (1.05–4.20) | 1.28 (0.71–2.31) | 3.08 (1.16–8.20) | 4.64 (1.74–12.4) | 446 (196–1016) | 2.51 (1.77–3.55) |
| | *N = 68* | N = 8 | N = 11 | *N = 4* | *N = 4* | *N = 7* | *N = 32* |
| Same-sex widowed persons | 1.66 (1.34–2.06) | 2.03 (1.31–3.15) | 1.11 (0.69–1.79) | 0.49 (0.12–1.96) | 8.23 (3.08–21.9) | 510 (198–1311) | 1.97 (1.46–2.66) |
| | *N = 103* | *N = 20* | *N = 17* | *N = 2* | *N = 4* | *N = 5* | *N = 43* |

NA, not applicable

Hazard ratios among persons aged 18 years or older obtained in Cox proportional hazards regression models with age as the underlying time stratified for birth year and socioeconomic confounders (municipality, population density, educational level, and relative income two years before the actual year).

[a]Analyses of overall mortality based on data for period between 1 January 2000 and 30 September 2011 (N = 652,159 deaths). Analyses of cause-specific mortality based on data for period between 1 January 2000 and 31 December 2010 (*N* = 613,380 deaths).

**Table 2.** Overall and cause-specific mortality in the combined group of same-sex married, divorced or widowed compared with i) opposite-sex married persons or ii) opposite-sex married, divorced or widowed persons. Hazard ratios with 95% confidence intervals, Denmark 2000-2011[a]

| | Same-sex married, divorced or widowed vs opposite-sex married persons | | Same-sex married, divorced or widowed vs opposite-sex married, divorced or widowed persons | |
|---|---|---|---|---|
| | Hazard ratio (95% confidence interval) | | Hazard ratio (95% confidence interval) | |
| Cause of death | Original method[b] | New method[b] | Original method[b] | New method[b] |
| Women | | | | |
| Overall mortality | 1.89 (1.60–2.23) | 1.72 (1.36–2.17) | 1.54 (1.31–1.82) | 1.55 (1.15–2.08) |
| Cancer mortality | 1.62 (1.28–2.05) | 1.71 (1.14–2.56) | 1.58 (1.26–2.00) | 1.64 (1.08–2.48) |
| Cardiovascular disease mortality | 1.32 (0.75–2.33) | 1.39 (0.51–3.79) | 1.08 (0.62–1.91) | 1.03 (0.38–2.78) |
| AIDS mortality | NA | NA | NA | NA |
| Respiratory tract disease mortality | 0.85 (0.36–2.05) | NA | 0.74 (0.35–1.67) | NA |
| Other cause of death | 1.47 (1.08–2.01) | 1.55 (0.90–2.68) | 1.28 (0.95–1.72) | 1.33 (0.75–2.35) |
| Suicide | 6.40 (3.42–12.0) | 6.25 (2.08–18.7) | 4.50 (2.41–8.40) | 4.30 (1.11–16.6) |
| Men | | | | |
| Overall mortality | 1.38 (1.25–1.53) | 1.42 (1.24–1.63) | 1.17 (1.06–1.29) | 1.17 (1.00–1.36) |
| Cancer mortality | 1.12 (0.92–1.35) | 1.15 (0.81–1.62) | 1.08 (0.90–1.31) | 1.09 (0.78–1.53) |
| Cardiovascular disease mortality | 1.23 (0.95–1.58) | 1.36 (0.88–2.09) | 1.20 (0.94–1.53) | 1.22 (0.79–1.87) |
| AIDS mortality | 356 (223–567) | 388 (213–706) | 144 (100–207) | 149 (87–255) |
| Respiratory tract disease mortality | 1.12 (0.73–1.74) | 1.05 (0.44–2.48) | 0.91 (0.58–1.40) | 0.83 (0.33–2.11) |
| Other cause of death | 1.58 (1.32–1.88) | 1.72 (1.32–2.23) | 1.35 (1.14–1.60) | 1.34 (1.31–1.36) |
| Suicide | 4.09 (2.73–6.12) | 4.17 (2.06–8.45) | 3.09 (2.07–4.62) | 3.22 (1.68–6.18) |

NA, not applicable due to zero (AIDS mortality) or too few deaths (respiratory tract disease mortality).

Hazard ratios according to actual marital status among persons aged 18 years or older obtained in Cox proportional hazards regression models with age as the underlying time stratified for birth year and socioeconomic confounders (municipality, population density, educational level, and relative income two years before the actual year).

[a]Analyses of overall mortality based on data for period between 1 January 2000 and 30 September 2011 ($n = 652{,}159$ deaths). Analyses of cause-specific mortality based on data for period between 1 January 2000 and 31 December 2010 ($n = 613{,}380$ deaths).

[b]Original method described in our 2013 article (1). New method based on random selection of only one partner in a same-sex marriage (see text).

As suggested, HRs for overall mortality were higher in divorced and widowed persons than in currently married persons, a finding that applied to both men and women and to persons in both opposite-sex and same-sex marriages (Table 1). Our original report of increased cancer mortality in same-sex married women remained valid, even when restricting the comparison to currently same-sex vs currently opposite-sex married women (HR = 1.75; 95% confidence interval: 1.36-2.26). In both sexes, HRs for death from cardiovascular or respiratory tract diseases, suicide, AIDS and other causes were generally higher among same-sex divorced or widowed persons than among persons who were currently same-sex married.

## Robustness analyses: impact of intra-couple correlations among same-sex married persons

Malterud *et al*. also raise the relevant question of how, if at all, intra-couple correlations between same-sex married individuals might have influenced our HRs for same-sex married individuals. They correctly point out that each same-sex married person has a close connection with at least one other individual in the analysis (i.e. the same-sex spouse). Theoretically, if two partners in a same-sex marriage are identical with respect to their risk of dying during follow-up, our originally published HR estimates[1] could have been non-trivially biased and would be associated with somewhat too narrow confidence intervals.

To evaluate the possible impact of such intra-couple correlations, we recalculated the HRs for overall and cause-specific mortality, this time using data for only one person in each same-sex marriage. This reflects the unlikely, theoretical worst-case situation, in which all same-sex married couples exhibit perfect correlation with respect to mortality during follow-up.

Specifically, on the date of each couple's same-sex marriage, we randomly selected one of the partners for the study, while the other partner was censored. The selected partner was followed until death, end of follow-up or date of entry into a new same-sex marriage, at which date a new random selection would take place. The non-selected partner was censored on the date of the same-sex marriage, and

this person was only allowed to enter follow-up on the day of entry in a new same-sex marriage, provided the person was randomly selected for follow-up in that new same-sex marriage. This strategy ensured that partners in a same-sex marriage were considered to be correlated for as long as they had not entered a new same-sex marriage with another person. To enable direct comparison with findings in our original, published analyses, for power reasons we combined the same-sex married, divorced and widowed persons in one category, again using opposite-sex married persons as the reference. To reduce the variance caused by the random selection of the same-sex married persons under observation, we repeated the random sampling procedure 20 times, with each analysis providing HR estimates for overall and cause-specific mortality, using the same data and identical methodology (Cox proportional hazards regression analysis) as in the original article.[1] As the resulting HR estimates in this robustness analysis, we used the exponentiated mean values of the 20 obtained log(HR) estimates for each outcome. The calculation of the variance for each HR was based on the knowledge that it is composed of the sum of the variance from each sampling and the variance between samplings.[2] Based on this variance, we calculated 95% confidence intervals for the resulting HRs.

Subsequently, we addressed the same question regarding the possible impact of intra-couple correlation, this time using more directly comparable categories of same-sex and opposite sex married persons. Using the same method as in our paper,[1] in which both persons in a same-sex couple were kept under observation, we first calculated a new set of HRs for overall and cause-specific mortality, comparing same-sex married, divorced or widowed with opposite-sex married, divorced or widowed persons. To take possible intra-couple correlation in same-sex married couples into account, we next repeated the random selection procedure 20 times (as above) to follow only one partner in each same-sex marriage, and calculated a new set of HRs using the combined category of opposite-sex married, divorced or widowed persons as reference. As seen in Table 2, HR estimates for overall mortality and cause-specific mortality were largely unaffected by any possible correlation between partners in a same-sex marriage, regardless of the chosen reference category. However, as expected, HRs were lower in the set of analyses using the combined category of opposite-sex married, divorced and widowed persons than in the analyses using only opposite-sex married persons as reference, reflecting the higher background mortality in opposite-sex divorced and widowed than in currently opposite-sex married persons. Specifically, the increased cancer mortality (women only) and the markedly elevated suicide risk among currently or formerly same-sex married men and women were confirmed, although confidence intervals widened as a result of the fewer outcomes in each analysis.

We greatly appreciate the comments by Malterud *et al*. These extra analyses provide population-based evidence that the well-established increased mortality associated with divorce and widowhood after heterosexual marriage applies to divorce and widowhood after homosexual marriage as well. Also, the finding of similar HR estimates, although with wider confidence intervals, after taking the possible correlation between partners in same-sex marriage into account, provides reassurance that the results of our original article remain valid.[1] Regardless of reference category, persons who are, or were previously, in a same-sex marriage had elevated overall mortality (notably among women) compared with persons who are, or were previously, in an opposite-sex marriage. Patterns of increased mortality from cancer (women only), suicide (both sexes) and AIDS (men only) among persons who are, or were previously, in a same-sex marriage, remained present.

## References

1. Frisch M, Simonsen J. Marriage, cohabitation and mortality in Denmark: national cohort study of 6.5 million persons followed for up to three decades (1982–2011). *Int J Epidemiol* 2013;**42**:559–78
2. Harrell FE Jr. *Regression Modeling Strategies: With Applications to Linear Models, Logistic Regression, and Survival Analysis*. New York, NY: Springer, 2001.