Life expectancy and active life expectancy by marital status among older U. S. adults: Results from the U.S. Medicare Health Outcome Survey (HOS)

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A R T I C L E   I N F O

A B S T R A C T

Background: Previous investigations of the relationship between marital status and life expectancy and healthy life expectancy rely on the assumption that participants will remain in a given marital status until death. This study estimated total life expectancy (TLE) and active life expectancy (ALE) for respondents by their baseline marital status using a large longitudinal sample of the U.S. community-dwelling elderly population.
Methods: Data were from the Medicare Health Outcomes Survey Cohort 15 (2012 baseline, 2014 follow-up). We included respondents aged ≥65 years (n = 164,597). Multi-state models estimated TLE and ALE by marital status to allow participants' marital status to change during the remaining lifetime.
Results: Between 65 and 85 years, married men and women had a longer TLE and ALE than unmarried men and women. For example, at 65 years, TLE for married men was 18.6 years, 2.2 years longer than unmarried men, and ALE for married men was 12.3 years, 2.4 years longer than unmarried men. Similarly, at 65 years, TLE for married women was 21.1 years, 1.5 years longer than unmarried women, and ALE for married women was 13.0 years, 2.0 years longer than unmarried women. Such marriage protection effects decreased with age. In sub-groups of unmarried persons, never married persons had the shortest TLE and ALE among men, and never married, divorced, and widowed persons had a similar, and shorter, TLE and ALE among women. The difference in TLE between married and unmarried persons was smaller after adjusting for baseline activity limitation status.
Conclusions: This study provides additional evidence for marriage's protective effect, with the magnitude of protection being greater for younger as compared to older persons. Selection bias was a large contributor to longer life expectancy among married persons.

1. Introduction

During the second half of the twentieth century, the United States has witnessed an increased life expectancy, with the greatest gains noted among adults 65 years of age and older (Klenk et al., 2016). As the demographic pyramid has been shifting, marriage patterns have changed due to increasing divorce rates as well as changes in family structure (Hendi, 2019; Seltzer, 2019). Analyses of large, longitudinal samples have shown that married persons tend to have lower mortality rates and longer life expectancy than unmarried persons (Shurtleff, 1955; Rendall et al., 2011; Manzoli et al., 2007; Lillard & Waite, 1995; Johnson et al., 2000; Kaplan & Kronick, 2006, Chiu, 2019; Espenshade, 1983.) A systematic review comprised of studies published between 1995 and 2005 indicated that, among the elderly, marriage was a significant and independent predictor of survival, a finding that did not differ between men and women (Manzoli et al., 2007). The overall relative risk of death for married versus non-married persons was 0.88 and 0.90 for men and women, respectively. With regard to life expectancy, many population-based longitudinal studies have shown longer life expectancy among married persons than unmarried persons, for both men and women (Chiu, 2019; Martikainen et al., 2014). Yet, investigators have examined the possible explanations of these findings less often, such as the role of selection bias (marriage selection) and the association of marriage with a healthier life (marriage protection) (Verbrugge, 1979a). Specifically, marriage selection refers to the finding that physically and mentally healthier persons are more likely to get married, while marriage protection refers to marriage's association with a myriad of presumed benefits (social, psychological, economic, and environmental) that are associated with better health (Espinoza & Evans, 2008; Goldman, 1994).

The protective effects of marriage are associated with a lower morbidity among married persons, too (Goldman et al., 1995; Verbrugge, 1979b; Williams & Umberson, 2004). Previous investigators have found that married persons have decreased morbidity, as measured by a longer healthy life expectancy indicator (i.e., number of remaining life years in "good" health) (Robine et al., 1999; Chiu, 2019; Martikainen et al., 2014; Kaprio et al., 1996). Martikainen et al. (2014) found that married persons had the longest life expectancy living in the community (instead of in a long-term care institution), followed by widowed persons and divorced persons, and never married persons had the shortest life expectancy in the community. Among men, life expectancy in the community at age 65 was 15.8, 13.7, 12.1, and 11.8 years for these four groups, respectively, and among women, life expectancy in the community at age 65 was 19.0, 17.9, 16.7, and 18.1 years, respectively (Martikainen et al., 2014). Using data from the U.S. Health and Retirement Study (HRS), Chiu (2019) compared disability-free life expectancy between couples (married/cohabiters living with their spouses/partners) and singles (separated, widowed, divorced, never married, or not cohabiting) and found that, for both men and women, couples had a greater disability-free life expectancy at age 50 than singles (Chiu, 2019).

The previous studies that estimated healthy life expectancy by marital status modeled transition probabilities between three exclusive states (good health or independent state, poor health or dependent state, and death) with marital status as one of the predictors (in addition to age, sex, etc.) (Chiu, 2019; Martikainen et al., 2014). These analyses were based on "the standard assumption that men and women will remain in a given marital status until death" (Martikanen et al., 2014). Unlike other factors, marital status is not a permanent state and may change during the lifespan. For example, a married person may become divorced or widowed in subsequent years, and an unmarried person may get married. Therefore, these analyses likely overestimated the protective effects of marriage on life expectancy and healthy life expectancy.

The active life expectancy (ALE), also called disability-free life expectancy (DFLE), is the number of future life years with no difficulty in performing ADLs (i.e., in "active" state) or non-disabled state, and is a good indicator of the overall long-term health of individuals, where lower ALE indicates a shorter life span in full health (Sullivan, 1971; Katz et al., 1983). Estimation of ALE allows the overall protective effects of marriage, including both mortality and morbidity, to be quantified in a single value index. It would be particularly useful to compare the difference in projected years of life remaining in an "active" state for persons at a given age based on their **baseline** marital status. Such an analysis allows a participant's marital status to change during future life years, therefore providing an unbiased estimation of the effects of marital status on total life expectancy (TLE) and ALE. This can be done by modeling transitions between different marriage-by-active states for cohorts of participants according to their baseline marital status (Kalbfleisch & Lawless, 1985; van den Hout & Matthews, 2009).

The main goal of this study is to examine the association between marital status and TLE and ALE in a large longitudinal sample of U.S. community-dwelling older adults. Specifically, we estimated the total projected remaining life years (TLE) and the projected remaining life years that were in an active state (ALE) for participants according to their age and marital status at baseline. The multi-state models were used for this analysis in order to allow participants' marital status and active state to change during their remaining lifetime. To compare the difference in the protective effects of marriage between men and women, all estimates were conducted separately by sex. We also examined the role that selection bias played in total life expectancy estimation.

2. Materials and methods

Data sources: The data were obtained from the Medicare Health Outcome Survey (HOS), a nationwide annual survey of Medicare beneficiaries (Centers for Medicare & Medicaid Services, 2012). Each year, the HOS randomly selects a cohort of Medicare beneficiaries who voluntarily enrolled in Medicare Advantage private health plans. The selected individuals who complete a baseline survey are resurveyed two years later. This study used the Cohort 15 whose baseline data were collected in 2012 and follow-up data were collected in 2014. The HOS data contains the date of death if death occurred by January 31, 2015. We included all respondents aged 65 years or older who participated in the baseline survey. The total sample was 164,597. Among these respondents, 100,290 (61%) were alive at follow-up and completed the follow-up survey, 26,111 (16%) died before the follow-up survey, and 38,196 (23%) did not participate in the follow-up survey. An additional 88 participants died after having completed the follow-up survey. Of note, although potential bias might exist between participants and nonparticipants in the follow-up survey, no difference in baseline characteristics, including age, sex, race, disability status, and chronic conditions, between these two groups was noted.

Measures: The HOS asked respondents about their current marital status (Centers for Medicare & Medicaid Services, 2019). There are five possible answers to this question: (1) married; (2) divorced; (3) separated; (4) widowed; (5) never married.

The HOS also asks respondents whether they have difficulty with the following six basic activities of daily living (ADLs): (1) bathing, (2) dressing, (3) eating, (4) getting in or out of chairs, (5) walking, and (6) using the toilet. These questions have been used for calculating ALE (Robine et al., 1999; Katez et al., 1983; Rogers et al., 1989). A participant was classified as in an active state if this person reported having no difficulty for any of these six ADLs (Robine et al., 1999).

Statistical analysis: The multi-state models were used to estimate ALE and TLE for cohorts of persons according to their initial marital status (Kalbfleisch & Lawless, 1985; van den Hout & Matthews, 2009). Because the HOS data were collected at baseline and at follow-up after 2 years, we estimated TLE and ALL at ages 65, 67, …, and 95 years. To illustrate this method, we describe a process with k transient states $s = (1, 2, …, k)$ for k levels of marriage-by-ADL categories (for example, "active and married," "dependent and married," "active and divorced," "dependent and divorced," etc.) and one absorbing state $s = k + 1$ for dead. Let $p_t^{i,j} = \Pr(s_{t+2} = j | s_t = i)$ be transition probability from state i at age t to state j at age $t + 2$.

The transition probabilities between different marriage-by-ADL states were estimated from log-linear models with age as a time-dependent predictor assuming a constant instantaneous transition rate in the age interval (van den Hout & Matthews, 2009; Gardiner, Liu, & Luo, 2008). The probability of death for each transient state during each age interval was estimated based on the probability of death for the total population and hazard ratio of death for each state relative to the reference group (active and married) at different ages. We used the probability of death from the 2012 U.S. life tables (Arias et al., 2016) as the probability of death for the total population and estimated hazard ratios using a Cox proportional hazard model with time-varying covariates from the HOS data (van den Hout & Matthews, 2009).

For an age cohort of individuals with known numbers of persons in each states i at the starting age x, l_x^i, the expected numbers of persons in each states at ages $x + 2$, $x + 4$, …, can be obtained iteratively based on transition probabilities $p_t^{i,j}$ as $l_{t+2}^i = l_t^i(1 - \sum_{j=1, j \neq i}^{k+1} p_t^{i,j}) + \sum_{j=1, j \neq i}^{k} l_t^j p_t^{j,i}$. Let L_t^i be number of years lived in state i during the age interval from t to $t + 2$ for the age cohort. The expected number of remaining life years in state i for this age cohort is $e_x^i = \left(\sum_{t>x} L_t^i \right) / l_x$ where $l_x = \sum_{i=1}^{k} l_x^i$ is the total number of persons at the starting x. Therefore, TLE for this age cohort is TLE $= \sum_{i=1}^{k} e_x^i$. Let s_A be the notion for all active states ("active and married", "active and divorced," etc.), ALE for this age cohort is summation of e_x^i over all active states, ALE $= \sum_{i \in s_A} e_x^i$. We used the bootstrap method to estimate the standard error of the estimated TLE and

ALE and test differences between different subgroups (van den Hout & Matthews, 2009).

3. Results

At baseline, the average participant age was 75.1 years, with 53% of participants between 65 and 74 years old, 34% of participants between 75 and 84 years old, and 13% of participants 85 years or older (Table 1). Women comprised 58% (95,115 of 164,597) of the sample, and white non-Hispanics 76% of the sample. For the total sample, approximately 55% of participants were married, 13% were divorced, 1% were separated, 27% were widowed, and 4% were never married. The same marital status distributions were observed at the follow-up survey (data not shown). Compared to men, women were more likely to be widowed (38% vs. 12%) and divorced (15% vs. 11%), and less likely to be married (42% vs. 72%).

Table 2 presents TLE and ALE at different ages for those who were married, divorced, separated, widowed, and never married. At younger ages (65-83 years), married persons had the longest TLE and ALE of the five marital categories for both men and women. While separated persons had lower TLE and ALE than married persons, separated men and women had slightly higher TLE and ALE than divorced, widowed, and never married men and women. At older ages (>87 years), married men and women had a similar TLE and ALE as divorced, widowed, and never married men and women, respectively, and separated persons had the longest TLE and ALE, but the differences were not statistically significant (standard error of estimates are available in Appendix 1). Divorced, widowed, and never married persons had a similar and the lowest TLE and ALE at all ages.

Table 2 also presents the percent of future life years being in an active state. In general, men were expected to spend a higher percent of future life years in an active state than women, and currently married persons were expected to spend a higher percent of future life years in an active state than persons who were divorced, separated, widowed, or never married. Fig. 1 presents percent of future life years being married by five categories of marital status. Not surprisingly, married men and women had the greatest percent of future life years being married.

Among persons who were not married, separated persons had the highest percent of future life years of being married as compared to persons who were divorced, widowed, or never married. Compared to women, men tended to have a higher percent of future life years being married for all marital status categories examined.

Next, we examined marital status as a binary measure by combining divorced, separated, widowed, and never married into one category entitled "unmarried." Table 3 presents total life expectancy for married persons and unmarried persons. In younger ages (65–83), married persons had a significantly longer TLE and ALE than unmarried persons of the same age, a finding seen for both men and women. The differences in TLE and ALE between married and unmarried persons were greater among men than among women. For example, a 65-year old married man was expected to live an additional 18.6 years, 2.2 years (14%) longer than a 65-year old unmarried man, who was expected to live an additional 16.4 years. Similarly, a 65-year old married woman was expected to live an additional 21.1 years, 1.5 years (8%) longer than a 65-year old unmarried woman, who was expected to live an additional 19.6 years. The gains in TLE and ALE among married persons decreased with age (in both absolute values and relative percentages) and disappeared for persons aged 85-87 years or older except for women where the gains in ALE among married persons were significant at all ages.

Fig. 2 depicts the unadjusted and adjusted (adjusted for baseline ADL states) difference in TLE between married and unmarried persons. Between the ages of 65 to 79, the adjusted difference between married and unmarried persons is smaller than the unadjusted difference. For example, among 65-year-old men, the unadjusted difference is 2.2 years and the adjusted difference is 0.9 years, indicating that selection bias contributes about 1.3 of 2.2 (61%) of the observed difference in marriage protection for life expectancy. Similarly, for 65-year-old women, the adjusted difference is 0.5 and the unadjusted difference is 1.5, indicating that selection bias contributes about 1.0 of 1.5 (64%) of the observed difference in marriage protection for life expectancy.

4. Discussion

This study answers the following questions: Does life expectancy and active life expectancy differ by marital status? If so, does the magnitude of the protective effect of marriage differ by age and sex, and which subgroups of unmarried persons have the lowest life expectancy and active life expectancy? While life expectancy and healthy life expectancy by marital status have been examined in different populations, previous investigations had assumed that marital status would remain unchanged until death (Martikainen et al., 2014; Kaprio et al., 1996; Peltonen et al., 2017). Therefore, these analyses likely overestimated the protective effect of marriage, resulting in the conclusion of a significant increase in life expectancy and healthy life expectancy for married persons. By contrast, our analyses allowed participants' marital status as well as ADL states to change during the remaining lifetime. Additionally, the large sample size of the Medicare HOS data enabled us to observe the impact of age, sex, and category of marital status on life expectancy with good reliability in an older (and less studied) population. Because the Centers for Medicare & Medicaid Services has administered the HOS annually since 1998, it is possible to obtain annual estimates and ascertain changes over time with regard to the health of the elderly.

Consistent with many previous studies (Chiu, 2019; Kaprio et al., 1996; Martikainen et al., 2014), our investigation demonstrated that married persons have a significantly greater life expectancy and active life expectancy as compared to unmarried persons from age 65 to 85 for both men and women. This protective effect of marriage with regard to life expectancy lessened with age and disappeared among participants greater than 85 years old, a finding seen by other investigators, too (Rendall et al., 2011; Johnson et al., 2000). Although marriage was protective for both men and women from age 65 to 85, the effect was greater for men in absolute values as well as relative percentages. Additionally, both married and unmarried men were more likely to

Table 1
Baseline sample characteristics, 2012 Medicare Health Outcome Survey (HOS).

	Total (n = 164,597)		Men (n = 69,482)		Women (n = 95,115)	
	N	Percent	N	Percent	N	Percent
Age, Mean (SD)	75.1 (7.4)		74.6 (7.0)		75.5 (7.7)	
65-74	87,972	53.4%	38,741	55.8%	49,231	51.8%
75-84	55,676	33.8%	23,647	34.0%	32,029	33.7%
85-94	19,313	11.7%	6738	9.7%	12,575	13.2%
95+	1636	1.0%	356	0.5%	1280	1.3%
Women	95,115	57.8%	–	–	–	–
Race/ethnicity						
White non-Hispanics	121,334	76.1%	32,822	79.5%	44,806	77.3%
Black non-Hispanics	13,031	8.2%	2423	5.9%	4998	8.6%
Hispanics	15,735	9.9%	3641	8.8%	5152	8.9%
Other	9404	5.9%	2402	5.8%	3001	5.2%
Marital status						
Married	87,241	54.6%	48,466	71.7%	38,775	42.0%
Divorced	21,241	13.3%	7210	10.7%	14,031	15.2%
Separated	2159	1.4%	961	1.4%	1198	1.3%
Widowed	42,711	26.7%	8057	11.9%	34,654	37.5%
Never married	6545	4.1%	2863	4.2%	3682	4.0%
Any ADL limitation	60,523	37.6%	23,511	34.6%	37,012	39.8%
Died during the follow up[a]	26,199	15.9%	12,033	17.3%	14,166	14.9%

[a] Died between baseline survey and January 31, 2015.

Table 2

Total Life Expectancy (TLE) and Active Life Expectancy (ALE) by Marital Status at Ages 65 to 95 years, U.S. men and Women.

Age (x)	Married			Divorced			Separated			Widowed			Never married		
	TLE	ALE	%[a]	TLE	ALE	%[a]	TLE	ALE	%[a]	TLE	ALE	%[a]	TLE	ALE	%[a]
Men															
65	18.6	12.3	66%	16.3	10.0	61%	17.3	10.4	60%	16.2	9.8	61%	16.2	9.9	61%
67	17.1	11.1	65%	14.9	9.0	61%	15.8	9.5	60%	15.1	8.9	59%	14.8	9.1	61%
69	15.6	9.9	63%	13.6	8.1	59%	14.4	8.5	59%	13.9	8.0	57%	13.5	8.2	61%
71	14.2	8.8	62%	12.4	7.2	58%	13.1	7.5	57%	12.8	7.1	55%	12.3	7.4	60%
73	12.8	7.6	60%	11.3	6.3	56%	11.8	6.5	55%	11.7	6.2	53%	11.2	6.5	58%
75	11.5	6.6	57%	10.2	5.5	53%	10.6	5.6	53%	10.6	5.4	51%	10.1	5.7	56%
77	10.3	5.6	54%	9.2	4.7	51%	9.6	4.8	50%	9.5	4.6	49%	9.0	4.9	54%
79	9.1	4.7	51%	8.3	4.0	48%	8.6	4.1	48%	8.5	3.9	47%	8.1	4.1	52%
81	8.0	3.8	48%	7.4	3.3	45%	7.7	3.4	45%	7.5	3.3	44%	7.1	3.5	49%
83	7.0	3.1	45%	6.6	2.8	42%	6.9	2.9	42%	6.6	2.7	41%	6.2	2.8	46%
85	6.0	2.5	41%	5.8	2.3	39%	6.2	2.4	40%	5.8	2.2	38%	5.3	2.3	43%
87	5.2	1.9	38%	5.1	1.9	37%	5.5	2.1	38%	5.1	1.8	35%	4.5	1.8	40%
89	4.4	1.5	34%	4.4	1.5	34%	5.0	1.8	36%	4.4	1.4	32%	3.8	1.4	37%
91	3.8	1.2	31%	3.9	1.2	32%	4.5	1.6	35%	3.8	1.1	28%	3.2	1.1	35%
93	3.2	0.9	28%	3.4	1.0	30%	4.1	1.4	34%	3.4	0.8	25%	2.6	0.8	32%
95	2.8	0.7	26%	2.9	0.8	28%	3.7	1.3	34%	2.9	0.6	22%	2.1	0.6	30%
Women															
65	21.1	13.0	62%	19.7	11.1	57%	19.9	11.1	55%	19.7	10.8	55%	19.3	11.2	58%
67	19.5	11.7	60%	18.1	10.0	55%	18.4	10.0	54%	18.2	9.8	54%	17.8	10.2	57%
69	17.9	10.5	59%	16.5	8.9	54%	16.9	8.9	53%	16.8	8.9	53%	16.3	9.2	57%
71	16.3	9.3	57%	15.0	7.9	52%	15.4	7.8	51%	15.4	7.9	51%	14.9	8.2	55%
73	14.8	8.1	55%	13.6	6.8	50%	14.0	6.9	49%	14.1	7.0	50%	13.6	7.2	53%
75	13.3	7.0	52%	12.3	5.9	48%	12.7	5.9	47%	12.7	6.2	49%	12.3	6.3	51%
77	12.0	5.9	50%	11.1	5.0	45%	11.5	5.1	44%	11.4	5.4	47%	11.1	5.4	48%
79	10.6	5.0	47%	9.9	4.1	42%	10.3	4.3	41%	10.2	4.6	45%	10.0	4.5	45%
81	9.4	4.1	44%	8.8	3.4	39%	9.2	3.6	39%	9.0	3.9	43%	8.9	3.7	42%
83	8.2	3.3	40%	7.7	2.7	35%	8.2	2.9	36%	7.9	3.2	40%	7.9	3.0	38%
85	7.1	2.6	37%	6.8	2.1	32%	7.3	2.4	33%	6.9	2.6	37%	7.0	2.4	34%
87	6.1	2.0	34%	5.9	1.6	28%	6.4	1.9	30%	6.0	2.0	34%	6.1	1.8	30%
89	5.2	1.6	30%	5.1	1.2	24%	5.7	1.6	28%	5.2	1.6	30%	5.3	1.4	26%
91	4.4	1.2	27%	4.4	0.9	21%	5.0	1.3	25%	4.5	1.2	26%	4.5	1.0	22%
93	3.8	0.9	24%	3.8	0.7	18%	4.4	1.0	23%	3.9	0.9	22%	3.9	0.7	19%
95	3.2	0.7	22%	3.3	0.5	15%	3.9	0.8	22%	3.4	0.6	18%	3.3	0.5	15%

Standard errors of TLE and ALE estimates are in Appendix 1.

[a] Percent of future life years in active state (=ALE/TLE*100%).

spend a higher proportion of their future life years married as compared to married and unmarried women, respectively. This would mean that a married woman would be far more likely to become a widow, as opposed to a married man becoming a widower and, not surprisingly, investigators have found that older men are more likely to remarry as compared to older women (Cleveland & Gianturco, 1976; Federal Interagency Forum on Aging-Related Statistics, 2016).

Regarding subgroups of unmarried persons, our analyses demonstrated that never married persons had the shortest life expectancy in all ages among men, while never married, divorced, and widowed persons had a similar, and shorter, life expectancy among women. In their systematic review and meta-analysis, Manzoli et al. (2007) found that married persons had lower mortality rates as compared to persons who were widowed, divorced/separated, and never married. Furthermore, using data from the National Health Interview Survey combined with the National Death Index, Kaplan and Kronick (2006) found an increased risk of death for unmarried persons compared to married persons and, within this unmarried category, having never been married was the strongest predictor of premature mortality.

According to Verbrugge (1979b), the protective effect of marriage may be due to (1) healthier persons are more likely to be married (selection) and (2) marriage may lead to better health. Given that the difference in TLE between married and unmarried persons is smaller than the unadjusted (observed) difference, the increase in total life expectancy among married men and women may be largely due to selection bias. For TLE, the selection bias decreases with age, disappearing at age 85 for men and at age 79 for women. By contrast, differences between married and unmarried persons in ALE disappear completely after

adjusting for baseline ADL state (not shown). This lack of difference by marital status is no surprise, given that ADL states are a strong determining factor of ALE and one of the two components of the ALE measure. Our results highlight selection bias is a large contributor to the protective effect of marriage.

These findings may have significant implications for long-term planning and identifying "at risk" individuals, given that the population 65 years of age and older is projected to more than double between 2010 and 2050 (Vincent & Velkoff, 2010). This demographic shift may be associated with changes in marital status as well as living situation. Of note, the divorce rate among adults aged 50 and older doubled between 1990 and 2010 (Brown & Lin, 2012) and, in terms of living situation, persons who were divorced, widowed, and never married were more likely to use long-term institutional care than were married persons (Chiu, 2019; Martikainen et al., 2014). On a related note, elderly persons who live alone were noted to have greater mortality and an increased risk of institutionalization (Pimouguet et al., 2016).

This study had a number of limitations. First, because our analysis used data from the Medicare HOS, a survey of Medicare beneficiaries who voluntarily enrolled in private Medicare Advantage health plans, this sample may be younger and healthier than the overall Medicare population (Byhoff et al., 2016). Second, marital status was self-reported, possibly leading to misclassification. For example, among persons who reported being married, divorced, separated, or widowed at the baseline survey, 0.16% reported having never been married at the follow-up survey. Third, different transition probabilities might be associated with number of previous marriages, duration of marriage, and marital dissolution type (i.e., widowed or divorced) (Brown & Lin,
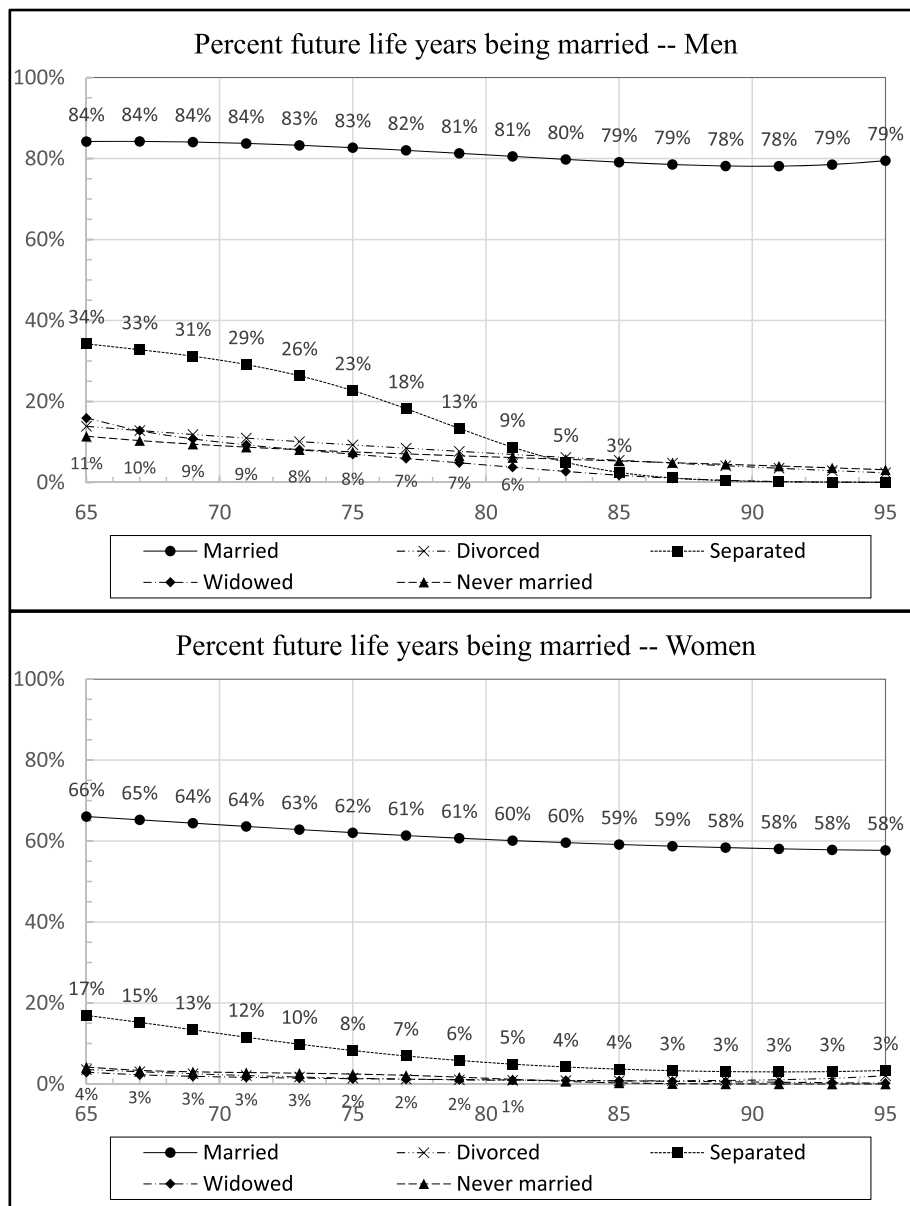
Fig. 1. Percent of future life years being married by current marital status.

2012). Fourth, we assumed only a single transition from baseline to follow-up, which may underestimate the impact of marital status on life expectancy (Gill et al., 2005; Laditka & Wolf, 1998). However, some investigators showed that the impact of this assumption on TLE and ALE estimates was relatively small (Crimmins et al., 2009; Cai et al., 2010).

The Medicare Health Outcomes Survey data provide an opportunity to monitor the health of the U.S. community-dwelling older population, a growing population investigators have traditionally overlooked. The HOS is the largest longitudinal survey of the U.S. elderly population, and

MSLT analyses never have been conducted using these data to compute TLE and ALE with good reliability. By applying the multi-state models to a novel data set, we accounted for changes in participants' marital status during the remaining lifetime. We also were the first study to examine ALE by marital status and to demonstrate the role of selection bias on TLE. Further research should examine the impact of changes of marital status, duration of marriage (or being widowed or divorced), number of previous marriage(s)/divorce(s), and living arrangements on life expectancy. Similarly, adding questions regarding cohabitation and
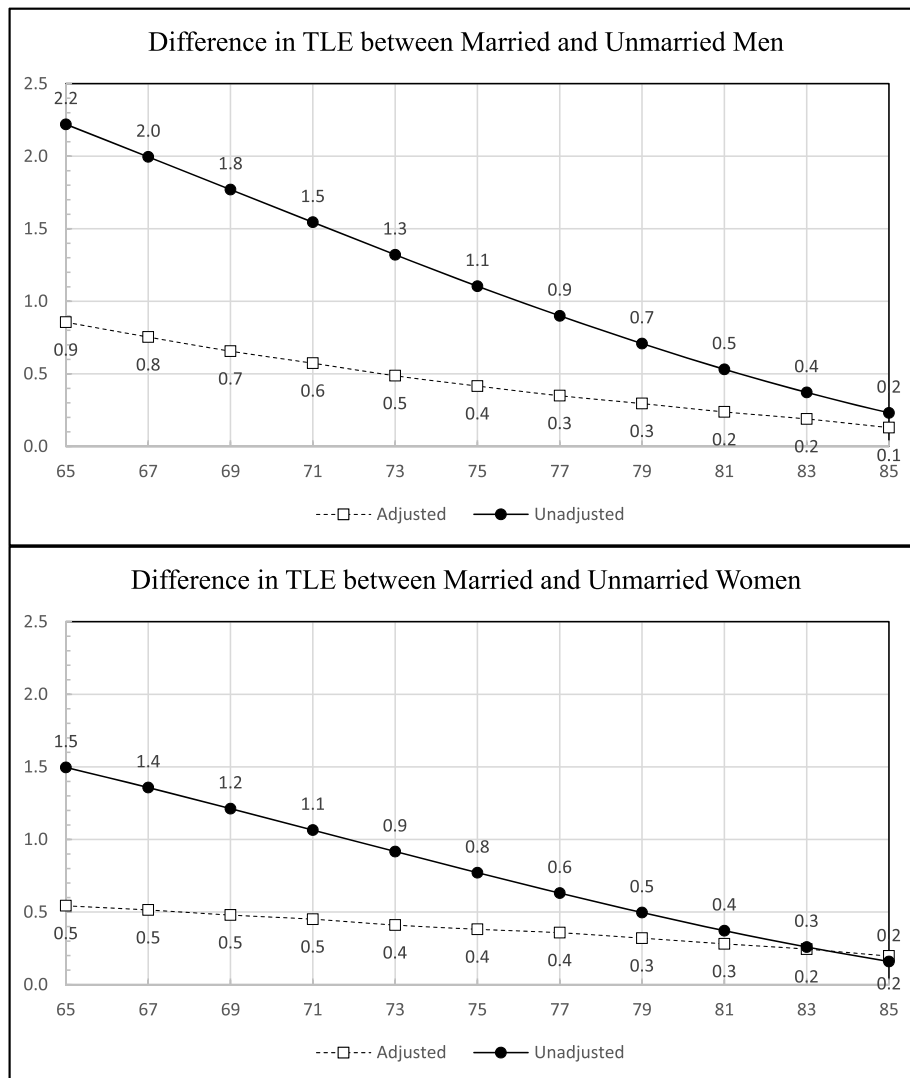
Fig. 2. Difference in total life expectancy (TLE) according to marital status and gender.
Adjusted: adjusted for baseline ADL states.

unmarried partners in the HOS will be increasingly important in future years to understand the impact of cohabitation and same sex marriage on life expectancy.

Ethical approval

This article used publicly available data from the. Medicare HOS Limited Data Set available through the Centers for Medicare & Medicaid.

Informed consent

None.

Author statement

With regard to specific contributions:
HJ was in charge of the conceptualization, methodology, software, validation, and data curation. Both HJ and EL were involved in the

(*continued*)

Age (x)	Married			Divorced			Separated			Widowed			Never married		
	TLE	ALE	%	TLE	ALE	%	TLE	ALE	%	TLE	ALE	%	TLE	ALE	%
93	0.09	0.05	1.3%	0.3	0.1	3%	1.0	0.5	8%	0.1	0.1	1.4%	0.4	0.2	5%
95	0.12	0.06	1.7%	0.3	0.1	4%	1.2	0.6	10%	0.1	0.1	1.8%	0.4	0.2	6%
Women															
65	0.04	0.04	0.2%	0.10	0.07	0.3%	0.2	0.2	0.5%	0.09	0.07	0.2%	0.3	0.2	1%
67	0.04	0.04	0.2%	0.10	0.07	0.3%	0.2	0.1	0.4%	0.08	0.06	0.2%	0.3	0.2	1%
69	0.04	0.04	0.2%	0.10	0.07	0.3%	0.2	0.1	0.5%	0.07	0.05	0.2%	0.3	0.2	1%
71	0.04	0.04	0.2%	0.10	0.07	0.3%	0.2	0.1	0.5%	0.07	0.05	0.2%	0.3	0.2	1%
73	0.04	0.04	0.2%	0.11	0.07	0.3%	0.2	0.1	0.6%	0.07	0.05	0.2%	0.3	0.2	1%
75	0.05	0.04	0.2%	0.11	0.07	0.4%	0.3	0.2	0.7%	0.06	0.04	0.2%	0.3	0.2	1%
77	0.05	0.04	0.3%	0.11	0.07	0.4%	0.3	0.2	0.8%	0.05	0.04	0.2%	0.3	0.2	1%
79	0.05	0.04	0.3%	0.12	0.07	0.5%	0.3	0.2	1%	0.05	0.03	0.3%	0.3	0.2	1%
81	0.06	0.04	0.3%	0.13	0.07	0.6%	0.4	0.2	1%	0.05	0.03	0.3%	0.3	0.2	1%
83	0.07	0.04	0.4%	0.14	0.07	0.7%	0.4	0.2	1%	0.04	0.03	0.3%	0.3	0.1	1%
85	0.08	0.04	0.5%	0.14	0.07	0.8%	0.5	0.2	2%	0.04	0.03	0.3%	0.3	0.1	2%
87	0.09	0.05	0.6%	0.15	0.07	0.9%	0.6	0.3	3%	0.04	0.02	0.4%	0.3	0.1	2%
89	0.10	0.05	0.8%	0.16	0.07	1%	0.8	0.4	4%	0.03	0.02	0.4%	0.3	0.1	2%
91	0.12	0.06	1%	0.18	0.07	1%	1.0	0.4	5%	0.03	0.02	0.5%	0.3	0.1	2%
93	0.15	0.06	1%	0.21	0.08	2%	1.2	0.5	7%	0.03	0.02	0.6%	0.3	0.1	3%
95	0.19	0.07	2%	0.25	0.08	2%	1.4	0.6	9%	0.03	0.02	0.7%	0.3	0.1	3%

Appendix 2. Standard Error of Estimates in Table 3

Age (x)	Married Men			Unmarried Men			Difference	
	TLE	ALE	%	TLE	ALE	%	TLE	ALE
65	0.04	0.04	0.2%	0.08	0.07	0.3%	0.12	0.09
67	0.04	0.04	0.2%	0.08	0.07	0.3%	0.11	0.08
69	0.04	0.04	0.2%	0.08	0.06	0.3%	0.11	0.08
71	0.04	0.04	0.2%	0.08	0.06	0.3%	0.11	0.08
73	0.03	0.03	0.2%	0.08	0.06	0.4%	0.11	0.07
75	0.03	0.03	0.2%	0.07	0.06	0.4%	0.10	0.07
77	0.03	0.03	0.3%	0.07	0.05	0.4%	0.10	0.07
79	0.03	0.03	0.3%	0.07	0.05	0.5%	0.10	0.06
81	0.03	0.03	0.3%	0.06	0.05	0.5%	0.10	0.06
83	0.04	0.03	0.4%	0.06	0.05	0.6%	0.10	0.06
85	0.04	0.03	0.5%	0.06	0.05	0.7%	0.10	0.06
87	0.05	0.03	0.6%	0.06	0.04	0.8%	0.11	0.06
89	0.06	0.04	0.7%	0.06	0.04	0.9%	0.12	0.06
91	0.07	0.04	1.0%	0.06	0.05	1.1%	0.13	0.06
93	0.09	0.05	1.3%	0.06	0.05	1.4%	0.15	0.07
95	0.12	0.06	1.7%	0.06	0.05	1.7%	0.18	0.08
	Married Women			Unmarried Women			Difference	
65	0.04	0.04	0.2%	0.05	0.05	0.2%	0.09	0.06
67	0.04	0.04	0.2%	0.05	0.04	0.2%	0.08	0.06
69	0.04	0.04	0.2%	0.05	0.04	0.2%	0.08	0.06
71	0.04	0.04	0.2%	0.04	0.04	0.2%	0.08	0.05
73	0.04	0.04	0.2%	0.04	0.04	0.2%	0.08	0.05
75	0.05	0.04	0.2%	0.04	0.03	0.2%	0.08	0.05
77	0.05	0.04	0.3%	0.04	0.03	0.2%	0.09	0.05
79	0.05	0.04	0.3%	0.03	0.03	0.2%	0.09	0.05
81	0.06	0.04	0.3%	0.03	0.03	0.3%	0.09	0.05
83	0.07	0.04	0.4%	0.03	0.03	0.3%	0.10	0.05
85	0.08	0.04	0.5%	0.03	0.02	0.3%	0.11	0.05
87	0.09	0.05	0.6%	0.03	0.02	0.4%	0.11	0.05
89	0.10	0.05	0.8%	0.02	0.02	0.4%	0.12	0.06
91	0.12	0.06	1.1%	0.02	0.02	0.5%	0.14	0.06
93	0.15	0.06	1.4%	0.02	0.02	0.6%	0.17	0.07
95	0.19	0.07	1.9%	0.01	0.02	0.6%	0.20	0.07

[1]: percent of future life years in active state (=ALE/TLE*100%).

[2]: difference between married and unmarried persons for TLE and ALE, respectively.

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