

# Loneliness and health expectancy among older adults: A longitudinal population-based study

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## Abstract

**Background:** The population health impact of loneliness remains unknown. We quantified the impact of loneliness on total life expectancy (TLE) and health expectancy (the duration of remaining life lived in different health states) among older adults, aged  $\geq 60$  years.

**Design:** Multistate life table analysis of a nationally representative longitudinal survey.

**Setting:** Singapore.

**Participants:** Survey participants ( $n = 3449$ ) interviewed in 2009, 2011–12, and 2015.

**Measurements:** Health states were defined using self-rated health (SRH) status and activity of daily living (ADL)/instrumental ADL (IADL) status. Participants with somewhat or very unhealthy SRH were considered as unhealthy. Those reporting health-related difficulty with any ADL/IADL were considered to have limitation in ADLs/IADLs. TLE and health expectancy (healthy and unhealthy life expectancy (HLE and UHLE) in the context of SRH, and active and inactive life expectancy (ALE and IALE) in the context of ADLs/IADLs) were estimated using the multistate life table method with a microsimulation approach, considering loneliness as time varying.

**Results:** At age 60, 70, and 80, those sometimes lonely or mostly lonely generally had shorter TLE, HLE and ALE, similar UHLE and IALE, and a higher proportion of remaining life with unhealthy SRH or with ADL/IADL limitations versus those never lonely. For example, at the age of 60, those sometimes lonely versus never lonely had shorter TLE (by 5.4 [95% Confidence Interval: 3.4–7.9] years), shorter HLE (by 5.9 [4.1–8.6] years), similar UHLE (difference: 0.6 [–0.7–1.7] years), and higher proportion of remaining life with unhealthy SRH (by 6.2 [1.2–10.8] percentage points). For those mostly lonely versus never lonely, TLE was shorter by 3.6 (0.7–6.6) years, HLE was shorter by 4.8 (2.3–8.2) years, UHLE was similar (difference: 1.2 [–0.1–4.0] years), and proportion

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of remaining life with unhealthy SRH was higher by 7.2 (2.1–18.1) percentage points.

**Conclusion:** Identification and management of loneliness may increase years of life with healthy SRH and without limitation in ADLs/IADLs among older adults.

**KEYWORDS**

activities of daily living, Asia, health expectancy, loneliness, older adult, self-rated health, Singapore

## INTRODUCTION

Loneliness, the “perceived discrepancy between” one’s “desired and actual social relationships”<sup>1</sup> or “a situation experienced by an individual where there is an unpleasant or inadmissible lack of (quality of) certain relationships”,<sup>2</sup> is a subjective phenomenon. It is distinct from social isolation (“the objective state of having few social relationships or infrequent social contact with others”).<sup>3</sup> It has been highlighted that “loneliness is often stigmatised, trivialised, or ignored”,<sup>4</sup> even though loneliness presents a public health challenge, given its link with numerous adverse health outcomes.

Loneliness contributes to “poorer physical and mental health, and unhealthy lifestyle”.<sup>5</sup> It is a key contributor to unhealthy self-rated health (SRH) among older adults.<sup>6,7</sup> Lonely older adults are more likely to experience functional status limitations, including limitations in activities of daily living (ADLs) or instrumental ADLs (IADLs).<sup>6,7</sup> Loneliness is a risk factor for reduced social engagement and quality of life,<sup>6</sup> depressive symptoms,<sup>7</sup> coronary heart disease and stroke,<sup>8</sup> and death.<sup>7,9</sup>

Loneliness is prevalent at all ages, however, more so among those aged 15–24 years and  $\geq 80$  years.<sup>10</sup> Loneliness among older adults has become a social and public health concern with population aging<sup>4,11</sup> and the control measures for the Coronavirus Disease 2019, such as staying at home and physical distancing.<sup>12</sup> Policy makers are paying attention to the role of loneliness in affecting health and quality of life. For instance, in 2018, the United Kingdom established a Ministerial lead on loneliness and launched a national strategy for tackling loneliness,<sup>11,13</sup> and in 2021, Japan appointed a ‘Minister of loneliness’.<sup>14</sup>

The increasing policy focus on loneliness is encouraging. However, for greater public, clinical, and policy attention to the health risks posed by loneliness, especially among older adults, it is imperative to assess its impact on morbidity and mortality not only separately, as has already been done (detailed above), but also on holistic population health indicators that consider morbidity

### Key Points

- This is the first study to quantify the impact of loneliness on health expectancy (the duration of remaining life lived in different health states).
- Health states were defined using self-rated health status and activity of daily living status.
- Lonely older adults had a shorter life and fewer healthy or active life years versus those not lonely.

### Why Does this Paper Matter?

The study findings highlight the population health impact of loneliness, and the importance of identifying and managing it among older adults.

and mortality concurrently—this has not been done till date. One such population health indicator is health expectancy, i.e., “the analysis of both healthy and unhealthy years of life where health can be defined along various dimensions”.<sup>15</sup> Health expectancy captures both quantity and quality of life years by adding a quality-of-life aspect to total life expectancy (TLE).<sup>16</sup>

We utilize two health dimensions that are most commonly used for assessing health expectancy among older adults<sup>17</sup>—SRH and ADL/IADL status—to estimate health expectancy by loneliness status. SRH is an informative and widely used single indicator of health.<sup>18</sup> When assessing health expectancy using SRH, the terms healthy life expectancy (HLE) and unhealthy life expectancy (UHLE) are often used for the years of remaining life lived with healthy and unhealthy SRH, respectively.<sup>15</sup> ADLs, i.e., basic activities that are essential for personal care, such as eating and toileting, and IADLs, i.e., activities that are key for independent living and

community functioning, such as doing housework and taking public transport,<sup>19</sup> are another key health dimension among older adults.<sup>20</sup> When assessing health expectancy using ADL/IADL status, the terms active life expectancy (ALE) and inactive life expectancy (IALE) are commonly used for the years of remaining life lived without and with limitation in ADLs/IADLs, respectively.<sup>15</sup>

Singapore, a Southeast Asian nation, is a relevant setting for assessing the impact of loneliness on health expectancy among older adults, aged  $\geq 60$  years. First, it has a rapidly aging population—the proportion of older adults is expected to increase from 19.7% in 2017 to 40% in 2050.<sup>21</sup> Second, being an Asian nation, with the Chinese forming the majority ethnic group, it has a collectivist (vs an individualistic) culture.<sup>22</sup> Previous studies suggest levels of loneliness to be higher in collectivistic (vs individualistic) societies.<sup>23–25</sup> Thus, the detrimental impact of loneliness may also be more prominent in a collectivistic society, like Singapore.

We thus aim to estimate TLE, HLE and UHLE, and ALE and IALE by loneliness status among community-dwelling older adults in Singapore. Given the link of loneliness with mortality,<sup>7,9</sup> we hypothesize that those lonely have a shorter TLE versus those not lonely. Lonely older adults have poorer SRH and are more likely to experience functional status limitations,<sup>6,7</sup> thus we hypothesize those lonely versus not lonely have shorter HLE and longer UHLE, and shorter ALE and longer IALE.

## METHODS

### Data

Data are from three waves of a nationally representative longitudinal survey, Panel on Health and Aging of Singaporean Elderly (PHASE), initiated in 2009. Its sampling approach and methodology are described elsewhere.<sup>26</sup> Briefly, 4990 older adults were enrolled and interviewed in 2009 (Wave 1). Of them, 3103 were interviewed in 2011–2012 (Wave 2), and 1572 were interviewed in 2015 (Wave 3). Information on participants' mortality was obtained primarily through the national Registry of Births and Deaths databases. PHASE Waves 2 and 3, analysis of de-identified data of PHASE Wave 1, and linkage with the deaths databases were approved by the institutional review board at the National University of Singapore (NUS-IRB Reference Codes: 10-441, 11-020E, 12-159E and B-14-235). Derivation of the analysis sample, comprising 3449 participants, is described in Supplemental Material: Methods and Results.

## Measures

### Loneliness

The Three-Item Loneliness Scale,<sup>27</sup> comprising the items, *How often do you feel that you lack companionship? How often do you feel left out? How often do you feel isolated from others?*, each with five response options (*never [score = 0], rarely, occasionally, fairly often, and always [score = 4]*), was used at each wave. The scale's internal consistency reliability was high (Cronbach's alpha = 0.92 at Wave 1). At each wave, item scores were summed for a cumulative score (range 0–12; higher score – greater extent of loneliness), which was then categorized as never lonely (score = 0), sometimes lonely (score = 1–3), and mostly lonely (score = 4–12).<sup>9</sup>

Across waves, the cumulative score was missing for 9.1–9.9% participants. The missing values were imputed 50 times, separately for each wave, using multivariate linear regression by Markov Chain Monte Carlo method,<sup>28</sup> and the average value across the 50 imputed datasets was assigned to the missing values. A range of variables reported to predict loneliness were included in the regression equation (see Supplemental Material: Methods and Results).

### Living health state: SRH (healthy/unhealthy)

At each wave, SRH was assessed by asking “In general, how would you describe your state of health?” with five response options (*very healthy, healthier than average, of average health, somewhat unhealthy, very unhealthy*). Those responding as somewhat unhealthy or very unhealthy were considered as unhealthy, and the rest considered as healthy.

### Living health state: ADL/IADL status (active/inactive)

At each wave, participants self-reporting health-related difficulty with any of the six ADLs (bathing, dressing, eating, standing up from bed/chair or sitting down on a chair, walking indoors, and toileting) or seven IADLs (preparing own meals, shopping, managing money, using the telephone, doing housework, taking transportation, and taking prescribed medication) were considered as inactive (and those not reporting health-related difficulty with any ADL/IADL were considered as active). A composite measure, comprising ADLs and IADLs, to define functional status is considered to be better than ADLs alone,<sup>29</sup> and has been used for estimating health expectancy.<sup>30,31</sup>

## Absorbing health state: Death

The date of death of deceased participants, until 31 December 2015, was determined from the national Registry of Births and Deaths databases, supplemented by information from PHASE Waves 2 and 3.

## Covariates

Covariates (detailed in Supplemental Material: Methods and Results) that could confound the relationship between loneliness and the considered health states<sup>7,32</sup> were accounted for. All covariates, except gender, ethnicity, and education level, were considered as time varying.

## Outcome: Health expectancy

We computed two distinct types of health expectancy: (i) HLE and UHLE (based on healthy and unhealthy SRH, respectively), and (ii) ALE and IALE (based on active and inactive ADL/IADL status, respectively).

## Analysis

We applied the discrete-time multistate life table (MSLT) method to the longitudinal data,<sup>33</sup> separately for each type of health expectancy. The analysis was conducted in SAS 9.4 using the SPACE (Stochastic Population Analysis for Complex Events) program,<sup>33,34</sup> which uses a micro-simulation approach to estimate health expectancy. Both population-based (i.e., health expectancy *irrespective of* health status at each age) and status-based (i.e., health expectancy *by* health status at each age) estimates were calculated—the analysis steps are detailed in Supplemental Material: Methods and Results.

## RESULTS

The proportion of participants who were unhealthy and inactive increased from 15% and 14%, respectively, at Wave 1, to 20% and 21%, respectively, at Wave 3. Although 42–53% of the participants reported being lonely (i.e., sometimes or mostly lonely) across waves, this proportion declined over time. Across the three waves, the proportion of unhealthy and inactive participants was higher among lonely than never lonely older adults (Table 1).

From an initial wave to the next wave, among those alive, 47–49% retained their loneliness status, 19–33%

had an improvement in loneliness status, and the rest experienced worsening (Table S1).

The adjusted (for covariates) population-based TLE and health expectancy estimates at the age of 60, 70, and 80, by loneliness status, are presented in Figures 1 and 2, and Tables 2 and 3. The corresponding unadjusted estimates are presented in Figures S1 and S2, and Tables S2 and S3. Next, the adjusted estimates are detailed.

In the context of SRH, at the age of 60, 70, and 80, those sometimes lonely versus never lonely had shorter TLE and HLE, similar UHLE, and spent a higher proportion of their remaining life with unhealthy SRH. For instance, at the age of 60, those sometimes lonely had shorter TLE (−5.4 [95% Confidence Interval (CI): −7.9 to −3.4] years; 21.4 vs 26.7 years) and HLE (−5.9 [−8.6 to −4.1] years; 17.1 vs 23.1 years), but similar UHLE (difference of 0.6 [−0.7 to 1.7] years; 4.2 vs 3.6 years) versus those never lonely. Consequently, they spent 19.8% of their remaining life with unhealthy SRH versus 13.6% for those never lonely, a difference of 6.2 [1.2–10.8] percentage points. A similar pattern was observed for those mostly lonely versus never lonely at the age of 60, 70, and 80; the only exception being the TLE estimate at the age of 80—although it was lower by 2.2 years for those mostly lonely (10.1 vs 12.3 years), the 95% CI of the difference [−4.0 to 0.1] did include zero, even if marginally. For instance, at the age 60, TLE was shorter by −3.6 [−6.6 to −0.7] years, HLE was shorter by −4.8 [−8.2 to −2.3] years, and the proportion of remaining life with unhealthy SRH was higher by 7.2 [2.1–18.1] percentage points for those mostly lonely versus those never lonely (Figure 1 and Table 2).

In the context of ADL/IADL status, at the age of 60, 70, and 80, those sometimes lonely had shorter TLE and ALE, similar IALE, and spent a higher proportion of their remaining life being inactive versus those never lonely. For instance, at the age of 60, those sometimes lonely versus never lonely had shorter TLE (−5.1 [−7.6 to −3.1] years; 21.5 vs 26.5 years) and ALE (−5.3 [−7.7 to −3.2] years; 16.5 vs 21.8 years), but similar IALE (0.2 [−1.2 to 1.5] years; 5.0 vs 4.7 years). Accordingly, they had a higher proportion of remaining life being inactive, by 5.3 [0.2–11.0] percentage points versus those never lonely (i.e., 23.1% vs 17.8%). The differences were less obvious when comparing those mostly lonely with those never lonely. For instance, at the age of 60, those mostly lonely versus never lonely did have shorter TLE and ALE, by −3.2 [−6.6 to 0.0] years and −3.0 [−5.4 to −0.1] years, respectively; however, their proportion of remaining life being inactive was similar (difference of 1.7 [−5.8 to 8.7] percentage points). At the age of 70 and 80, only ALE was shorter for those mostly lonely versus never

**TABLE 1** Demographics, health, and loneliness status of study participants

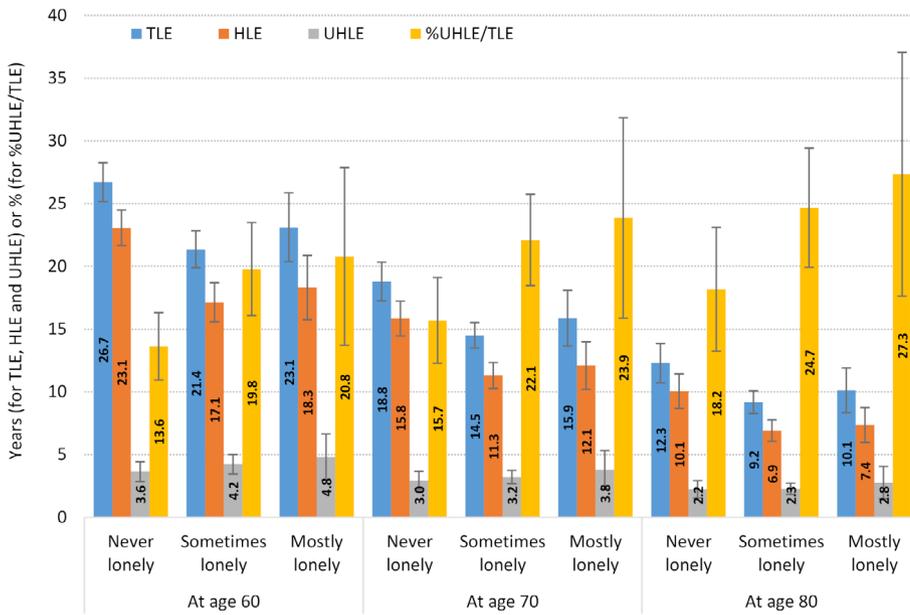
	Column percentage <sup>a</sup>		
	At Wave 1	At Wave 2	At Wave 3
Sample size	3448	3097	1572
Age (mean, SD)	70.1 (7.7)	71.8 (7.4)	75.0 (6.8)
% Women	53.3	54.5	55.2
% Chinese	82.7	83.7	84.1
% More than primary education	32.8	34.8	35.7
% Unhealthy	15.4	13.6	20.3
% Inactive	13.9	16.2	21.1
Loneliness			
Never lonely	46.9	58.2	53.8
Sometimes lonely	35.3	33.7	25.9
Mostly lonely	17.9	8.2	20.3
	<b>Never lonely</b>	<b>Sometimes lonely</b>	<b>Mostly lonely</b>
<i>Loneliness status (at Wave 1)</i>			
Sample size	1598	1237	613
Age (mean, SD)	69.1 (7.1)	71.3 (8.5)	70.3 (7.5)
% Women	59.4	41.6	60.4
% Chinese	78.9	86.7	84.7
% More than primary education	31.7	36.3	29.1
% Unhealthy	9.3	22.2	17.7
% Inactive	9.6	19.2	14.7
<i>Loneliness status (at Wave 2)</i>			
Sample size	1640	1173	284
Age (mean, SD)	70.5 (6.5)	73.7 (8.3)	73.9 (7.3)
% Women	50.9	57.8	66.5
% Chinese	86.8	79.3	79.4
% More than primary education	38.9	30.5	22.9
% Unhealthy	9.3	18.8	22.7
% Inactive	8.2	28.4	23.2
<i>Loneliness status (at Wave 3)</i>			
Sample size	797	437	338
Age (mean, SD)	74.4 (6.2)	76.5 (7.6)	74.7 (6.9)
% Women	52.9	56.6	59.5
% Chinese	86.3	83.6	79.0
% More than primary education	34.2	36.3	38.7
% Unhealthy	12.8	29.7	28.4
% Inactive	14.4	33.1	23.5

Abbreviations: SD, standard deviation; All estimates are weighted, using the respective wave sampling weights.

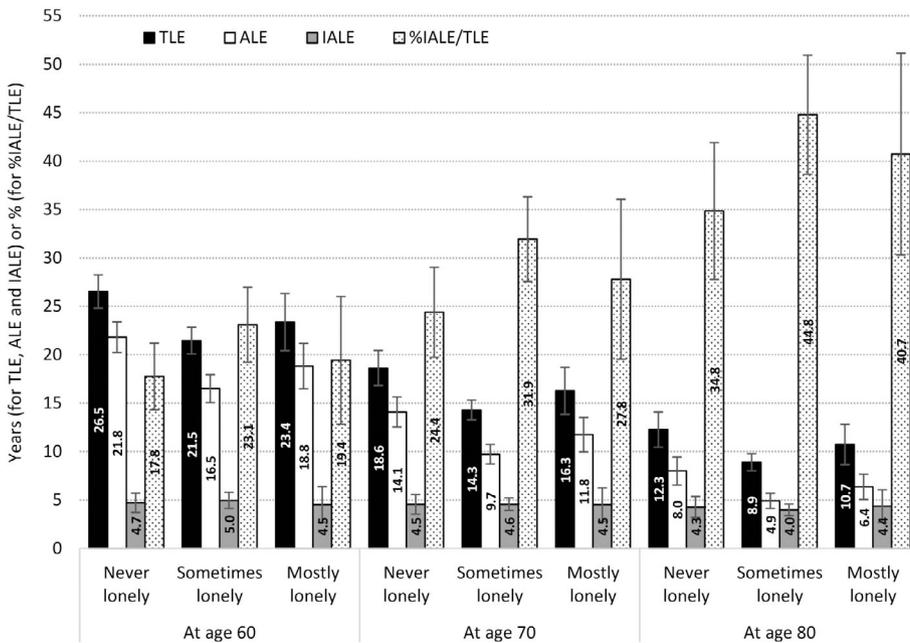
<sup>a</sup>Unless otherwise indicated.

lonely, whereas TLE, IALE, and proportion of remaining life being inactive were similar (Figure 2 and Table 3).

The unadjusted point estimates for the difference in UHLE or IALE and in the proportion of remaining life spent with unhealthy SRH or being inactive between



**FIGURE 1** Population-based *adjusted* (for covariates) estimates of total life expectancy, healthy life expectancy, and unhealthy life expectancy by loneliness status categories at the age of 60, 70, and 80. HLE, healthy life expectancy (years of remaining life lived with healthy self-rated health); TLE, total life expectancy (years of remaining life); UHLE, unhealthy life expectancy (years of remaining life lived with unhealthy self-rated health). Error bars indicate the 95% confidence interval of the estimated value



**FIGURE 2** Population-based *adjusted* (for covariates) estimates of total life expectancy, active life expectancy, and inactive life expectancy by loneliness status categories at the age of 60, 70, and 80. ALE, active life expectancy (years of remaining life lived without limitation in activities of daily living/instrumental activities of daily living); IALE, inactive life expectancy (years of remaining life lived with limitation in activities of daily living/instrumental activities of daily living); TLE, total life expectancy (years of remaining life). Error bars indicate the 95% confidence interval of the estimated value

**TABLE 2** Difference between loneliness status categories in *adjusted* population-based estimates of total life expectancy, healthy life expectancy, and unhealthy life expectancy at the age of 60, 70, and 80

Difference from 'Never lonely'	Age	TLE (95% CI)	HLE (95% CI)	UHLE (95% CI)	%UHLE/TLE (95% CI)
'Sometimes lonely' minus 'Never lonely'	60	<b>-5.4 (-7.9, -3.4)</b>	<b>-5.9 (-8.6, -4.1)</b>	0.6 (-0.7, 1.7)	<b>6.2 (1.2, 10.8)</b>
	70	<b>-4.3 (-6.6, -2.6)</b>	<b>-4.5 (-6.6, -3.0)</b>	0.3 (-0.8, 1.1)	<b>6.4 (1.1, 11.6)</b>
	80	<b>-3.1 (-5.0, -1.9)</b>	<b>-3.1 (-4.6, -2.0)</b>	0.0 (-0.8, 0.6)	<b>6.5 (0.9, 11.7)</b>
'Mostly lonely' minus 'Never lonely'	60	<b>-3.6 (-6.6, -0.7)</b>	<b>-4.8 (-8.2, -2.3)</b>	1.2 (-0.1, 4.0)	<b>7.2 (2.1, 18.1)</b>
	70	<b>-2.9 (-5.3, -0.3)</b>	<b>-3.8 (-6.4, -1.8)</b>	0.8 (-0.2, 3.1)	<b>8.2 (2.5, 19.7)</b>
	80	<b>-2.2 (-4.0, 0.1)</b>	<b>-2.7 (-4.5, -1.3)</b>	0.5 (-0.3, 2.3)	<b>9.2 (2.8, 21.2)</b>

Note: Estimates in boldface: the 95% confidence interval does not include zero.

Abbreviations: CI, confidence interval; HLE, healthy life expectancy (years of remaining life lived with healthy self-rated health); TLE, total life expectancy (years of remaining life); UHLE, unhealthy life expectancy (years of remaining life lived with unhealthy self-rated health).

**TABLE 3** Difference between loneliness status categories in *adjusted* population-based estimates of total life expectancy, active life expectancy, and inactive life expectancy at the age of 60, 70, and 80

Difference from 'Never lonely'	Age	TLE (95% CI)	ALE (95% CI)	IALE (95% CI)	%IALE/TLE (95% CI)
'Sometimes lonely' minus 'Never lonely'	60	<b>-5.1 (-7.6, -3.1)</b>	<b>-5.3 (-7.7, -3.2)</b>	0.2 (-1.2, 1.5)	<b>5.3 (0.2, 11.0)</b>
	70	<b>-4.3 (-6.5, -2.8)</b>	<b>-4.4 (-6.1, -2.7)</b>	0.0 (-1.3, 1.1)	<b>7.5 (1.0, 13.8)</b>
	80	<b>-3.4 (-5.1, -2.1)</b>	<b>-3.1 (-4.3, -1.8)</b>	-0.3 (-1.6, 0.5)	<b>9.9 (2.2, 17.1)</b>
'Mostly lonely' minus 'Never lonely'	60	<b>-3.2 (-6.6, 0.0)</b>	<b>-3.0 (-5.4, -0.1)</b>	-0.2 (-2.0, 1.8)	1.7 (-5.8, 8.7)
	70	-2.4 (-5.2, 0.3)	<b>-2.3 (-4.3, -0.1)</b>	0.0 (-1.8, 1.8)	3.4 (-5.9, 12.3)
	80	-1.5 (-3.6, 0.5)	<b>-1.6 (-3.0, -0.1)</b>	0.1 (-1.4, 1.8)	5.9 (-5.6, 15.8)

Note: Estimates in boldface: the 95% confidence interval does not include zero.

Abbreviations: ALE, active life expectancy (years of remaining life lived without limitation in activities of daily living/instrumental activities of daily living); CI, confidence interval; IALE, inactive life expectancy (years of remaining life lived with limitation in activities of daily living/instrumental activities of daily living); TLE, total life expectancy (years of remaining life).

those sometimes lonely or mostly lonely and those never lonely were generally higher than the adjusted point estimates (Tables S2 and S3).

The adjusted status-based health expectancy estimates are presented in Tables S8 and S9, and described in Supplemental Material: Methods and Results. The results of a sensitivity analysis, in which TLE and health expectancy were calculated in a non-imputed dataset, were qualitatively similar to those presented above—at the age of 60, 70, and 80, those who were never lonely had the highest TLE, HLE, and ALE (Tables S10 and S11).

## DISCUSSION

This study, the first to estimate health expectancy by loneliness status, found that never lonely older adults, at the age of 60, 70, and 80 had higher TLE, HLE and ALE, and lower proportion of their remaining life with unhealthy SRH or being inactive, relative to those sometimes lonely. However, when compared with those mostly lonely, never lonely older adults had a consistent advantage at the considered ages only for HLE and ALE. Furthermore, there was no difference in UHLE or IALE by loneliness status at any of the considered ages.

The findings partially support our hypotheses for the impact of loneliness on TLE and health expectancy. At the considered ages, we did find that loneliness resulted in lower absolute number of years of remaining life lived with healthy SRH or being active; however, it did not affect (increase) the absolute number of years of remaining life lived with unhealthy SRH or being inactive. At the individual level, these findings suggest that older adults who are lonely versus not lonely can expect to have a shorter life, with the penalty paid for by their years with healthy SRH or being active. However, they do not spend a greater number of years of their

remaining life with unhealthy SRH or being inactive. It will be helpful for older adults experiencing loneliness (and their family members and care providers) to consider this as they plan for their remaining life years. At the population level, the findings convey that an increase (or decrease) in older adults with loneliness may not necessarily translate into an increase (or decrease) in the years for which older adults have to be supported with their health or daily activities.

Nonetheless, the findings do point toward the importance of preventing, identifying, and addressing loneliness among older adults. Doing so would not only have immediate psychosocial benefits, but also, as our study suggests, benefit their TLE as well as the absolute number of years of remaining life with healthy SRH or being active. Although such efforts should ideally be universal, if one needs to prioritize, then focusing on older adult subgroups known to have a higher risk of developing loneliness can be an option. Such subgroups are defined not only by current circumstances, such as age, marital status, or living arrangement, but also life-course experiences, such as childhood economic problems or lower educational status.<sup>35,36</sup> A recent report from the National Academies of Sciences, Engineering, and Medicine recommends that healthcare providers should periodically assess older adults to identify those at risk of or experiencing loneliness, and initiate interventions to prevent or address loneliness either by themselves or by linking such older adults with suitable social care providers.<sup>3</sup>

In the context of identifying loneliness, it is important for healthcare providers to distinguish it from social isolation. Although loneliness is a subjective phenomenon representing one's perception or feeling of being socially isolated, social isolation is an objective state of "having few social relationships or infrequent social contact with others".<sup>3</sup> Thus, an older adult could be living alone or

have a limited social network, but may not be lonely. On the other hand, a wide social network or living with family does not equate to the absence of loneliness.<sup>3</sup> The independent effect of social network (an indicator of social isolation) on the transitions from a healthy to an unhealthy state and from an active to an inactive state observed in our analysis (Tables S4–S7) also supports the distinction between loneliness and social isolation. Providers should also be aware that loneliness is associated with, and an antecedent risk factor for depression.<sup>37–39</sup> Thus, they should consider evaluating and monitoring lonely older adults for depression. On the other hand, older adults consider loneliness to be salient to depression,<sup>40</sup> thus it is possible that some older adults who identify themselves as depressed may in fact be lonely.

For managing loneliness in an individual, a literature review of interventions showed that one-to-one interventions are generally more effective than group-based interventions.<sup>41</sup> The use of volunteers for weekly meetings and working on individual goals set up by participants may be an effective means of reducing loneliness and isolation, by gradually reintegrating older adults into their communities.<sup>42</sup> There are also some positive results using web-based computer interventions and computer games.<sup>41</sup> Common features of successful interventions to reduce loneliness include adaptability, community participation, and activities involving productive engagement.<sup>43</sup> Raising awareness of loneliness, offering social support, engaging physicians, and working with residents to create a “warm welcome” in the community are possible public health measures for tackling loneliness at the societal level.<sup>44</sup>

Our status-based estimates suggest that the detrimental impact of loneliness on health expectancy was greater among those starting out as unhealthy or inactive at the considered ages. This underscores the importance of maintaining one's health and functional activity throughout the life-course, such that one ages into old age in a healthy and active state, and strives to remain so thereafter. Doing so will have positive consequences in the form of more years of remaining life as well as more years of remaining life with healthy SRH and being active, even with a similar extent of loneliness.

Loneliness has been reported to be associated with greater engagement in unhealthy behaviors (e.g., alcohol use) and lesser engagement in health promoting behaviors (e.g., physical activity), poor sleep quality, impaired executive functioning, and adverse physiological changes (e.g., elevated systolic blood pressure, higher epinephrine and cortisol levels, and potentially, immune function impairments).<sup>45,46</sup> These behavioral and physiological pathways could be potential mechanisms linking loneliness with reduced TLE, HLE, and ALE.

Our findings pertain to Singapore, an Asian nation with a collectivist culture.<sup>22</sup> Future studies should assess the impact of loneliness on health expectancy in countries with an individualistic culture, which are reported to have lower levels of loneliness.<sup>23–25</sup>

Differences between sometimes lonely and never lonely in TLE and health expectancy were not always seen when comparing mostly lonely with never lonely, suggesting that those sometimes lonely are at greater risk than those mostly lonely. A possible reason could be that those with a greater extent of loneliness are more visible to their care providers—loneliness is reported to be associated with greater healthcare use<sup>47,48</sup>—and thereby receive help with their health conditions. Alternatively, our lower sample size for those mostly lonely could have led to lack of power to detect differences relative to those never lonely.

Our study has its limitations. First, ADL/IADL limitations were self-reported. However, this is common in population-based surveys, and is reported to be consistent with objective ADL/IADL assessment.<sup>29</sup> Loneliness and SRH were also self-reported, however, being subjective constructs, they are meant to be assessed so. Second, although several scales assess loneliness,<sup>1,2,27</sup> PHASE is a population-based survey that uses the Three-Item Loneliness Scale designed for large surveys.<sup>27</sup> Furthermore, the scale is recommended for use in clinical settings for identifying loneliness among older adults<sup>3</sup> and its items are among the four questions recommended for assessing loneliness among adults.<sup>49</sup> Third, the association of loneliness with SRH and ADL/IADL limitations can be bidirectional.<sup>7</sup> Thus, our analyses included time varying measurements of loneliness, SRH, and ADL/IADL limitations. Fourth, we excluded 1541 participants for the MSLT analysis (see Supplemental Material: Methods and Results). Nonetheless, they were similar, at Wave 1, to those included, in terms of demographics, loneliness, and ADL/IADL status. There was a slightly higher proportion, by 3.4 percentage points, of those with unhealthy SRH among the included—this may have led to slight overestimation of UHLE. Fifth, our sample size did not allow estimation of health expectancy separately for ADLs and IADLs or for each individual ADL and IADL. The same precluded us from assessing if the impact of loneliness on health expectancy varied by combinations of the covariates, such as Chinese males versus Malay females. Future studies, with more participants, should do so. Finally, we did not assess health expectancy using other health dimensions, such as chronic disease status or the Global Activity Limitation Index (GALI) status, as has been done in previous studies<sup>17</sup> (though not in the context of loneliness), either due to lack of objective data (for chronic diseases) or data in only one wave of PHASE

(for GALI). Future studies should assess the impact of loneliness on health expectancy using these health dimensions.

Our study has its strengths. First, incorporation of loneliness as a time varying covariate allowed participants to move across loneliness categories between consecutive survey waves, reflective of the real world, as loneliness is not a static construct.<sup>50</sup> Second, several demographic, social, and health covariates were accounted while computing the adjusted health expectancy estimates. Related, covariates which can vary over time were included in the analysis as time varying. Finally, the results of the sensitivity analysis, in the non-imputed dataset, were qualitatively similar to those of the main analysis.

In conclusion, we found that older adults who were sometimes lonely or mostly lonely generally had shorter TLE, HLE and ALE, and a higher proportion of remaining life with unhealthy SRH or with ADL/IADL limitations. Timely identification and management of loneliness may result in an increase in the years of life with healthy SRH and without limitation in ADLs/IADLs among older adults.

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## CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

## AUTHOR CONTRIBUTIONS

Rahul Malhotra: conception and design, acquisition of data, data analysis, interpretation of data, drafting article, final approval of version to be published. Md. I. Tareque: conception and design, data analysis, interpretation of data, drafting article, final approval of version to be published. Yasuhiko Saito: conception and design, critical revision of article, final approval of version to be published. Stefan Ma: conception and design, acquisition of

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The funding organizations had no role in the design or conduct of the study; collection, management, analysis, or interpretation of the results; or preparation, or approval of the manuscript.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

**Table S1:** Change in loneliness status among alive participants from any wave to the next wave.

**Table S2:** Difference between loneliness status categories in *unadjusted* population-based estimates of total life expectancy, healthy life expectancy and unhealthy life expectancy, at age 60, 70, and 80.

**Table S3:** Difference between loneliness status categories in *unadjusted* population-based estimates of total life expectancy, active life expectancy and inactive life expectancy, at age 60, 70, and 80.

**Table S4:** Regression estimates from the multinomial logistic regression model for the transition from 'healthy' as the initial health state to 'unhealthy' or 'dead' as the end health states.

**Table S5:** Regression estimates from the multinomial logistic regression model for the transition from 'unhealthy' as the initial health state to 'healthy' or 'dead' as the end health states.

**Table S6:** Regression estimates from the multinomial logistic regression model for the transition from 'active'

as the initial health state to 'inactive' or 'dead' as the end health states.

**Table S7:** Regression estimates from the multinomial logistic regression model for the transition from 'inactive' as the initial health state to 'active' or 'dead' as the end health states.

**Table S8:** Status-based *adjusted* (for covariates) estimates of total life expectancy, healthy life expectancy and unhealthy life expectancy by loneliness status, and difference between loneliness status categories in total life expectancy, healthy life expectancy and unhealthy life expectancy, at age 60, 70, and 80.

**Table S9:** Status-based *adjusted* (for covariates) estimates of total life expectancy, active life expectancy and inactive life expectancy by loneliness status, and difference between loneliness status categories in total life expectancy, active life expectancy and inactive life expectancy, at age 60, 70, and 80.

**Table S10:** Population-based *adjusted* estimates of total life expectancy, healthy life expectancy and unhealthy life expectancy by loneliness status categories at age 60, 70, and 80 in the non-imputed dataset (sensitivity analysis).

**Table S11:** Population-based *adjusted* estimates of total life expectancy, active life expectancy and inactive life expectancy by loneliness status categories at age 60, 70, and 80 in the non-imputed dataset (sensitivity analysis).

**Figure S1:** Population-based *unadjusted* estimates of total life expectancy, healthy life expectancy and unhealthy life expectancy by loneliness status categories at age 60, 70, and 80.

**Figure S2:** Population-based *unadjusted* estimates of total life expectancy, active life expectancy and inactive life expectancy by loneliness status categories at age 60, 70, and 80.

**Supplemental Material:** Methods and Results.

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