



Changes in disability-free life expectancy (DFLE) at birth between 2000 and 2010 across Japanese prefectures

Yuka Minagawa Sugawara · Yasuhiko Saito

Received: 17 October 2015 / Revised: 6 May 2016 / Accepted: 9 June 2016 / Published online: 28 June 2016
© Swiss School of Public Health (SSPH+) 2016

Abstract

Objectives The second phase of Healthy Japan 21 seeks to increase disability-free life expectancy (DFLE) more than life expectancy (LE) between 2013 and 2022. In the face of the rising incidence of disability, the feasibility of achieving this goal remains unclear.

Methods We examine changes in DFLE at birth between 2000 and 2010 across 47 prefectures, with particular attention given to changes in the absolute number of years and in the proportion of disability-free life years.

Results Although LE increased across all prefectures, there is a variation in DFLE. While the number of disability-free life years increased in many parts of the country, some prefectures had decreases in DFLE. Downturns become particularly evident when DFLE is interpreted in relative terms. The proportion of life spent without disability declined in the majority of prefectures.

Conclusions Results from subnational level analyses suggest that the rate of increase in DFLE lagged behind that in LE across Japanese prefectures during the past decade. More policy attention should be devoted to health-promotion initiatives at the prefecture level to achieve the nationwide health agenda.

Keywords Health expectancy · Disability-free life expectancy · Mortality · Morbidity · Japan

Introduction

Japan has long been leading the world in terms of population health status. The most recent figures for 2014 show that life expectancy (LE) at birth stood at 80.5 years for men and 86.8 years for women. By 2060, LE is projected to reach 84.2 years for men and 90.3 years for women (Cabinet Office, Government of Japan 2014). It has been suggested, however, that the expansion of LE is not always followed by increases in healthy years. Evidence suggests that with increased longevity there is a concomitant rise in chronic diseases. In 2014, for instance, the number of individuals with hypertension reached more than 10 million, a 1.1 million increase from 2011. A large number of people, moreover, suffer from diabetes: 15.5 % of men and 9.8 % of women older than 20 years of age were at risk of having diabetes in 2014 (Ministry of Health, Labour, and Welfare 2014a).

With the high prevalence of chronic conditions, there has been a growing interest in the quality of life lived. Health expectancy is widely used as a summary measure of population health that accounts for both mortality and morbidity (Robine et al. 2003). In 2013, the Japanese government added a measure of health expectancy to the health-promotion program, the second phase of Healthy Japan 21 (Ministry of Health, Labour, and Welfare 2015). Healthy Japan 21, launched in 2000, provides a 10-year national agenda for improving population health status. The priorities of the program include: (1) promoting preventive measures against diseases, (2) supporting the establishment of public health infrastructure, (3)

Electronic supplementary material The online version of this article (doi:10.1007/s00038-016-0847-3) contains supplementary material, which is available to authorized users.

Y. M. Sugawara (✉)
Faculty of Liberal Arts, Sophia University, 7-1 Kioicho,
Chiyoda-ku, Tokyo, Japan
e-mail: ysugawara@sophia.ac.jp

Y. Saito
University Research Center, Nihon University, 12-5 Gobancho,
Chiyoda-ku, Tokyo, Japan

identifying health-promotion objectives, and (4) facilitating collaborations across communities and sectors. In particular, strong attention is directed toward health-promotion initiatives at the subnational level. Each prefecture sets measurable objectives and implements health-promotion programs, ranging from the provision of health examination services to the establishment of mental health care facilities (Ministry of Health, Labour, and Welfare 2015). The second phase of Healthy Japan 21 (2013–2022) incorporates a quality-of-life dimension in one of the main goals. The preferred indicator is disability-free life expectancy (DFLE) at birth, denoting the expected number of life years free of disability. Specifically, the program seeks to increase DFLE at a faster rate than growth in LE between 2013 and 2022. The results from the decade 2000–2010 reveal that in Japan LE has grown faster than DFLE. The second phase of Healthy Japan 21 strives to reverse this trend and encourage increases in the number of healthy years to outpace increases in longevity for the period 2013–2022.

Whether the headline target of the program is attainable, however, remains in question. While studies focused on health expectancy at the country-level abound, limited attention has been paid to prefecture-level health expectancy. According to the Ministry of Health, Labour, and Welfare (2014b), in 2010, the difference in male DFLE at birth was 2.79 years (from 71.74 years in Aichi prefecture to 68.95 years in Aomori prefecture), and the range was 2.95 years for women (from 75.32 years in Shizuoka prefecture to 72.37 years in Shiga prefecture). While these results reveal DFLE differentials across prefectures, trends and changes in prefecture-level DFLE remain to be explored. This is due to the fact that the point of estimate of prefecture-level health expectancy varies by report. Estimates of prefecture-specific DFLE were published in 1999 and 2010. The results for 1999 are calculated at older ages (Hashimoto 2008), whereas the 2010 estimates are based at the time of birth (Ministry of Health, Labour, and Welfare 2014b). Recently, researchers have begun to examine changes in regional inequalities in health expectancy (Wohland et al. 2014), but due to discrepancies in the point of estimation, questions related to changes in DFLE values across Japanese prefectures remain unanswered. This is a critical issue, considering the fact that health-promoting initiatives at the subnational level are viewed as a means to achieve the nationwide agenda.

In this research, we examine differences in age-/gender-specific DFLE at birth across 47 Japanese prefectures in 2000 and 2010. The present study focuses on the time of birth as the point of estimation, which allows us to directly

investigate changes in prefecture-level DFLE over the past decade. Also, we analyze the proportion of life spent without disability, thereby testing the relationship between health and longevity. By estimating health expectancy measures at the subnational level and analyzing changes between 2000 and 2010, this research will be well placed to assess the feasibility of the goal of the second phase of Healthy Japan 21, that is, to increase DFLE more than LE between 2013 and 2022.

Methods

Data

DFLE at birth is calculated using the Sullivan (1971) method. This method applies data on the age-/gender-specific prevalence of health to a standard life table to estimate the average duration of life in which people can expect to live in a given health state. This research focuses on the prevalence of disability as the indicator of health. Information on disability comes from *Kokumin Seikatsu Kiso Chosa* (the Comprehensive Survey of Living Conditions of the People on Health and Welfare), a repeated cross-sectional survey conducted annually since 1986 by the Ministry of Health, Labour, and Welfare. It is a nationally representative survey of community residents in the sample unit areas of Japan, and it excludes the institutionalized population. The question on disability is included in the health module of a large-scale survey conducted every three years, with self-entry questionnaires administered in June of each survey year. We analyze data for 2001 and 2010 in this study. The 2001 survey included 2,47,278 households (response rate 87.4 %). The response rate was slightly lower in 2010 (79.4 %), with 2,29,785 households in the sample. Proxy responses are allowed when respondents, such as children younger than 12 years of age and those with disability, have difficulty completing the survey on their own. More detailed information about the survey can be found at <http://www.mhlw.go.jp/toukei/list/20-21.html>.

Data on mortality are obtained from age-/gender-/prefecture-specific standard period life tables from 2000 and 2010. These are abridged life tables with five-year age intervals, except for the first year of life. Using data from *Jinko Dotai Chosa* (Vital Statistics in Japan) and the Population Census, prefecture-level life tables have been constructed every 5 years since 1965. Details about prefecture-level life tables are presented at <http://www.mhlw.go.jp/toukei/saikin/hw/seimei/list54-57-02.html>.

While data on disability are obtained from 2001 and 2010, prefecture-specific life tables are drawn from 2000 and 2010. Note that, due to differences in the timing of data collection, there is a one-year discrepancy between information on disability (2001) and prefecture-level life Tables (2000), whereas data points are synchronized in 2010.

Measures

We estimate the prevalence of disability through the following two survey questions: “Are you currently institutionalized in hospitals, clinics, or long-term care facilities?” and “Do you have any limitations in carrying out normal activities due to health problems?” Responses to each question are given as “yes” or “no.” Those who answered “yes” to either question are considered to have disability. The prevalence of disability is then stratified by prefecture, gender, and age in accordance with the life tables. Since the question on disability is asked only for respondents older than 6 years of age, we use the information for those in the 6–9 age interval to estimate the prevalence rates for those between ages 0 and 5. Previous studies have used the same analytical strategy to estimate the prevalence of disability among the youngest population.

Using the Sullivan (1971) method, we first calculate the absolute number of years for 2000 and 2010 in which men and women in each prefecture can expect to live without disability (i.e., DFLE at birth). We also compute the expected duration of life with disability (DLE) at birth by age, gender, and prefecture. We then use the formulae provided by Jagger and her colleagues (2007) to test whether DFLE is significantly different between 2000 and 2010 at the 0.05 level. Finally, we compute the proportion of life free of disability for each gender by dividing DFLE at birth by LE at birth.

Results

Distribution of health expectancy across 47 prefectures

Tables 1 (men) and 2 (women) present the expected duration of life (LE at birth), the absolute number of years spent without disability (DFLE at birth), and the absolute number of years lived with disability (DLE at birth) across 47 Japanese prefectures in 2000 and 2010. We first focus on the average values of health expectancies across 47 prefectures. In 2010, the average number of disability-free years (DFLE at birth) was 69.0 for men and 72.1 for

women, compared with 68.0 years and 71.7 years, respectively, in 2000. The average duration of life spent with disability (DLE at birth) was 10.5 years for men and 14.3 years for women in 2010. As shown in Table 3, when figures on DFLE at birth are interpreted in relative terms, men and women in Japan on average spent more than 80 % of their lives free of disability in 2000 (men 87.6 %; women 84.6 %) and 2010 (men 86.8 %; women 83.4 %). In both years, females had longer DFLE, but they spent a smaller proportion of their lives without disability compared to their male counterparts.

Across prefectures, there are disparities in health expectancies. The gap in men’s DFLE at birth in 2000 reached 4.1 years, from 65.5 years in Kochi prefecture to 69.6 years in Nara prefecture [with a standard deviation (SD) of 0.91]. The proportion of disability-free life varied from 85.2 % (Kochi prefecture) to 89.3 % (Niigata prefecture). For women, the difference in DFLE at birth was 3.4 years (from 70.2 years in Tokyo to 73.6 years in Okinawa prefecture, SD of 0.74), and the proportion of disability-free life ranged from 83.2 % (Tokyo and Kagawa prefectures) to 87.2 % (Ibaraki prefecture). Inequalities in DFLE values remain large 10 years later. In 2010, the gap in male DFLE was 2.8 years (from 67.6 years in Aomori prefecture to 70.4 years in Shizuoka prefecture, SD of 0.66), and there was a 3.1-year difference in women’s DFLE (from 70.6 years in Osaka prefecture to 73.7 years in Gunma prefecture, SD of 0.77). The proportion of disability-free life ranged from 85.4 % (Oita prefecture) to 88.4 % (Akita prefecture) for men, and from 81.4 % (Hiroshima prefecture) to 85.8 % (Gunma prefecture) for women. Overall, these results indicate that patterns of regional inequalities have persisted over time between 2000 and 2010.

Changes in health expectancy between 2000 and 2010

Next, we turn to the changes in LE at birth, DFLE at birth, and DLE at birth between 2000 and 2010. During the study period, LE improved for both genders, whereas increases in DFLE were much smaller. Across 47 prefectures, LE rose on average by 1.9 years for men (from 77.6 to 79.5 years) and 1.7 years for women (from 84.7 to 86.4 years), but average DFLE increased by 1.0 year for men (from 68.0 to 69.0 years) and only by 0.4 years for women (from 71.7 to 72.1 years). Consequently, DLE increased for both genders: male DLE rose by 0.9 years (from 9.6 to 10.5 years) and female DLE increased by 1.3 years (from 13.0 to 14.3 years). Moreover, when DFLEs

Table 1 Male life expectancy (LE) at birth, disability-free life expectancy (DFLE) at birth, and life with disability (DLE) at birth (Japan, 2000–2010)

	LE at birth			DFLE at birth			DLE at birth		
	2000	2010	Difference	2000	2010	Difference	2000	2010	Difference
Hokkaido	77.6	79.2	1.6	67.9 (67.3–68.5)	68.7 (68.0–69.4)	0.8	9.7 (9.1–10.3)	10.5 (9.8–11.2)	0.8
Aomori	75.7	77.3	1.6	67.0 (66.4–67.6)	67.6 (66.9–68.3)	0.6	8.7 (8.1–9.3)	9.7 (9.0–10.4)	1.0
Iwate	77.1	78.5	1.4	66.9 (66.3–67.4)	68.1 (67.4–68.8)	1.2	10.2 (9.6–10.4)	10.4 (9.7–11.0)	0.2
Miyagi	77.7	79.7	2.0	68.3 (67.8–68.8)	68.9 (68.3–69.5)	0.6	9.4 (8.9–9.9)	10.8 (10.2–11.4)	1.4*
Akita	76.8	78.2	1.4	67.5 (66.9–68.0)	69.1 (68.5–69.7)	1.6*	9.3 (8.8–9.8)	9.1 (8.7–9.5)	−0.2
Yamagata	77.7	80.0	2.3	68.6 (68.0–69.1)	69.5 (68.9–70.1)	0.9	9.1 (8.5–9.8)	10.5 (9.6–11.4)	1.4
Fukushima	77.2	78.8	1.6	68.0 (67.9–69.2)	68.6 (67.9–69.2)	0.6	9.2 (8.6–9.8)	10.2 (9.6–11.0)	1.0
Ibaraki	77.2	79.1	1.9	68.8 (68.2–69.4)	69.7 (69.1–70.4)	0.9	8.4 (7.8–9.0)	9.4 (8.9–9.9)	1.0
Tochigi	77.1	79.1	2.0	67.9 (67.4–68.4)	69.3 (68.7–69.9)	1.4*	9.2 (8.6–9.7)	9.8 (9.2–10.4)	0.6
Gunma	77.9	79.4	1.5	68.9 (68.3–69.5)	69.8 (69.1–70.4)	0.9	9.0 (8.4–9.6)	9.6 (9.0–10.3)	0.6
Saitama	78.0	79.6	1.6	68.5 (67.8–69.2)	69.2 (68.6–69.8)	0.7	9.5 (8.8–10.2)	10.4 (9.8–11.0)	0.9
Chiba	78.0	79.9	1.9	69.3 (68.7–69.9)	69.9 (69.1–70.7)	0.6	8.7 (8.1–9.3)	10.0 (9.2–10.8)	1.3
Tokyo	78.0	79.9	1.9	68.1 (67.6–68.6)	68.7 (68.1–69.3)	0.6	9.9 (9.4–10.4)	11.2 (10.6–11.8)	1.3*
Kanagawa	78.2	80.3	2.1	69.2 (68.7–69.7)	69.6 (69.0–70.1)	0.4	9.0 (8.5–9.5)	10.7 (10.2–11.2)	1.7*
Niigata	77.7	79.5	1.8	69.4 (68.9–69.9)	68.6 (68.0–69.1)	−0.8	8.3 (7.8–8.8)	10.9 (10.4–11.3)	2.6
Toyama	78.1	79.7	1.6	68.5 (68.0–69.1)	69.2 (68.6–69.9)	0.7	9.6 (9.0–10.2)	10.5 (9.8–11.1)	0.9
Ishikawa	78.0	79.7	1.7	67.6 (67.0–68.3)	69.8 (69.1–70.5)	2.2*	10.4 (9.7–11.0)	9.9 (9.2–10.6)	−0.5
Fukui	78.5	80.5	2.0	68.6 (68.0–69.2)	69.6 (68.9–70.3)	1.0	9.9 (9.3–10.5)	10.9 (10.2–11.5)	1.0
Yamanashi	77.9	79.6	1.7	68.4 (67.9–68.9)	69.7 (69.0–70.4)	1.3*	9.5 (8.9–10.1)	9.9 (9.2–10.6)	0.4
Nagano	78.9	80.9	2.0	69.4 (68.8–70.0)	69.9 (69.3–70.6)	0.5	9.5 (8.9–10.1)	10.9 (10.3–11.6)	1.4*
Gifu	78.1	79.9	1.8	68.9 (68.3–69.5)	69.4 (68.7–70.0)	0.5	9.2 (8.6–9.8)	10.5 (9.9–11.2)	1.3*
Shizuoka	78.2	80.0	1.8	68.8 (68.2–69.4)	70.4 (69.9–70.9)	1.6*	9.4 (8.8–10.0)	9.6 (9.1–10.1)	0.2
Aichi	78.0	79.7	1.7	69.1 (68.5–69.7)	70.2 (69.6–70.8)	1.1	8.9 (8.3–9.5)	9.5 (8.9–10.1)	0.6
Mie	77.9	79.7	1.8	68.1 (67.6–68.6)	69.4 (68.7–70.1)	1.3	9.8 (9.2–10.4)	10.3 (9.6–11.0)	0.5
Shiga	78.2	80.6	2.4	68.6 (68.0–69.2)	69.3 (68.6–70.1)	0.7	9.6 (9.0–10.2)	11.3 (10.6–12.0)	1.7
Kyoto	78.1	80.2	2.1	68.3 (67.6–69.0)	69.1 (68.3–69.8)	0.8	9.8 (9.1–10.5)	11.1 (10.4–11.9)	1.3
Osaka	77.0	79.0	2.0	66.9 (66.3–67.5)	68.0 (67.4–68.6)	1.1	10.1 (9.5–10.7)	10.9 (10.4–11.4)	0.8
Hyogo	77.6	79.6	2.0	67.9 (67.3–68.4)	68.4 (67.8–69.1)	0.5	9.7 (9.2–10.3)	11.2 (10.5–11.8)	1.5*
Nara	78.3	80.1	1.8	69.6 (68.9–70.2)	69.2 (68.4–69.9)	−0.4	8.7 (8.1–9.4)	10.9 (10.2–11.6)	2.2*
Wakayama	77.0	79.1	2.1	67.3 (66.7–67.9)	69.4 (68.7–70.1)	2.1*	9.7 (9.1–10.3)	9.7 (9.0–10.4)	0.0
Tottori	77.4	79.0	1.6	67.5 (67.1–67.9)	68.7 (68.0–69.3)	1.2*	9.9 (9.4–10.4)	10.3 (9.7–10.9)	0.4
Shimane	77.6	79.5	1.9	66.9 (66.2–67.5)	69.3 (68.6–69.9)	2.4*	10.7 (10.1–11.3)	10.2 (9.6–10.8)	−0.5
Okayama	77.8	79.8	2.0	67.9 (67.3–68.5)	68.2 (67.5–68.9)	0.3	9.9 (9.3–10.5)	11.6 (10.9–12.3)	1.7*
Hiroshima	77.8	79.9	2.1	67.3 (66.7–67.9)	68.9 (68.2–69.6)	1.6*	10.5 (9.9–11.1)	11.0 (10.3–11.7)	0.5
Yamaguchi	77.0	79.0	2.0	68.3 (67.7–68.9)	69.3 (68.6–70.0)	1.0	8.7 (8.1–9.3)	9.7 (9.0–10.4)	1.0
Tokushima	77.2	79.4	2.2	66.8 (66.2–67.5)	68.5 (67.8–69.2)	1.7*	10.4 (9.7–11.0)	10.9 (10.2–11.6)	0.5
Kagawa	78.0	79.7	1.7	67.7 (67.1–68.3)	68.4 (67.7–69.1)	0.7	10.3 (9.7–10.9)	11.3 (10.6–12.0)	1.0
Ehime	77.3	79.1	1.8	67.3 (66.7–67.9)	68.3 (67.6–69.0)	1.0	10.0 (9.4–10.6)	10.8 (10.1–11.5)	0.8
Kochi	76.9	78.9	2.0	65.5 (64.9–66.2)	67.7 (66.9–68.4)	2.2*	11.4 (10.7–12.0)	11.2 (10.5–11.9)	−0.2
Fukuoka	77.2	79.3	2.1	67.4 (66.9–67.9)	68.3 (67.7–68.8)	0.9	9.8 (9.3–10.3)	11.0 (10.5–11.6)	1.2*
Saga	76.9	79.3	2.4	66.4 (65.8–66.9)	68.7 (68.1–69.3)	2.3*	10.5 (10.0–11.0)	10.6 (10.0–11.2)	0.1
Nagasaki	77.2	78.9	1.7	66.1 (65.4–66.7)	67.8 (67.1–68.5)	1.7*	11.1 (10.5–11.7)	11.1 (10.4–11.8)	0.0
Kumamoto	78.3	80.3	2.0	68.4 (67.8–69.0)	68.8 (68.1–69.5)	0.4	9.9 (9.3–10.5)	11.5 (10.8–12.2)	1.6*
Oita	77.9	80.1	2.2	67.5 (66.8–68.2)	68.4 (67.7–69.2)	0.9	10.4 (9.7–11.1)	11.7 (10.9–12.4)	1.3
Miyazaki	77.4	79.7	2.3	67.9 (67.3–68.5)	69.4 (68.6–70.1)	1.5*	9.5 (9.1–10.1)	10.3 (9.6–11.1)	0.8
Kagoshima	77.0	79.2	2.2	68.0 (67.4–68.6)	69.2 (68.5–69.9)	1.2	9.0 (8.4–9.6)	10.0 (9.3–10.7)	1.0

Table 1 continued

	LE at birth			DFLE at birth			DLE at birth		
	2000	2010	Difference	2000	2010	Difference	2000	2010	Difference
Okinawa	77.6	79.4	1.8	68.6 (68.0–69.3)	69.1 (68.3–69.8)	0.5	9.0 (8.3–9.6)	10.3 (9.6–11.1)	1.3
Average	77.6	79.5	–	68	69	–	9.6	10.5	–

The 95 % confidence intervals are in parentheses. Asterisks indicate significant differences between 2000 and 2010 ($p < 0.05$). Prefectures are numbered in the official order of prefectures from north (Hokkaido prefecture) to south (Okinawa prefecture)

are converted to relative values, the proportion of disability-free life decreased on average by 0.8 % points for men (from 87.6 to 86.8 %), and by 1.2 % points for women (from 84.6 to 83.4 %).

At the prefecture-level, male DFLE at birth improved in 45 prefectures, compared with 33 prefectures for female DFLE. The absolute number of DFLE years increased significantly in 14 prefectures for men and in 5 prefectures for women ($p < 0.05$). It is also important to note that there are reductions in the absolute number of disability-free years in numerous prefectures. Between 2000 and 2010 men's DFLE declined in two prefectures, with a 0.8-year decrease in Niigata prefecture and a 0.4-year reduction in Nara prefecture. In contrast, female DFLE decreased in 13 prefecture, with the largest reduction of a 0.9-year in Oita prefecture, followed by Okinawa and Ibaraki prefectures (with a 0.7-year decrease), and Shiga, Nara, and Hiroshima prefectures (with a 0.6-year decrease). These results stand in stark contrast to the longevity results, in which LE at birth improved in every prefecture for both genders. In fact, men's DFLE increased more than LE only in four prefectures. For women, DFLE increased in 33 prefectures, but none of the increases exceeded the increases in LE. It seems that there are discrepancies between the pace of LE and DFLE increases.

Perhaps the most startling feature of the present results comes from the proportional analyses. As shown in Figs. 1 and 2, decreases in health expectancy become particularly evident when the absolute number of disability-free life years is converted into relative values. For men, the proportion of disability-free life declined in 38 out of 47 prefectures between 2000 and 2010. Niigata prefecture had the largest decline of 3.1 % points, followed by Nara prefecture (2.5 % points) and Kanagawa prefecture (1.9 % points). Downturns are much steeper among women. The proportion of disability-free life declined in 45 out of 47 prefectures. Women in Oita prefecture had the greatest reduction in the proportion of disability-free life (3.3 % points). The exceptions were Gunma prefecture and Ishikawa prefecture, where the proportion of disability-free life remained unchanged or slightly improved. Overall, these results elucidate downturns in the health expectancy of Japanese prefectures during the past decade.

Discussion

The present study focused on differences in the absolute number and proportion of disability-free life years across prefectures, and it investigated changes in LE at birth, DFLE at birth, and DLE at birth between 2000 and 2010. Our results show that there was a marked rise in LE at birth during the study period. The average duration of life at birth improved uniformly for men and women in every prefecture in the past decade. Inequalities in health expectancy, however, have persisted across prefectures. While the absolute number of disability-free years increased in many parts of the country, we noted reductions in DFLE in some prefectures. Further, the expected duration of life spent with disability increased for a large number of prefectures. Crucially, the rate of increase in DFLE lagged behind that in longevity for the majority of prefectures. Downturns in health expectancy became particularly evident when we interpreted DFLE values in relation to the overall length of life. The proportion of disability-free life decreased in 38 out of 47 prefectures for men and in 45 out of 47 prefectures for women between 2000 and 2010.

Taken together, these results reveal discrepancies between the pace of increase in longevity and that in health expectancy across Japanese prefectures. In the face of increasing chronic illnesses, an extension of life years can mean longer yet diseased lives (Robine and Michel 2004). The present findings offer support for the expansion of morbidity hypothesis (Gruenberg 1977). Using national-level data on self-rated health status for the period 1995–2004, Yong and Saito (2009) found that gains in LE were mainly due to increases in years of poor self-rated health. Our results lend further support for the expansion of morbidity hypothesis at the subnational level over the decade 2000–2010. The European Union (EU) seeks an increase of two healthy life years (HLYs) at birth for the next 10 years, but recent evidence suggests widening disparities in HLYs across member states (Jagger et al. 2013; Lagiewka 2012). In Japan, the second phase of Healthy Japan 21 has set a target of having improvements in DFLE at birth outpace those in LE at birth between 2013 and 2022. Our results show, however, that the goal was not

Table 2 Female life expectancy (LE) at birth, disability-free life expectancy (DFLE) at birth, and life with disability (DLE) at birth (Japan, 2000–2010)

	LE at birth			DFLE at birth			DLE at birth		
	2000	2010	Difference	2000	2010	Difference	2000	2010	Difference
Hokkaido	84.8	86.3	1.5	70.8 (70.1–71.5)	71.4 (70.6–72.2)	0.6	14.0 (13.3–14.7)	14.9 (14.1–15.7)	0.9
Aomori	83.5	85.4	1.9	71.8 (71.1–72.4)	71.3 (70.6–72.0)	–0.5	11.7 (11.1–12.4)	14.1 (13.4–14.8)	2.4*
Iwate	84.5	85.9	1.4	71.1(70.5–71.7)	71.3 (70.6–72.0)	0.2	13.4 (13.0–13.8)	14.6 (13.9–15.3)	1.2*
Miyagi	84.7	86.4	1.7	71.1 (70.5–71.7)	72.1 (71.5–72.8)	1.0	13.6 (13.0–14.2)	14.3 (13.6–14.9)	0.7
Akita	84.3	86.0	1.7	71.7 (71.1–72.3)	72.4 (71.7–73.0)	0.7	12.6 (12.0–13.2)	13.6 (13.0–14.2)	1
Yamagata	84.6	86.3	1.7	71.6 (71.0–72.2)	72.0 (71.3–72.7)	0.4	13.0 (12.4–13.6)	14.3 (13.6–15.0)	1.3
Fukushima	84.1	86.1	2.0	72.3 (71.7–72.9)	72.3 (71.6–72.9)	0.0	11.8 (11.2–12.4)	13.8 (13.1–14.5)	2.0*
Ibaraki	84.1	85.8	1.7	73.4 (72.7–74.0)	72.7 (72.0–73.4)	–0.7	10.7 (10.1–11.4)	13.1 (12.4–13.8)	2.4*
Tochigi	84.0	85.7	1.7	71.8 (71.2–72.5)	72.7 (72.1–73.4)	0.9	12.2 (11.5–12.8)	13.0 (12.3–13.7)	0.8
Gunma	84.4	85.9	1.5	72.4 (71.8–73.0)	73.7 (73.0–74.4)	1.3	12.0 (11.4–12.6)	12.2 (11.5–12.9)	0.2
Saitama	84.3	85.9	1.6	70.5 (69.7–71.3)	71.2 (70.6–71.9)	0.7	13.8 (13.0–14.6)	14.7 (14.0–15.3)	0.9
Chiba	84.4	86.2	1.8	71.8 (71.1–72.5)	71.9 (71.0–72.7)	0.1	12.6 (11.9–13.3)	14.3 (13.5–15.2)	1.7*
Tokyo	84.4	86.4	2.0	70.2 (69.7–70.8)	71.7 (71.1–72.3)	1.5*	14.2 (13.6–14.8)	14.7 (14.1–15.3)	0.5
Kanagawa	84.7	86.7	2.0	72.0 (71.4–72.6)	72.6 (72.0–73.2)	0.6	12.7 (12.1–13.3)	14.1 (13.5–14.7)	1.4*
Niigata	85.2	87.0	1.8	72.7 (72.1–73.3)	72.4 (71.7–73.0)	–0.3	12.5 (11.9–13.1)	14.6 (14.0–15.2)	2.1*
Toyama	85.2	86.8	1.6	72.2 (71.6–72.8)	72.9 (72.3–73.6)	0.7	13.0 (12.4–13.6)	13.9 (13.2–14.5)	0.9
Ishikawa	85.1	86.8	1.7	71.0 (70.5–71.6)	72.5 (71.7–73.3)	1.5*	14.1 (13.4–14.8)	14.3 (13.5–15.1)	0.2
Fukui	85.4	87.0	1.6	72.2 (71.6–72.8)	72.9 (72.2–73.6)	0.7	13.2 (12.6–13.9)	14.1 (13.4–14.8)	0.9
Yamanashi	85.2	86.7	1.5	72.9 (72.3–73.5)	73.1 (72.3–73.8)	0.2	12.3 (11.7–12.9)	13.6 (12.9–14.3)	1.3
Nagano	85.2	87.2	2.0	71.7 (71.0–72.3)	72.7 (72.0–73.4)	1.0	13.5 (12.9–14.2)	14.5 (13.8–15.2)	1
Gifu	84.3	86.3	2.0	71.7 (71.1–72.4)	72.8 (72.1–73.5)	1.1	12.6 (11.9–13.3)	13.5 (12.8–14.2)	0.9
Shizuoka	84.9	86.2	1.3	72.9 (72.2–73.5)	73.5 (73.0–74.0)	0.6	12.0 (11.4–12.7)	12.7 (12.2–13.2)	0.7
Aichi	84.2	86.2	2.0	71.5 (70.8–72.2)	73.1 (72.4–73.8)	1.6*	12.7 (12.0–13.4)	13.1 (12.4–13.8)	0.4
Mie	84.5	86.3	1.8	72.0 (71.4–72.7)	72.3 (71.6–73.0)	0.3	12.5 (11.6–13.4)	14.0 (13.3–14.7)	1.5
Shiga	84.9	86.7	1.8	71.6 (70.9–72.2)	71.0 (70.3–71.8)	–0.6	13.3 (12.7–14.0)	15.7 (14.9–16.4)	2.4*
Kyoto	84.8	86.6	1.8	71.2 (70.5–72.0)	72.1 (71.3–72.9)	0.9	13.6 (12.8–14.4)	14.5 (13.7–15.3)	0.9
Osaka	84.0	85.9	1.9	70.7 (70.1–71.4)	70.6 (70.0–71.2)	–0.1	13.2 (12.6–13.9)	15.3 (14.7–15.9)	2.1*
Hyogo	84.3	86.2	1.9	70.4 (69.7–70.9)	71.6 (71.0–72.3)	1.2*	13.9 (13.3–14.6)	14.6 (13.9–15.2)	0.7
Nara	84.8	86.6	1.8	72.1 (71.3–72.8)	71.5 (70.7–72.4)	–0.6	12.7 (12.0–13.5)	15.1 (14.3–15.9)	2.4*
Wakayama	84.3	85.7	1.4	71.2 (70.6–71.9)	72.1 (71.4–72.8)	0.9	13.1 (12.4–13.8)	13.6 (12.9–14.3)	0.5
Tottori	84.9	86.1	1.2	71.6 (70.9–72.2)	71.7 (71.0–72.4)	0.1	13.3 (12.7–14.0)	14.4 (13.7–15.1)	1.1
Shimane	85.4	87.1	1.7	71.8 (71.2–72.4)	73.2 (72.5–73.8)	1.4*	13.6 (12.9–14.3)	13.9 (13.3–14.6)	0.3
Okayama	85.2	86.9	1.7	72.1 (71.5–72.8)	71.7 (71.0–71.5)	–0.4	13.1 (12.4–13.8)	15.2 (14.5–15.9)	2.1
Hiroshima	85.1	86.9	1.8	71.3 (70.7–71.9)	70.7 (70.0–71.5)	–0.6	13.8 (13.2–14.4)	16.2 (15.4–16.9)	2.4*
Yamaguchi	84.6	86.1	1.5	71.9 (71.2–72.6)	72.4 (71.6–73.2)	0.5	12.7 (12.1–13.4)	13.7 (12.9–14.5)	1
Tokushima	84.5	86.2	1.7	70.9 (70.2–71.6)	70.7 (70.0–71.5)	–0.2	13.6 (13.0–14.3)	15.5 (14.7–16.2)	1.9*
Kagawa	84.8	86.3	1.5	70.6 (69.9–71.3)	71.3 (70.6–72.0)	0.7	14.2 (13.6–14.9)	15.0 (14.3–15.7)	0.8
Ehime	84.6	86.5	1.9	71.9 (71.2–72.5)	72.0 (71.2–72.7)	0.1	12.7 (12.1–13.4)	14.5 (13.8–15.3)	1.8*
Kochi	84.8	86.5	1.7	70.8 (70.1–71.5)	71.6 (70.8–72.4)	0.8	14.0 (13.3–14.7)	14.9 (14.1–15.7)	0.9
Fukuoka	84.6	86.5	1.9	71.3 (70.8–71.9)	71.0 (70.3–71.6)	–0.3	13.3 (12.7–13.9)	15.5 (14.9–16.2)	2.2*
Saga	85.0	86.6	1.6	71.2 (70.6–71.9)	71.8 (71.1–72.5)	0.6	13.8 (13.1–14.5)	14.8 (14.1–15.5)	1
Nagasaki	84.8	86.3	1.5	70.9 (70.3–71.6)	71.3 (70.6–72.1)	0.4	13.9 (13.2–14.6)	15.0 (14.2–15.7)	1.1
Kumamoto	85.3	87.0	1.7	72.3 (71.7–73.0)	72.0 (71.2–72.7)	–0.3	13.0 (12.3–13.7)	15.1 (14.4–15.8)	2.1*
Oita	84.7	86.9	2.2	72.2 (71.5–72.9)	71.3 (70.5–72.0)	–0.9	12.5 (11.8–13.2)	15.6 (14.9–16.3)	3.1*
Miyazaki	85.0	86.6	1.6	72.1 (71.4–72.8)	73.1 (72.4–73.8)	1.0	12.9 (12.2–13.6)	13.5 (12.8–14.2)	0.6
Kagoshima	84.7	86.3	1.6	71.5 (70.8–74.3)	72.4 (71.6–73.1)	0.9	13.2 (12.6–13.9)	13.9 (13.2–14.5)	0.7

Table 2 continued

	LE at birth			DFLE at birth			DLE at birth		
	2000	2010	Difference	2000	2010	Difference	2000	2010	Difference
Okinawa	86.1	87.0	0.9	73.6 (72.9–74.3)	72.9 (72.1–73.7)	–0.7	12.5 (11.8–13.2)	14.1 (13.3–14.9)	1.6
Average	84.7	86.4	–	71.7	72.1	–	13.0	14.3	–

The 95 % confidence intervals are in parentheses. Asterisks indicate significant differences between 2000 and 2010 ($p < 0.05$). Prefectures are numbered in the official order of prefectures from north (Hokkaido prefecture) to south (Okinawa prefecture)

reached for the majority of prefectures during the period 2000–2010. These results have an important bearing on public health policy, as Healthy Japan 21 directs attention to the subnational levels to accomplish its nationwide health-promotion agenda.

To further assess the validity of the agenda of the program, we estimated DFLE at birth in 2025 in each prefecture by multiplying the projected values of LE at birth in 2025 by the expected proportion of disability-free life in 2025. We focused on the proportion DFLE years, rather than the number of DFLE years, to ensure that DFLE at birth would not be larger than LE at birth (Jagger et al. 2013). Also, we imposed an assumption that the pace of change in the proportion of disability-free life would remain at the pace of change between 2000 and 2010. Age- and gender-specific life tables for each prefecture were drawn from the National Institute of Population and Social Security Research (2012). Results in Online Resource 1 indicate a slow pace of growth in health expectancy in the future. If the pattern of the decade 2000–2010 continues, increases in DFLE at birth are projected to be smaller than increases in LE at birth for men and women in every prefecture for the period 2010–2025. Thus, the gap between the length of life and healthy life is likely to persist. These results suggest that, on the basis of the results from the past decade, the major target of the second phase of Healthy Japan 21 will be difficult to meet.

Several explanations have been discussed in the literature for the increasing incidence of disability in recent years. First, chronic diseases have become much more prevalent in the country over time. Given that chronic illnesses are powerful risk factors for disability (Freedman and Martin 2000; Freedman et al. 2007), increases in these health conditions may in part explain the larger number of people who experience activity-limiting conditions in daily life. Second, people are experiencing longer life but declining health (Olshansky et al. 1991; Robine and Michel 2004). Our results in fact show that the expected length of life (LE at birth) and life with disability (DLE at birth) have simultaneously increased over the decade 2000–2010.

Therefore, the longer lives of the Japanese people might be the reason they spend more years with disability. And third, the introduction of a new long-term care policy may have something to do with the reported prevalence of disability. In April 2000, the government launched the long-term care insurance (LTCI) policy under which people aged 65 years old and above are eligible for in-home and institutional long-term care services (Tamiya et al. 2011; Yong and Saito 2012). The need for care is determined by the levels of difficulties in activities of daily living, such as walking, bathing, and toileting (Tsutsui and Muramatsu 2005). It has been suggested that the new policy led to increases in the number of persons who report health problems to be eligible for LTCI services (Mitchell et al. 2006). To test this hypothesis, we calculated the duration of disability-free life between ages 0 and 64 and compared the results with DFLE at birth. The results of partial DFLE between ages 0 and 64 and DFLE at birth were almost identical, suggesting that the new policy may have had only a limited impact on the prevalence of disability.

The results of this work allow a number of conclusions to be drawn, but these issues should be seen in light of this study's limitations. First, we assumed that the pattern from the period 2000–2010 would remain unchanged for the decade 2013–2022. We focused on the period between 2000 and 2010 in accordance with the agenda of Healthy Japan 21, but it is difficult to forecast future trends in mortality and morbidity for an aging population (Robine and Michel 2004). While we anticipated declines in health expectancy in the near future, there may be factors that can reverse the past trend. Growing policy attention has been given to measures to reduce chronic conditions and prevent disability. *Shokuiku*, or the food and nutrition education program, for example, was launched in 2005 to help people choose healthy diets and enjoy positive lifestyles (Shokuiku Promotion Office, Cabinet Office, Government of Japan 2010). The second phase of Healthy Japan 21 also aims to improve people's nutritional-intake, eating habits, and leisure activities. These various policy and program measures may contribute to changing Japanese lifestyles,

Table 3 The percentage of life spent without disability (Japan, 2000–2010)

	Men			Women		
	2000	2010	Difference	2000	2010	Difference
Hokkaido	87.5	86.7	-0.8	83.5	82.7	-0.8
Aomori	88.5	87.4	-1.0	86.0	83.5	-2.5
Iwate	86.8	86.8	0.0	84.2	83.0	-1.2
Miyagi	87.9	86.5	-1.4	84.0	83.5	-0.5
Akita	87.9	88.4	0.5	85.1	84.2	-0.9
Yamagata	88.2	86.9	-1.4	84.6	83.4	-1.2
Fukushima	88.1	87.0	-1.1	86.0	84.0	-2.0
Ibaraki	89.1	88.1	-1.0	87.2	84.8	-2.5
Tochigi	88.1	87.6	-0.5	85.5	84.9	-0.6
Gunma	88.4	87.9	-0.5	85.8	85.8	0.0
Saitama	87.8	86.9	-0.9	83.7	82.9	-0.7
Chiba	88.9	87.5	-1.4	85.1	83.4	-1.7
Tokyo	87.3	86.0	-1.3	83.2	83.0	-0.2
Kanagawa	88.5	86.6	-1.9	85.0	83.8	-1.2
Niigata	89.3	86.2	-3.1	85.3	83.2	-2.1
Toyama	87.8	86.9	-0.9	84.7	84.0	-0.7
Ishikawa	86.7	87.6	0.9	83.5	83.5	0.1
Fukui	87.4	86.5	-0.9	84.5	83.8	-0.7
Yamanashi	87.8	87.6	-0.3	85.6	84.3	-1.3
Nagano	88.0	86.4	-1.5	84.1	83.3	-0.8
Gifu	88.2	86.8	-1.4	85.1	84.3	-0.8
Shizuoka	88.0	88.0	0.0	85.8	85.2	-0.6
Aichi	88.6	88.1	-0.5	84.9	84.8	-0.1
Mie	87.5	87.1	-0.3	85.2	83.8	-1.5
Shiga	87.7	86.0	-1.7	84.3	81.9	-2.4
Kyoto	87.4	86.1	-1.3	84.0	83.2	-0.8
Osaka	86.9	86.1	-0.8	84.2	82.2	-2.0
Hyogo	87.5	86.0	-1.5	83.5	83.1	-0.3
Nara	88.8	86.4	-2.5	85.0	82.6	-2.4
Wakayama	87.4	87.7	0.3	84.5	84.1	-0.4
Tottori	87.2	86.9	-0.3	84.3	83.2	-1.1
Shimane	86.1	87.1	1.0	84.1	84.0	-0.1
Okayama	87.2	85.5	-1.8	84.7	82.5	-2.2
Hiroshima	86.5	86.2	-0.3	83.8	81.4	-2.4
Yamaguchi	88.7	87.7	-1.0	85.0	84.1	-0.9
Tokushima	86.6	86.3	-0.3	83.9	82.1	-1.8
Kagawa	86.8	85.8	-0.9	83.2	82.6	-0.6
Ehime	87.1	86.4	-0.7	85.0	83.2	-1.7
Kochi	85.2	85.8	0.5	83.4	82.7	-0.7
Fukuoka	87.3	86.1	-1.2	84.3	82.0	-2.3
Saga	86.3	86.7	0.4	83.8	82.9	-0.9
Nagasaki	85.6	86.0	0.4	83.7	82.7	-1.0
Kumamoto	87.4	85.7	-1.7	84.8	82.7	-2.1
Oita	86.7	85.4	-1.2	85.3	82.0	-3.3

Table 3 continued

	Men			Women		
	2000	2010	Difference	2000	2010	Difference
Miyazaki	87.7	87.1	-0.7	84.8	84.4	-0.4
Kagoshima	88.2	87.4	-0.9	84.4	83.8	-0.5
Okinawa	88.4	87.0	-1.5	85.5	83.8	-1.7
Average	87.6	86.8		84.6	83.4	

thereby leading to the prevention of disabling conditions in the future.

Second, several weaknesses of our disability variable should be noted. To begin, the point of estimation is different for disability (2001) and mortality (2000) due to a gap in the timing of data collection. This is an obvious limitation, but given small changes in disability-free life expectancy between 1998 and 2001 (Hashimoto et al. 2010), this research used the original data of 2001, rather than estimating disability rates in 2000. Readers should bear in mind that there may be a discrepancy between the present estimates of disability and actual prevalence rates. Further, our disability measure is rather crude. Increasing attention is being paid to the degree of severity of disabling conditions. Some studies have combined information about activities of daily living (ADL) and instrumental activities of daily living (IADL) and determined the degree of disability (Jagger et al. 2007). Due to data restrictions, however, we only focused on the existence of activity-limiting health problems. Also, we assumed the same disability rates for the youngest population (i.e., those in the 0–5 age interval) and for those in the 6–9 age interval, and thus imputation of disability prevalence may have yielded biased estimates. Overall, the development of a more detailed disability measure should be a subject of future research.

The third limitation has to do with the sample. Although the rate of institutionalization remains low in Japan, institutionalized individuals nevertheless might influence the computation of health expectancy (Yong and Saito 2009). We, therefore, incorporated data on institutionalization in hospitals, clinics, or long-term care facilities. However, information on those staying at elderly nursing homes is not included in the analysis. As a result, we assumed the same prevalence of disability for those in institutions and in households, indicating that we may have slightly overestimated DFLE at birth.

Finally, mechanisms behind regional disparities in health remain to be explored. Our results demonstrate differentials in LE at birth, DFLE at birth, and DLE at birth

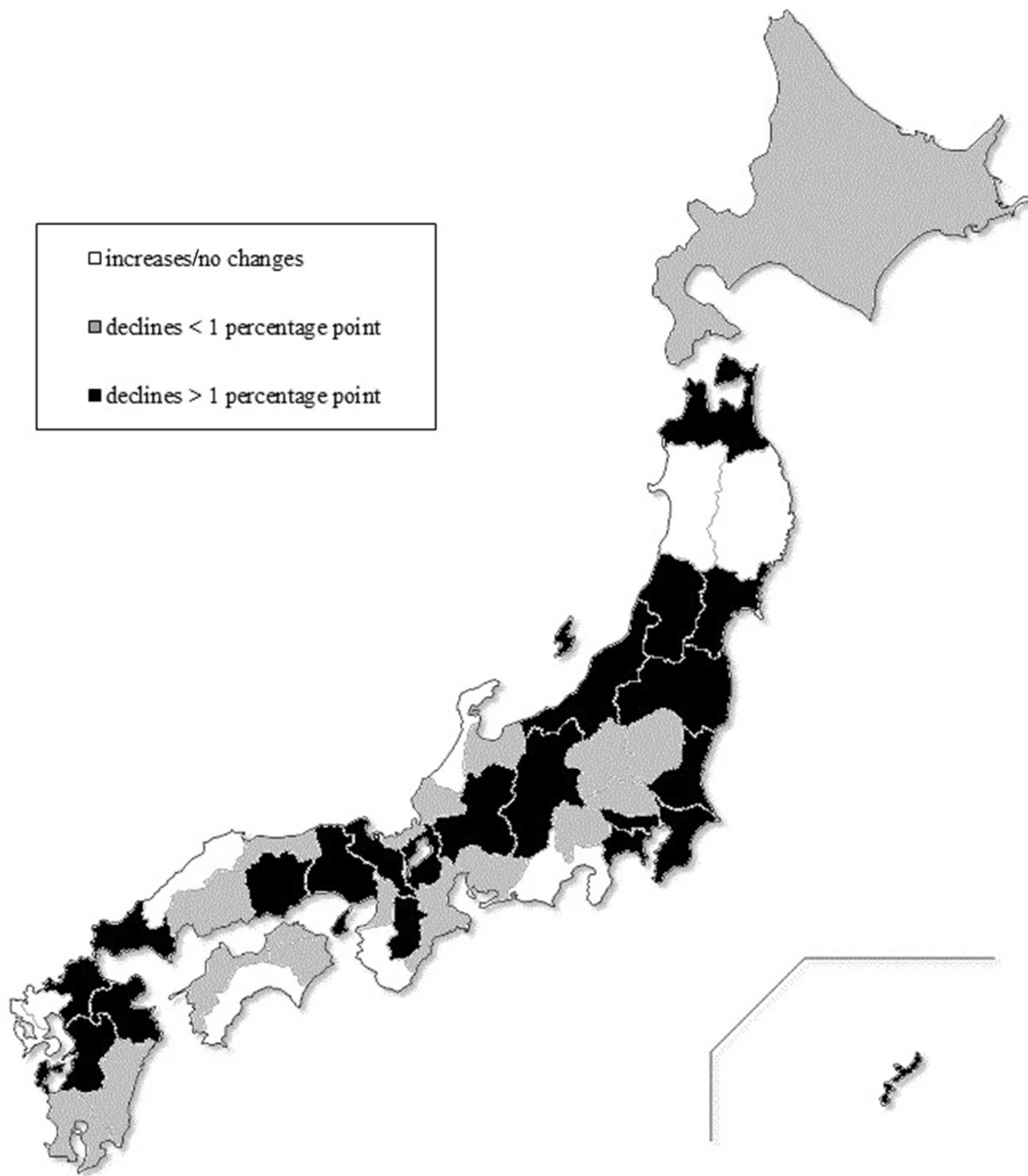


Fig. 1 Changes in the percentage of life spent without disability across 47 prefectures, men (Japan, 2000–2010)

across 47 Japanese prefectures. Previous research has reported relationships between prefecture-level health outcomes and various socioeconomic and environmental factors (Robine et al. 2012). In Aomori prefecture, for instance, poor diet, characterized by high salt consumption and low intake of vegetables, is related to high mortality rates from heart and cerebrovascular diseases (Health and

Welfare department, Aomori prefecture 2013). Investigating factors behind diverging health outcomes across prefectures will be an interesting avenue for future research.

In sum, comparisons of changes in prefecture-level health expectancy between 2000 and 2010 not only reveal inequalities across prefectures, but also illustrate the gap

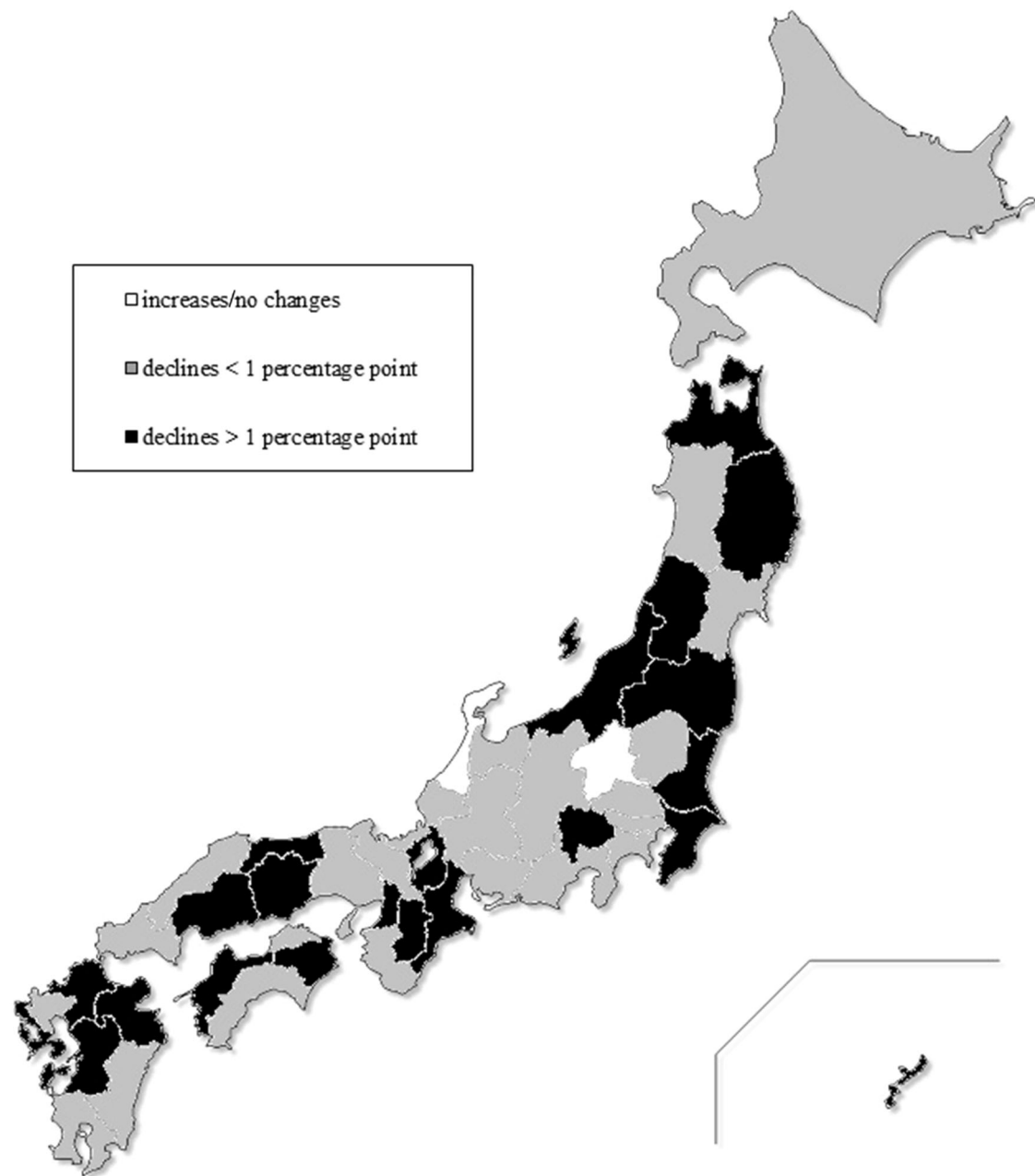


Fig. 2 Changes in the percentage of life spent without disability across 47 prefectures, women (Japan, 2000–2010)

in the rate of increase in health and that in longevity during the past decade. These results raise the question over the possibility of achieving the headline target of the second phase of Healthy Japan 21. Our findings underscore the importance of directing more policy attention toward reducing health differentials at the subnational level.

Acknowledgments Support for this research was provided by the Japan Society for the Promotion of Science (Grant-in-Aid for Scientific Research 20638621). We acknowledge the Ministry of Health, Labour, and Welfare for providing us access to the data of *Kokumin*

Seikatsu Kiso Chosa (the Comprehensive Survey of Living Conditions of the People on Health and Welfare).

References

- Cabinet Office, Government of Japan (2014) Annual Report on the Aging Society: 2014 (Summary). <http://www8.cao.go.jp/kourei/whitepaper/w-2014/zenbun/>. Accessed 3 Feb 2016
- Freedman VA, Martin LG (2000) Contribution of chronic conditions to aggregate changes in old-age functioning. *Am J Public Health* 90:1755–1760

- Freedman VA, Schoeni RF, Martin LG, Cornman JC (2007) Chronic conditions and the decline in late-life disability. *Demography* 44(3):459–477
- Gruenberg EM (1977) The failure of success. *Milbank Meml Fund Q* 55(1):3–24
- Hashimoto S (2008) Research on standardization of health expectancy measures in region (2007–2008) (in Japanese). <http://toukei.umin.jp/kenkoujyumyou/>. Accessed 3 Feb 2016
- Hashimoto S et al (2010) Trends in disability-free life expectancy in Japan, 1995–2004. *J Epidemiol* 20(4):308–312
- Health and Welfare Department, Aomori Prefecture (2013) Healthy Aomori 21 (second phase). <http://www.pref.aomori.lg.jp/welfare/health/21keikaku.html>. Accessed 3 Feb 2016
- Jagger C, Cox B, Le Roy S, and the EHEMU (2007) Health expectancy calculation by the Sullivan Method. EHEMU Technical Report 2006-3
- Jagger C, Matthews R, Matthews F, Robinson T, Robine JM, Brayne C, Medical Council Cognitive Function and Ageing Study Investigators (2007) The burden of diseases on disability-free life expectancy in later life. *J Gerontol A Biol Sci Med Sci* 62:408–414
- Jagger C, McKee M, Christensen K, Lagiweka Km Nusselder W, Van Oyen H, Cambois E, Jeune B, Robine JM (2013) Mind the gap—reaching the European target of a 2-year increase in healthy life years in the next decade. *Eur J Public Health* 23:829–833
- Lagiewka K (2012) European innovation partnership on active and healthy ageing: triggers of setting the headline target of 2 additional healthy life years at birth at EU average by 2020. *Arch Public Health* 70(1):23
- Ministry of Health, Labour, and Welfare (2014a) Patient Survey (in Japanese). <http://www.mhlw.go.jp/toukei/saikin/hw/kanja/14/>. Accessed 3 Feb 2016
- Ministry of Health, Labour, and Welfare (2014b) Annual Health, Labour and Welfare Report 2014 (Summary). <http://www.mhlw.go.jp/wp/hakusyo/kousei/14/>. Accessed 3 Feb 2016
- Ministry of Health, Labour, and Welfare (2015) Evaluations of the Second Phase of Healthy Japan 21 http://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kenkou_iryuu/kenkou/kenkounippon21.html. Accessed 3 Feb 2016
- Mitchell OS, Piggott J, Shimizutani S (2006) Aged-care support in Japan: perspectives and challenges. *Benefits Q* 22(1):7–18
- National Institute of Population and Social Security Research (2012) Future projection on population and households. <http://www.ipss.go.jp/syoushika/tohkei/Mainmenu.asp>. Accessed 3 Feb 2016
- Olshansky SJ, Rudberg MA, Carnes BA, Cassel CK, Brody JA (1991) Trading off longer life for worsening health: the expansion of morbidity hypothesis. *J Aging Health* 3(2):194–216
- Robine JM, Michel JP (2004) Looking forward to a general theory on population aging. *J Gerontol A Biol Sci Med Sci* 59(6):M590–M597
- Robine JM, Jagger C, Mathers CD, Crimmins EM, Suzman RM (eds) (2003) *Determining health expectancies*. Wiley, Chichester
- Robine JM et al (2012) Exploring the impact of climate on human longevity. *Expl Gerontol* 47(9):660–671
- Shokuiku Promotion Office, Cabinet Office, Government of Japan (2010) The Japanese spirit-food and nutrition education in Japan. http://www8.cao.go.jp/syokuiku/data/eng_pamph/. Accessed 3 February 2016
- Sullivan DF (1971) A single index of mortality and morbidity. *HSMHA Health Rep* 86:347–354
- Tamiya N, Noguchi H, Nishi A, Reich MR, Ikegami N, Hashimoto H, Shibuya K, Kawachi I, Campbel JC (2011) Population ageing and wellbeing: lessons from Japan's long-term care insurance policy. *Lancet* 378(9797):1183–1192
- Tsutsui T, Muramatsu N (2005) Care-needs certification in the long-term care insurance system of Japan. *J Am Geriatr Soc* 53:522–527
- Wohland P, Rees P, Gillies C, Alvanides S, Matthews FE, O'Neill V, Jagger C (2014) Drivers of inequality in disability-free expectancy at birth and age 85 across space and time in Great Britain. *J Epidemiol Commun H* 68(9):826–833
- Yong V, Saito Y (2009) Trends in healthy life expectancy in Japan: 1986–2004. *Demog Res* 20:467–494
- Yong V, Saito Y (2012) National long-term care insurance policy in Japan a decade after implementation: some lessons for aging countries. *Ageing Int* 37:271–284