ORIGINAL ARTICLE: EPIDEMIOLOGY,
CLINICAL PRACTICE AND HEALTH

Gender, educational and ethnic differences in active life expectancy among older Singaporeans

Angelique Chan,[1,2] Rahul Malhotra,[1,3] David B Matchar,[1,4] Stefan Ma[5] and Yasuhiko Saito[1,6]

[1]Health Services and Systems Research (HSSR), Duke-NUS Graduate Medical School, [2]Department of Sociology, National University of Singapore, [5]Epidemiology & Disease Control Division, Singapore Ministry of Health, Singapore, [3]Duke Global Health Institute, Duke University, [4]Department of Medicine, Duke University Medical Center, Durham, North Carolina, USA; and [6]Advanced Research Institute for the Sciences and Humanities, Nihon University, Tokyo, Japan

Aim: The aim of the present study was to compute total life expectancy (TLE), active life expectancy (ALE) and inactive life expectancy among older Singaporeans by gender, education and ethnicity.

Methods: Data from a longitudinal survey of older Singaporeans were used. No difficulty in carrying out activities of daily living or instrumental activities of daily living was considered as "active." Transition probabilities across health states (active/inactive/dead) were assessed to develop multistate life tables, which estimated TLE, ALE and inactive life expectancy.

Results: At age 60 years, women, versus men, had significantly higher TLE (25.9, 95% confidence interval [CI] 24.0–27.8 *vs* 21.6, 95% CI 20.1–23.1), but similar ALE (18.1, 95% CI 17.0–19.2 *vs* 18.9, 95% CI 17.7–20.2). Those with high (secondary or higher), versus low (primary or less), education had significantly higher TLE (28.5, 95% CI 25.0–32.0 *vs* 22.5, 95% CI 21.1–23.9) and ALE (23.5, 95% CI 21.2–25.7 *vs* 17.1, 95% CI 16.1–18.0) at age 60 years. Those of Chinese, versus non-Chinese, ethnicity had significantly higher ALE at age 60 years (19.4, 95% CI 18.4–20.3 *vs* 15.0, 95% CI 13.4–16.7).

Conclusion: Unlike Western nations, there was no gender difference in ALE among older adults in Singapore. However, difference in ALE by education among older Singaporeans was similar to that observed in Western societies. Policies focusing specifically on improving women's health at all ages, in addition to policies that increase population education levels, are promising approaches to improving ALE. Recognizing ethnic differences in ALE will help target policies that increase ALE in multicultural societies. **Geriatr Gerontol Int 2016; 16: 466–473.**

Keywords: active life expectancy, disability transitions, education, gender, Singapore.

Introduction

Healthy life expectancy (HLE), the average number of healthy years a person at a given age is expected to live, is recognized as a population-level health indicator.[1,2] For general policy, a common metric is HLE at birth. For example, the European Commission has set the target of 2 years' increase in HLE at birth from 2010 to 2020 in the European Union (EU). However, with a rapidly expanding older population, and the need to set and evaluate health policy and population-wide health promotion interventions, such as retirement policy and health insurance policy, it is valuable to consider HLE at older ages. Such HLE has been computed for many countries, such as for Singapore at age 55 years,[3] Brazil at age 60 years,[4] Denmark at age 65 years,[5] Japan at age 65 years[6] the USA at age 70 years[7] and 25 EU countries at age 50 years.[8]

All the aforementioned studies calculate HLE at older ages based on prevalence of health states, partly because many countries have repeated cross-sectional surveys providing regular estimates of population health. Such prevalence-based HLE reflects the current health composition of a real population adjusted for prevalent mortality levels. However, it does not indicate the expected life cycle events of individuals exposed to current morbidity conditions. Prevalence is a result of dynamic

doi: 10.1111/ggi.12493

processes of transitions by people among health states, including death. As articulated by Crimmins *et al.*, looking at disability prevalence does not inform whether the change in disability prevalence has occurred through a change in transition to a disabled state, change in recovery from a disabled state or changes in mortality.[9] Furthermore, because computing prevalence-based HLE requires existing life tables, which are often available only for the population overall and by gender, it is often difficult to compute HLE for population subgroups defined by characteristics such as education or ethnicity. These limitations can be addressed by computing HLE based on multistate life table methods with longitudinal survey data.

Assessment for differences in HLE across population subgroups allows for identification of those "at-risk." Previous studies have found that HLE differs by gender, education and ethnicity.[10] In general, women and people with higher education have longer HLE.[11–18] In the USA, white people have longer HLE compared with African-American people.[13,18]

Singapore represents a valuable context for examining HLE. Although the population is dominantly ethnically Chinese, and might be expected to have similar HLE for Chinese residents as those living in Southern China, Taiwan and Hong Kong, the trajectory of education, sanitation and standard of living has been distinctive. In Singapore, there are just two studies on HLE of older adults, and both assess differences in HLE only by gender, not by education or ethnicity.[3,19] Furthermore, both studies calculated prevalence-based HLE, limiting our ability to assess the effects of gender, education or ethnicity on health transitions. Therefore, we utilized newly available longitudinal survey data to estimate transitions across health states and HLE, by gender, education and ethnicity, applying a multistate life table method. Based on previous studies, we expect to observe longer HLE for women and for those with high education. A previous study showed better health conditions among Chinese Singaporeans.[20] Therefore, we hypothesized longer HLE for those of Chinese ethnicity compared with those of other ethnicities.

Materials and methods

Data source

Data from two waves of a longitudinal survey on the health of community-based older (aged >60 years at wave 1) Singaporeans were utilized. The details of wave 1, carried out in 2009, are available elsewhere.[21] Briefly, 4990 older adults or their proxy respondents were interviewed face-to-face after informed consent was given. A total of 3103 older adults or their proxy respondents were re-interviewed at wave 2, in 2011–2012.

Analysis sample

Of the 4990 wave 1 participants, 16 with missing information on education were excluded. Of the remaining, those who were alive but refused participation in wave 2 (*n* = 1137) and those who could not be contacted in wave 2 (*n* = 459) were excluded given lack of data on their health state at wave 2. Thus, the current analysis was limited to 3378 individuals who were alive and interviewed at wave 2 (*n* = 3097) or were reported as dead by their family when contacted at wave 2 (*n* = 281). There was no significant difference by age, sex, ethnicity, education and health state (defined below) at wave 1 between those included in (*n* = 3378) and excluded from (*n* = 1596) the analysis.

Measures

Although the concept of HLE is unique, different terms are used for it depending on the measure used to define health. For example, disability-free life expectancy is used when disability is used as a health measure.[22,23] Also, active life expectancy (ALE) is used when activities of daily living (ADL) or instrumental ADL (IADL) are used as health measures.[11,13] We used the latter.

At each survey wave, participants reported on the difficulty in carrying out six ADL (taking a bath/shower, dressing up, eating, standing up from and sitting down on a bed/chair, walking in the house, and using the toilet) and seven IADL (preparing own meals, leaving home to purchase necessary items/medication, taking care of financial matters, using the telephone, dusting, cleanup and other light housework, taking public transport to leave home and taking medication). At each wave, those reporting difficulty in carrying out any of the 13 activities alone without assistance of a person or assistive device because of their health or physical state were considered in an inactive health state for the wave. Those reporting no difficulty for all activities were considered in an active health state for the wave. Use of both ADL and IADL, and of self-reported difficulty in carrying them out, for defining active and inactive health states has been reported previously.[9,11,24] As suggested, we used any limitation in ADL or IADL to maximize the specificity; that is, individuals designated as active were able to carry out a comprehensive range of activities.[25] In wave 2, participants could also be in an absorbing health state, death.

Calculation of the probability of transition across health states and ALE requires information on date of death. Wave 1 participants were followed up, and the date of death for those who died during the follow-up period was obtained through data-linkage with the national Registry of Births and Deaths databases. Self-reported information, including national identification number, name, date of birth and gender, which were reported by the respondent or their proxy in the wave 1
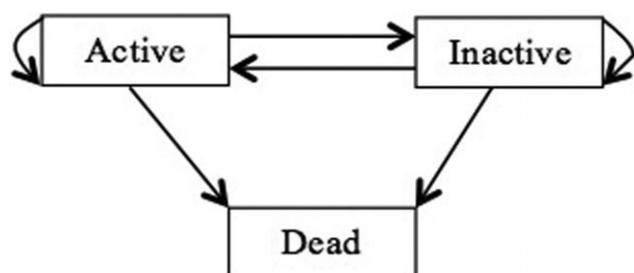
interview, were used for the data-linkage with the deaths databases. For the majority (243; 86.5%) of the 281 participants who were dead when contacted at wave 2, the date of death was available in the deaths databases and used. For those (8/281; 2.8%) who were reported as dead at wave 2, but could not be located in the deaths databases, the date of death reported by next-of-kin at wave 2 was utilized. For the rest (30/281; 10.7%), who were reported as dead at wave 2, but could not be located in the deaths databases or whose exact date of death was not available, it was assigned as the mid-point between the wave 1 interview date and wave 2 contact date. The inability to locate some of those who had died in the deaths databases is likely the result of missing or incorrect/misspelt values on the variables (national identification number, name, date of birth and gender) used for the data-linkage, as these variables were self-reported by the respondent or their proxy in wave 1.

Based on the highest educational level completed, those with primary education or less were considered to have low education and the rest (secondary education or higher) to have high education. Ethnicity was self-reported; non-Chinese ethnic groups (Malay 10.0%, Indian 6.1%, others 1.2%) were combined for the analysis.

Statistical analysis

The analytical model (Fig. 1) consisted of two living health states (active and inactive) and one absorbing health state (death). It was used to examine the effect of gender, education (low/high) and ethnicity (Chinese/non-Chinese) separately on transition probabilities and ALE. There were six possible health transitions: staying in the same health state (active to active, and inactive to inactive), worsening health (active to inactive), improving health (inactive to active) and mortality (active to dead, and inactive to dead).

Annual probabilities of transition between health states were estimated from the two survey waves, and multistate life tables were constructed based on estimated transition probabilities using the IMaCh

(Interpolated Markov Chain) software program.[26,27] The IMaCh program has been used in several recent studies to compute HLE, and provides standard errors of the estimated total, active and inactive life expectancies in order to test their statistical significance.[9,11,27,28] It was developed at the Institut National d'études Démographiques by Brouard *et al.*[26] based on estimating transition probability using interpolation of Markov chains introduced by Laditka and Wolf.[29]

Estimation of transition probabilities and construction of multistate life tables were carried out by gender, education and ethnicity separately, partly because the number of transitions across health states was insufficient to estimate stable transition probabilities by more than two covariates other than age. First, the IMaCh program estimated the parameters of covariates for transition probabilities between health states in the two waves based on a multinomial logistic regression model and maximum likelihood. The statistical approach utilized by the IMaCh program for estimating life expectancies is detailed in Lièvre *et al.*[27] Briefly, the transition probabilities are estimated by the following multinomial logistic regression equation, where p_{ij} is a probability of transition from state i at age x to state j after time h, and α, β and γ represent estimated coefficients. Transition probabilities are a function of age and covariates, which in the current study are gender or education or ethnicity. Each covariate is included in the equation separately.

$$\ln\left(p_{ij}(x, x+h)/p_{iK}(x, x+h)\right) = \alpha + \beta \cdot x + \gamma \cdot \text{covariate}$$
$$i = 1 \text{ to } K, j = 1 \text{ to } K, K = \text{number of states in the model},$$
$$i \neq j$$

Then, based on the age-specific transition probabilities computed from the estimated parameters, multistate life tables were constructed to obtain total, active and inactive life expectancies for each subgroup defined by covariates.

All analyses were weighted by survey weights available for wave 1. The longitudinal survey and matching with the Singapore Registry of Births and Deaths were approved by the institutional review board at the National University of Singapore.

Results

The number and proportion of individuals transitioning or remaining in a health state from wave 1 to wave 2, overall and by gender, by education and by ethnicity is presented in Table 1. Overall, the majority of those active and those inactive at wave 1 remained in the same health state at wave 2 (87.3% and 55.2%, respectively). The proportion that had died by wave 2 was higher among those inactive (20.7%) compared with those active (3.9%) at wave 1.

Figure 1 Analytical model, comprising two non-absorbing living health states (active and inactive) and one absorbing health state (death).

Table 1 Health transitions, overall, by gender and by education, wave 1 to wave 2

Health state in wave 1[†]	Health state in wave 2[‡]		
	Active	Inactive	Dead
Overall			
Active	2280 (87.3%)[§]	342 (8.8%)	144 (3.9%)
Inactive	123 (24.2%)	352 (55.2%)	137 (20.7%)
Women			
Active	1079 (85.2%)	233 (12.5%)	39 (2.4%)
Inactive	96 (24.3%)	280 (57.6%)	90 (18.1%)
Men			
Active	1201 (89.4%)	109 (5.2%)	105 (5.4%)
Inactive	27 (24.0%)	72 (47.9%)	47 (28.1%)
High education			
Active	779 (94.3%)	53 (3.9%)	19 (1.8%)
Inactive	23 (34.4%)	44 (50.1%)	14 (15.5%)
Low education			
Active	1501 (83.4%)	289 (11.6%)	125 (5.1%)
Inactive	100 (22.5%)	308 (56.0%)	123 (21.5%)
Chinese			
Active	1672 (88.5%)	215 (7.8%)	92 (3.7%)
Inactive	92 (25.7%)	235 (53.4%)	95 (20.9%)
Non-Chinese			
Active	608 (81.1%)	127 (13.9%)	52 (5.0%)
Inactive	31 (18.3%)	117 (62.1%)	42 (19.6%)

[†]In wave 1, in the overall analysis sample (n = 3378), the number (%) in the active and inactive states were 2766 (81.9%) and 612 (18.1%), respectively. [‡]In wave 2, in the overall analysis sample (n = 3378), the number (%) in the active, inactive and dead states were 2403 (71.1%), 694 (20.5%) and 281 (8.3%), respectively. [§]Weighted row %.

The proportion dead at wave 2 was higher among men, versus women, both among those active (5.4% *vs* 2.4%) and those inactive (28.1% *vs* 18.1%) at wave 1. The proportion experiencing worsening health transition (active to inactive) was much higher among women (12.5%) compared with men (5.2%). The proportion dead at wave 2 was higher among those with low, versus high, education for both those active (5.1% *vs* 1.8%) and those inactive (21.5% *vs* 15.5%) at wave 1. The proportion experiencing worsening health transition was higher among those of non-Chinese, versus Chinese, ethnicity (13.9% *vs* 7.8%) and the proportion experiencing improving health transition was higher among those of Chinese, versus non-Chinese, ethnicity (25.7% *vs* 18.3%).

The annual age-specific transition probabilities between ages 60 and 90 years by gender are shown in Figure 2a–d. Gender affected the transition from active to inactive, being significantly higher for women, versus men, at all ages from 60 to 90 years. For women, versus men, transition from an active state to dead was significantly lower at age 66 years and older, and transition from an inactive state to dead was significantly lower

from age 74 to 86 years. Similar patterns were observed for transition probabilities by education and by ethnicity (figures not shown). Transition from active to inactive was significantly lower for those with high, versus low, education, and of Chinese, versus non-Chinese, ethnicity except at very high ages. Although transition from an active state to dead was significantly lower for those with high, versus low, education from age 66 to 80 years, this transition did not differ by ethnicity. Differences in recovery to an active state and in transition to death from an inactive state were not significant by education or ethnicity.

Using the transition probabilities, total, active and inactive life expectancies were computed by gender, by education and by ethnicity (Table 2). Women, versus men, had significantly higher total life expectancy (TLE; 95% confidence interval [CI]) at age 60 years (25.9, 95% CI 24.0–27.8 *vs* 21.6, 95% CI 20.1–23.1). Contrary to our hypothesis, expected years in active life at age 60 years was neither statistically nor substantively different between men and women. However, women, versus men, had a significantly higher inactive life expectancy (IALE) at age 60 years (7.8, 95% CI 6.4–9.2
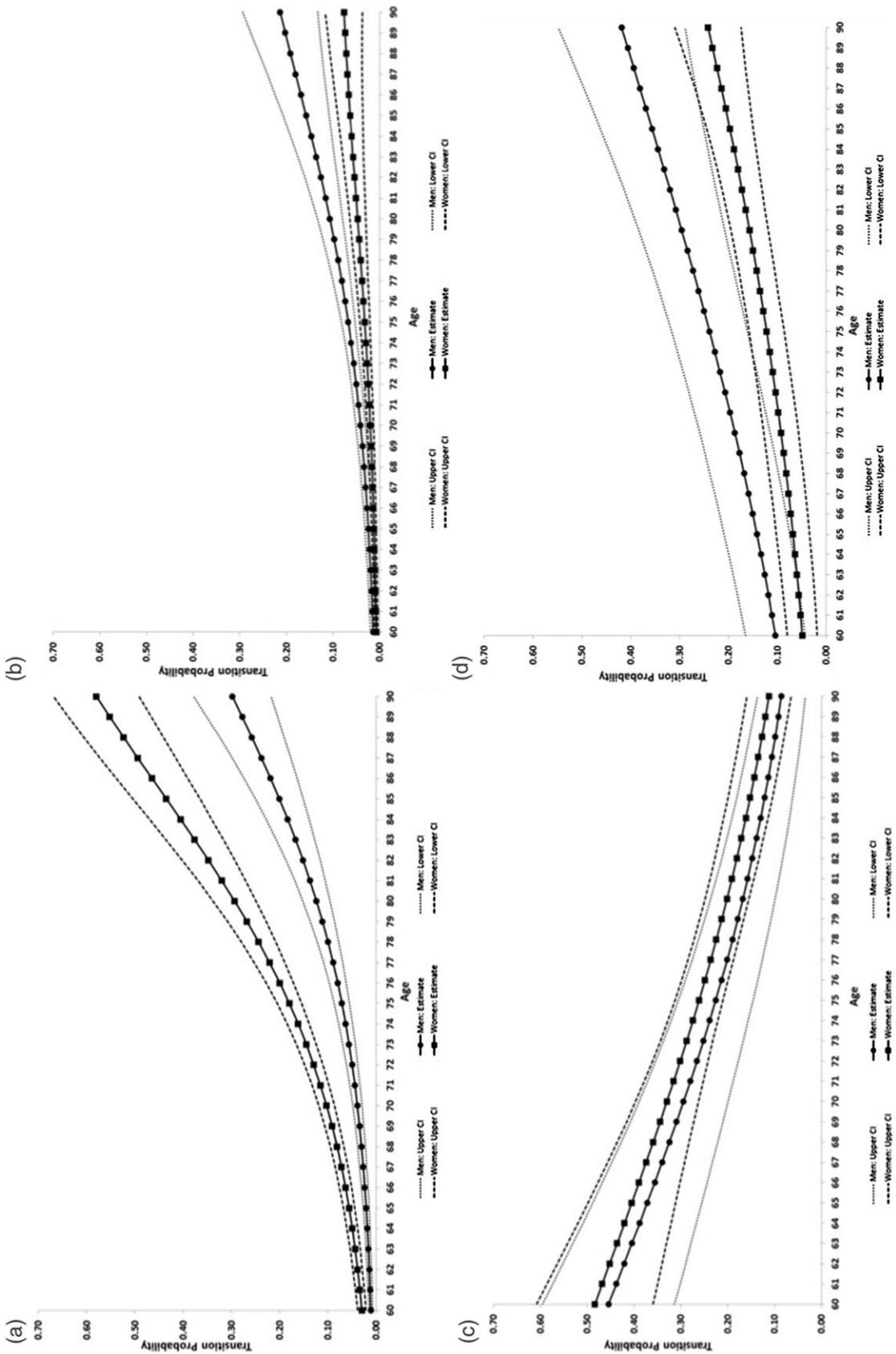
Figure 2 Probability of transition from: (a) active to inactive states; (b) active to dead state; (c) Inactive to active state; (d) inactive to dead state from age 60 to 90 years, by gender.

Table 2 Estimates of life expectancy, active life expectancy, inactive life expectancy and proportion of active life among remaining life at age 60 and 85 years, by gender, by education and by ethnicity

	Selected age	TLE	95% CI	ALE	95% CI	IALE	95% CI	ALE/TLE (%)
Gender								
Women	60	25.9	(24.0, 27.8)	18.1	(17.0, 19.2)	7.8	(6.4, 9.2)	69.9
	85	8.6	(6.8, 10.4)	2.2	(1.5, 2.8)	6.4	(4.8, 8.0)	25.3
Men	60	21.6	(20.1, 23.1)	18.9	(17.7, 20.2)	2.6	(1.9, 3.3)	87.8
	85	5.8	(4.7, 6.9)	3.0	(2.2, 3.8)	2.8	(1.8, 3.8)	51.8
Education								
High	60	28.5	(7.8, 10.6)	23.5	(21.2, 25.7)	5.1	(2.8, 7.3)	82.2
	85	9.7	(6.7, 12.6)	4.8	(3.3, 6.3)	4.9	(2.4, 7.3)	49.9
Low	60	22.5	(21.1, 23.9)	17.1	(16.1, 18.0)	5.4	(4.5, 6.3)	75.9
	85	7.3	(6.0, 8.7)	2.3	(1.7, 2.9)	5.0	(3.8, 6.3)	31.2
Ethnicity								
Chinese	60	24.4	(23.0, 25.8)	19.4	(18.4, 20.3)	5.0	(4.1, 5.9)	79.5
	85	7.7	(6.3, 9.0)	2.8	(2.2, 3.5)	4.8	(3.6, 6.1)	36.9
Non-Chinese	60	21.7	(18.8, 24.5)	15.0	(13.4, 16.7)	6.6	(4.4, 8.8)	69.5
	85	7.2	(4.6, 9.9)	1.3	(0.7, 2.0)	5.9	(3.3, 8.5)	18.3

ALE, active life expectancy; CI, confidence interval; IALE, inactive life expectancy; TLE, total life expectancy.

vs 2.6 95% CI 1.9–3.3). This resulted in women, versus men, spending a lower proportion (69.9% *vs* 87.8%) of years of life remaining at 60 years in an active state. This gender difference, favoring women relative to men in TLE, but not in proportion of active life, was also observed at age 85 years.

Those with high, versus low, education had significantly higher TLE at age 60 years (28.5, 95% CI 25.0–32.0 *vs* 22.5, 95% CI 21.1–23.9), and as hypothesized, significantly higher ALE (23.5, 95% CI 21.2–25.7 *vs* 17.1, 95% CI 16.1–18.0). This translated into those with high, versus low, education spending a greater proportion (82.2% *vs* 75.9%) of years of life remaining at age 60 years in an active state. The advantage in absolute and relative ALE among those with high, versus low, education was maintained at age 85 years.

As hypothesized, those of Chinese ethnicity, relative to those of non-Chinese ethnicity, had significantly higher ALE at age 60 years (19.4, 95% CI 18.4–20.3 *vs* 15.0, 95% CI 13.4–16.7). Those of Chinese, versus non-Chinese, ethnicity also spent a higher proportion of years of life remaining at age 60 years (79.5% *vs* 69.5%) in an active state. These ethnic differences were maintained at age 85 years.

Discussion

The present study contributes to the existing literature by providing results from a longitudinal dataset for a more dynamic picture of differences by gender in life expectancy in Singapore, and by examining the effects of education and ethnicity on ALE. In highly aging Asian societies, there is an urgent need to understand whether increases in longevity are associated with more years spent in an active state, and whether this association extends across population subgroups. The policy ramifications include planning for financing healthcare at later ages and predicting healthcare utilization behavior among older adults. The present study provides a unique lens on one of the fastest aging populations in Asia that comprises Chinese, Malays and Indians. The results might be replicated in other Asian nations to understand the impact of increasing longevity on ALE.

These current analyses show several notable patterns. First, although gender does not influence absolute ALE, it has a substantial impact on relative ALE; that is, the proportion of ALE to TLE. At age 60 years, women, versus men, have a longer TLE; however, their ALE is comparable with men. Thus, an average woman aged 60 years is expected to be active for approximately just 70% of her remaining life compared with 88% for a man of the same age. This gender difference, not favoring women, in relative ALE is explained by the finding that women can expect significantly more years in an inactive health state, 7.8 years at age 60 years compared with 2.6 years for men. Underlying these gender differences in relative ALE and in absolute IALE are gender differences in transition from an active state. Active men are more likely to die, but less likely to become inactive in the process (or at least not as likely to be inactive for a sufficiently long period to be observed). Notably, differences in transition probabilities from an inactive to active state and to death were mostly not statistically significant between genders. This suggests that once older adults become inactive, gender has a negligible effect on recovery and on mortality.

Second, as hypothesized, having at least secondary education is associated with higher absolute and relative ALE. This association bodes well for Singapore. The proportion of older Singaporeans with at least secondary education is expected to more than double by 2040. Thus, incoming cohorts of older Singaporeans will have higher levels of education, leading to higher ALE that could translate into favorable patterns of healthcare behaviors and utilization over the life course.

Third, as hypothesized, ALE was higher for Chinese compared with non-Chinese. This finding is reflective of the significantly lower transition from an active to an inactive state for those of Chinese, versus non-Chinese, ethnicity. Ethnic differences, favoring those of Chinese ethnicity, in chronic diseases, healthy behaviors and preventive healthcare use over the life course, which in the disablement process are considered as risk factors for the development of functional disability (including limitations in ADL and IADL), likely underlie the lower transition from active to inactive for those of Chinese, versus non-Chinese, ethnicity.[30,31] For example, the Singapore National Health Survey 2010 reported that among adults aged 18–69 years, the prevalence of diabetes mellitus, obesity and abdominal fatness was the lowest for Chinese, and that of hypertension, high blood cholesterol, daily cigarette smoking and non-engagement in regular exercise was lower in Chinese than Malays.[32] Furthermore, the survey reported the prevalence of screening for diabetes mellitus, hypertension and high blood cholesterol to be higher among Chinese relative to Malays.[32] Similarly, the Singapore National Nutrition Survey 2010 observed the daily energy and fat intake, and the percentage exceeding twice the recommended daily allowance for energy and fat to be lower among Chinese relative to Malays and Indians. Furthermore, use of blended oils and consumption of deep-fried food and sweetened drinks was the highest for Malays.[33]

The two previous studies on HLE from Singapore, which also assess for gender differences in HLE, either use mobility ("ability to move around physically")[19] or diseases (chronic medical conditions), impairment ("bone/joint, lung/breathing, hearing, eye/vision, and mobility problems") and functional disability (assistance with ADL)[3] to define health. Given the variation in the measures used to define health, a direct comparison of the magnitude of the estimates obtained across the studies is not possible. However, the pattern of the gender difference, with women living longer than men (i.e. longer TLE) and women spending a greater duration as well as proportion of remaining life in an unhealthy state is consistent across the three studies, including the present, from Singapore.[3,19]

The current analysis had its limitations. Though potential participants ($n = 8400$) for the baseline (wave 1) were drawn randomly from a population register, the final number of respondents was 4990. Non-responders were similar in gender distribution, but were more likely to be aged less than 70 years and of ethnicity other than Chinese or Malay or Indian compared with those who responded; selection bias into the longitudinal survey thus cannot be ruled out. Although the baseline sample of the longitudinal survey utilized was relatively large, because of the limited number of transitions observed across health states by the first follow up carried out after an interval of 2 years, we could not construct multistate life tables that considered more than two variables (such as tables considering age and gender and education). Approximately one-third of the survey participants were lost to follow up by wave 2. Although the major characteristics of those who were lost to follow up were not significantly different from those who responded in wave 2, it again limited the number of observed health transitions.

These analyses have important policy implications. Policies targeted at preventive measures for both men and women, starting from young adulthood, could reduce IALE in later life. Specific focus on measures to improve women's health is required, as they are living longer and a larger proportion of these years are in an inactive state compared with men. Reducing IALE at older ages for both men and women will have social and financial impacts for individuals and their families. Gender differences in IALE, as observed in the current analyses, will have significant implications for future caregiving strategies and financial models of healthcare. Caregiving for older adults in Singapore is currently provided mainly by the family and foreign domestic workers.[34] As Singapore's population ages and total fertility rates continue to decrease, leading to smaller family sizes, caregiving demands on existing family members will escalate.[35] A new mix of family and long-term care services will be required to adequately care for Singaporean older adults. Additional years of ALE will also decrease the pressure on healthcare utilization. ALE is a fundamental aspect of quality of life; by improving quality of life of older adults we are truly embracing the notion that HLE is more important than life expectancy.

Acknowledgments

the manuscript. SM contributed to the data analysis and writing of the manuscript. All authors agreed with the manuscript's results and conclusions. AC is the guarantor.

Disclosure statement

References

1 Robine JM, Ritchie K. Healthy life expectancy: evaluation of global indicator of change in population health. *BMJ* 1991; **302**: 457–460.

2 World Health Organization. The World health report: 1997: conquering suffering, enriching humanity: executive summary.

3 Yong V, Saito Y, Chan A. Gender differences in health and health expectancies of older adults in Singapore: an examination of diseases, impairments,and functional disabilities. *J Cross Cult Gerontol* 2011; **26**: 189–203.

4 Andrade FCD, Guevara PE, Lebrao ML, de Oliveira Duarte YA, Santos JL. Gender differences in life expectancy and disability-free life expectancy among older adults in Sao Paulo, Brazil. *Womens Health Issues* 2011; **21**: 64–70.

5 Jeune B, Brønnum-Hansen H. Trends in health expectancy at age 65 for various health indicators, 1987–2005, Denmark. *Eur J Ageing* 2008; **5**: 279–285.

6 Seko R, Hashimoto S, Kawado M *et al*. Trends in life expectancy with care needs based on long-term care insurance data in Japan. *J Epidemiol* 2012; **22**: 238–243.

7 Suthers K, Kim JK, Crimmins E. Life expectancy with cognitive impairment in the older population of the United States. *J Gerontol B Psychol Sci Soc Sci* 2003; **58**: S179–SS86.

8 Jagger C, Gillies C, Moscone F *et al*. Inequalities in healthy life years in the 25 countries of the European Union in 2005: a cross-national meta-regression analysis. *Lancet* 2009; **372**: 2124–2131.

9 Crimmins EM, Hayward MS, Hagedorn A *et al*. Change in disability-free life expectancy for Americans 70 years old and older. *Demography* 2009; **46**: 627–646.

10 Cantu PA, Hayward MD, Hummer RA *et al*. New estimates of racial/ethnic differences in life expectancy with chronic morbidity and functional loss: evidence from the national health interview survey. *J Cross Cult Gerontol* 2013; **28**: 283–297.

11 Yong V, Saito Y. Are there educational differentials in disability and mortality transitions in active life expectancy among Japanese older adults? Findings from a 10-year prospective cohort study. *J Gerontol B Psychol Sci Soc Sci* 2012; **67**: 345–353.

12 Chan A, Zimmer Z, Saito Y. Gender differentials in disability and mortality transitions: the case of older adults in Japan. *J Aging Health* 2011; **23**: 1285–1308.

13 Crimmins EM, Hayward MD, Saito Y. Changing mortality and morbidity rates and the health status and life expectancy of the older population. *Demography* 1994; **31**: 159–175.

14 Crimmins EM, Saito Y. Trends in healthy life expectancy in the United States, 1970–1990: gender, racial and educational differences. *Soc Sci Med* 2001; **52**: 1629–1641.

15 Guralink JM, Land KC, Blazer D *et al*. Educational status and active life expectancy among older Blacks and Whites. *N Engl J Med* 1993; **329**: 110–116.

16 Peres K, Jagger C, Lievre A *et al*. Disability-free life expectancy of older French people: gender and education differentials from the PAQUID cohort. *Eur J Ageing* 2005; **2**: 225–233.

17 Valkonen T, Sihvonen AP, Lahelma E. Health expectancy by level of education in Finland. *Soc Sci Med* 1997; **44**: 801–808.

18 Montez JK, Hayward MD. Cumulative childhood adversity, educational attainment, and active life expectancy among US adults. *Demography* 2014; **51**: 413–435.

19 Yong V, Saito Y, Chan A. Changes in the prevalence of mobility limitations and mobile life expectancy of older adults in Singapore, 1995–2005. *J Aging Health* 2010; **22**: 120–140.

20 Ng TP, Niti N, Chiam P *et al*. Prevalence and correlates of functional disability in multi-ethnic elderly Singaporeans. *J Am Geriatr Soc* 2005; **54**: 21–29.

21 Malhotra R, Chan A, Malhotra C *et al*. Prevalence, awareness, treatment and control of hypertension in the elderly population of Singapore. *Hypertens Res* 2010; **33**: 1223–1231.

22 Sullivan DF. A single index of mortality and morbidity. *HSMHA Health Rep* 1971; **86**: 347–354.

23 Crimmins EM, Saito Y, Ingegneri D. Trends in disability-free life expectancy in the United States. *Popul Dev Rev* 1997; **23**: 555–572.

24 Lubitz J, Cai L, Kramarow E *et al*. Health, life expectancy, and health care spending among the elderly. *N Engl J Med* 2003; **349**: 1048–1055.

25 Spector W, Fleishman J. Combining activities of daily living with instrumental activities of daily living to measure functional disability. *J Gerontol B Psychol Sci Soc Sci* 1998; **53**: 46–57.

26 Brouard N. Computing health expectancies using IMaCh (a maximum likelihood computer program using interpolation of Markov chains) [program]. 0.71a version. Mortality, Health and Epidemiology Research Unit: Institut National d'Etudes Demographiques (INED, Paris), 2002.

27 Lièvre A, Brouard N, Heathcote C. The estimation of health expectancies from cross-longitudinal surveys. *Math Popul Stud* 2003; **10**: 211–248.

28 Jagger C, Matthews R, Melzer D *et al*. Educational differences in the dynamics of disability incidence, recovery and mortality: findings from the MRC Cognitive Function and Ageing Study (MRC CFAS). *Int J Epidemiol* 2007; **36**: 358–365.

29 Laditka SB, Wolf DA. New methods for analyzing active life expectancy. *J Aging Health* 1998; **10**: 214–241.

30 Verbrugge LM, Jette AM. The disablement process. *Social Sci Med* 1994; **38**: 1–14.

31 Jette AM. Toward a common language for function, disability, and health. *Phys Ther* 2006; **86**: 726–734.

32 Epidemiology & Disease Control Division. *National Health Survey 2010*, 2010 edn. Singapore: Ministry of Health (MOH), 2010.

33 Research & Strategic Planning Division. *National Nutrition Survey 2010*, 2010 edn. Singapore: Health Promotion Board (HPB), 2010.

34 Østbye T, Malhotra R, Malhotra C *et al*. Does support from foreign domestic workers decrease the negative impact of informal caregiving? Results from Singapore survey on informal caregiving. *J Gerontol B Psychol Sci Soc Sci* 2013; **68**: 609–621.

35 Population Trends. *Population Trends 2013*, 2013 edn. Singapore: Department of Statistics (DOS), 2013.