

Gender gap in healthspan and life expectancy in Okinawa: health behaviours

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ABSTRACT

Background. Okinawa has one of the highest life expectancy rankings among the 47 prefectures in Japan. However, the growth in life expectancy has stalled and the gender gap has widened. This research aimed to (1) clarify the mortality structure responsible for the large gender gap in life expectancy in Okinawa, and (2) describe major health behaviours and risk factors that are contributing to this large gender gap through their effects on healthspan and lifespan-limiting diseases.

Methods. Statistics from the Ministry of Health, Labour and Welfare at 2 time points (1975 and 2005) were selected to investigate mortality shifts affecting life expectancy growth in Okinawa and Japan in recent decades. In addition, data on 3 major risk factors (smoking, obesity, alcohol consumption), one cluster of cardiovascular risk factors (metabolic syndrome), and the Breslow Health Practice Index were investigated for gender differences. Gamma glutamyl transferase (GGT), a novel risk factor for cause-specific (e.g. cardiovascular) and all-cause mortality, which may be influenced by these risk factors, was also examined for gender differences.

Results. Contrary to trends in most industrialised nations showing decreasing gender gaps in life expectancy, the gender gap has widened in both Okinawa (6.81 to 8.24 years) and Japan (5.22 to 6.94 years) between 1975 and 2005. Age-adjusted risk for each of the top 6 causes of death in 2005 was found to be 2 to 4 times higher in men than in women. Higher male death rates from cancer (particularly lung cancer), cardiovascular disease, as well as suicide and accidents played the most important role in the gender gap. Smoking, obesity, alcohol consumption, metabolic syndrome, health practices, and GGT level were all worse in men contributing to a higher risk for early onset of age-associated diseases and mortality.

Conclusion. When compared to women, major health behaviours and associated risk factors were far worse for men in Japan, particularly so in Okinawa, likely reflecting the strong role of social and behavioural factors behind gender differences in health practices. A focus on men's health in Okinawa should be a public health priority.

Key words: Health behavior; Japan; Life expectancy; Mortality

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INTRODUCTION

Life expectancy has increased worldwide in the 20th century, and Japan has had the highest life expectancy since the late 1970s when it surpassed Sweden.¹ In 2005, life expectancy in Japan was 78.1 years for men and 85.2 years for women.² Women almost always have a longer life expectancy than men; 6 years longer on average in industrialised countries.³ Modernisation incurred

the benefits of extensive public health and welfare infrastructures and advanced technological medicine, and the gender gap in life expectancy expanded. In recent decades, the gender gap has decreased in most developed nations,³⁻⁵ but it has widened persistently in Japan.⁶ Okinawa prefecture has one of the highest life expectancy rankings since 1975, but its growth in life expectancy has slowed considerably in recent years. Currently, men in

Okinawa live no longer than Japanese men on average, falling to 26th place among the 47 prefectures in 2000 and remaining in the middle place since.⁷ Although the gender gap in life expectancy in Japan has been reported,⁸⁻¹⁰ in-depth studies of Okinawa prefecture, where the gender gap is largest in Japan, are few.¹¹ This analysis aims (1) to clarify trends in the gender gap in life expectancy in Okinawa and Japan from 1975 to 2005 in terms of causes of death, and (2) to shed light upon the aetiology of the wide gender gap in Okinawa by examining common health behaviours and risk factors for age-associated disease and early mortality.

METHODS

Age-adjusted mortality data from the Ministry of Health Labour and Welfare in 2 time points (1975 and 2005) were compared in order to investigate changes in the top 6 causes of death that affected life expectancy growth of men and women in Okinawa and Japan. In addition, the most recent data from publicly available databases including the Health and Nutrition Survey (kokumin eiyō chōsa) and the Health Screening Exam (kenshin) were utilised to explore gender differences for 3 major risk factors (smoking, obesity, and alcohol consumption), one cluster of cardiovascular risk factors (metabolic syndrome), and the Breslow Health Practice Index. In addition, gamma glutamyl transferase (GGT), a novel risk factor for cause-specific (e.g. cardiovascular) and all-cause mortality, which may be influenced by these risk factors, was also examined for gender differences.

RESULTS

Gender gap in life expectancy

The TABLE shows male and female life expectancy in Okinawa and Japan from 1975 to 2005.¹² Male life expectancy grew 6.49 years in Okinawa and 7.00 years in Japan from 1975 to 2005, whereas female life expectancy grew 7.92 years in Okinawa and 8.74 years in Japan. Life expectancy for men in Okinawa was 0.36 years longer than the Japanese average in 1975, but had dropped to

0.15 years shorter by the year 2005. In Okinawa, the life expectancy lead for women declined from 1.95 years to 1.13 years during the same period, and the gender gap in life expectancy rose from 6.81 years in 1975 to 8.23 years in 2005 (in favour of women), the widest gender gap among the 47 Japanese prefectures. The gender gap in life expectancy in Japan also rose from 5.22 years to 6.95 years during the same period.

Age-adjusted death rates

FIGURE 1 shows the change in the age-adjusted death rates for the 6 leading causes of death in 1975 and 2005.² In 2005 in Okinawa, men had approximately 2 times higher total (all cause) mortality as well as mortality from cancer, heart disease, stroke, and pneumonia, compared to women. Mortality from accidents and suicide was approximately 3 to 4 times higher in men than in women. Comparing changes from 1975 to 2005, the gender gap increased in every leading cause of death (except accidents), with the suicide gap increasing the most (almost double). Okinawans had lower age-adjusted mortality from the 3 main causes of death (stroke, cancer, heart disease) in 1975. By 2005 mortality rates had almost evened out, thereby largely dissolving the mortality advantages seen in Okinawan men and reducing those for women.

Health risk behaviours

In developed nations such as Japan, tobacco use, high blood pressure, physical inactivity and obesity, high blood glucose, high dietary salt intake, and alcohol usage have been reported to be major risk factors for early mortality.¹³ Three health risk behaviours have large gender differences in Japan traditionally: smoking, obesity, and alcohol consumption. In addition, a composite index of health behaviours (Breslow Health Practice Index) and a cluster of metabolic risk factors (metabolic syndrome) are explored in this analysis. In addition, we assessed a novel putative risk factor for several age-related diseases (e.g. coronary heart disease, congestive heart failure, stroke, cancer) and all-cause (total) mortality—GGT, which can be influenced by health behaviours or risk factors. Although traditionally thought of as a liver enzyme, GGT is present in many cells and tissues, including liver, cardiac, and brain and is

TABLE
Gender gap in life expectancy at birth for men and women (1975-2005)

Year	Men		Women		Gender gap		Male growth in life expectancy (years)		Female growth in life expectancy (years)	
	Japan	Okinawa	Japan	Okinawa	Japan	Okinawa	Japan	Okinawa	Japan	Okinawa
1975	71.79	72.15	77.01	78.96	5.22	6.81	-	-	-	-
1980	73.57	74.52	79.00	81.72	5.43	7.20	1.78	2.37	1.99	2.76
1985	74.95	76.34	80.75	83.70	5.80	7.36	1.38	1.82	1.75	1.98
1990	76.04	76.67	82.07	84.47	6.03	7.80	1.09	0.33	1.32	0.77
1995	76.70	77.22	83.22	85.08	6.52	7.86	0.66	0.55	1.15	0.61
2000	77.71	77.64	84.62	86.01	6.91	8.37	1.01	0.42	1.40	0.93
2005	78.79	78.64	85.75	86.88	6.95	8.23	1.08	1.00	1.13	0.87

Source: Okinawa Prefecture, Department of Health and Welfare, 2011

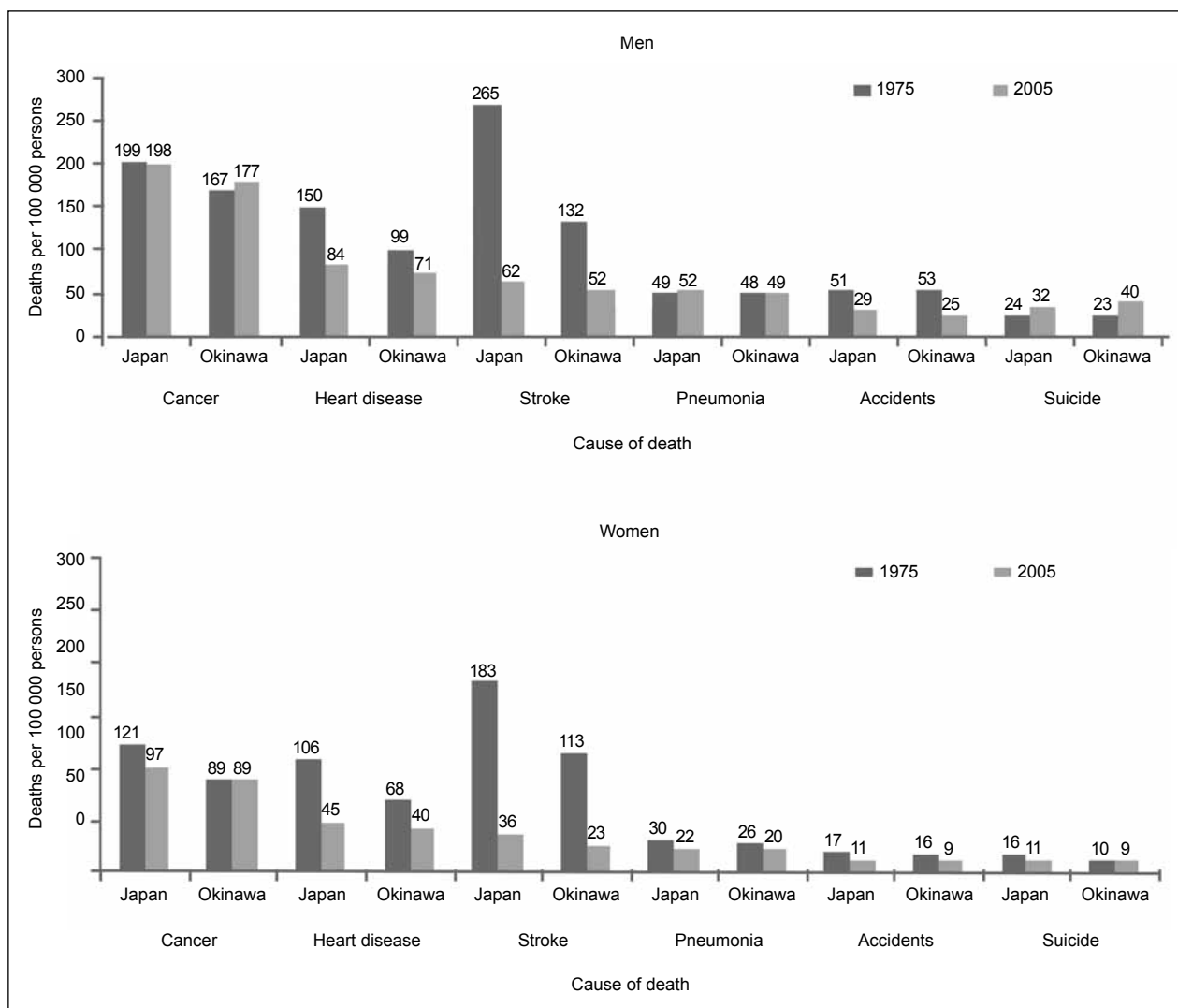


FIGURE 1. Age-adjusted death rates for men and women in Okinawa and Japan (1975-2005).

Source: Japan Ministry of Health, Labour and Welfare, 2007

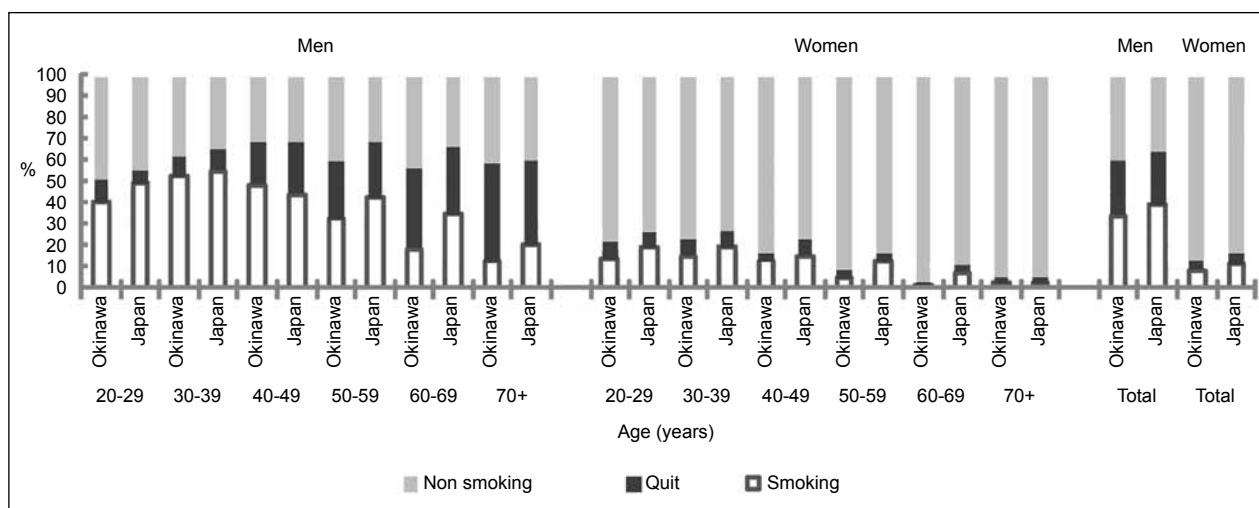


FIGURE 2. Percentage of smokers by age-group for men and women in Okinawa and Japan.

Source: Okinawa Prefecture, Department of Health and Welfare, 2007

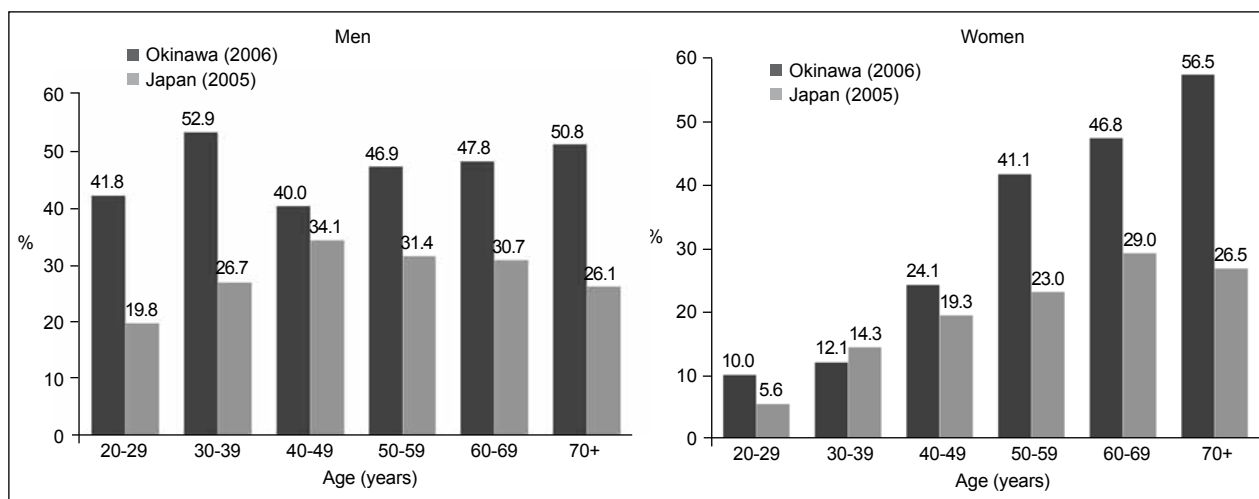


FIGURE 3. Percentage of obese (body mass index of >25) men and women in Okinawa and Japan.

Source: Okinawa Prefecture, Department of Health and Welfare, 2007

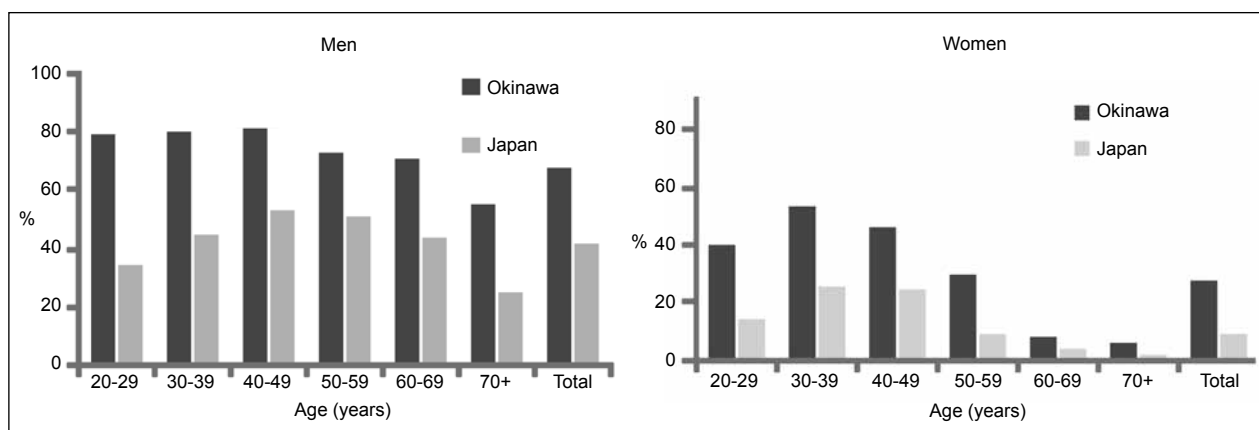


FIGURE 4. Percentage of habitual drinkers among men and women in Okinawa and Japan.

Source: Okinawa Prefecture, Department of Health and Welfare, 2007

increasingly recognised as a novel risk factor for morbidity in these related organ systems. It is unclear whether GGT plays a mechanistic role (possibly through influencing oxidative stress) or is simply an indicator of increased risk.¹⁴⁻¹⁷

Smoking

FIGURE 2 shows the proportion of men who are current or former smokers.¹⁸ About 6 in 10 men throughout Japan are either current or former smokers, compared to about 1 in 10 women. There are more current smokers among men in Japan than in Okinawa (39% vs. 34%), and this remains the case for every age category except for Okinawan men in their 40s, who smoke more than Japanese men (48% vs. 44%). There are more female smokers in Japan than in Okinawa in every age-group, with the exception of those aged 70 or older where numbers are similar. Okinawan male smokers far outnumber female smokers in every age

category, with the number approximately 4 times higher for men aged <50 years, 8 times higher for men in their 50s, and 18 times higher for men in their 60s.

Obesity

FIGURE 3 shows higher levels of obesity in the Okinawan population than in the mainland Japanese population.¹⁸ More men are obese in Okinawa than in mainland Japan in every age category. Approximately half of the men in each age-group in Okinawa are obese (body mass index, >25), according to the Japanese standard definitions of obesity. Moreover, more men are obese than women in Okinawa in every age category (except for age 70 years and older), with the number 4 times higher for men in their 20s, and 5 times higher for men in their 30s. Men are at higher risk of cardiovascular diseases, diabetes, obesity-linked cancers, fatty liver, and a multitude of other diseases. Moreover, higher risk is apparent from an earlier age with longer

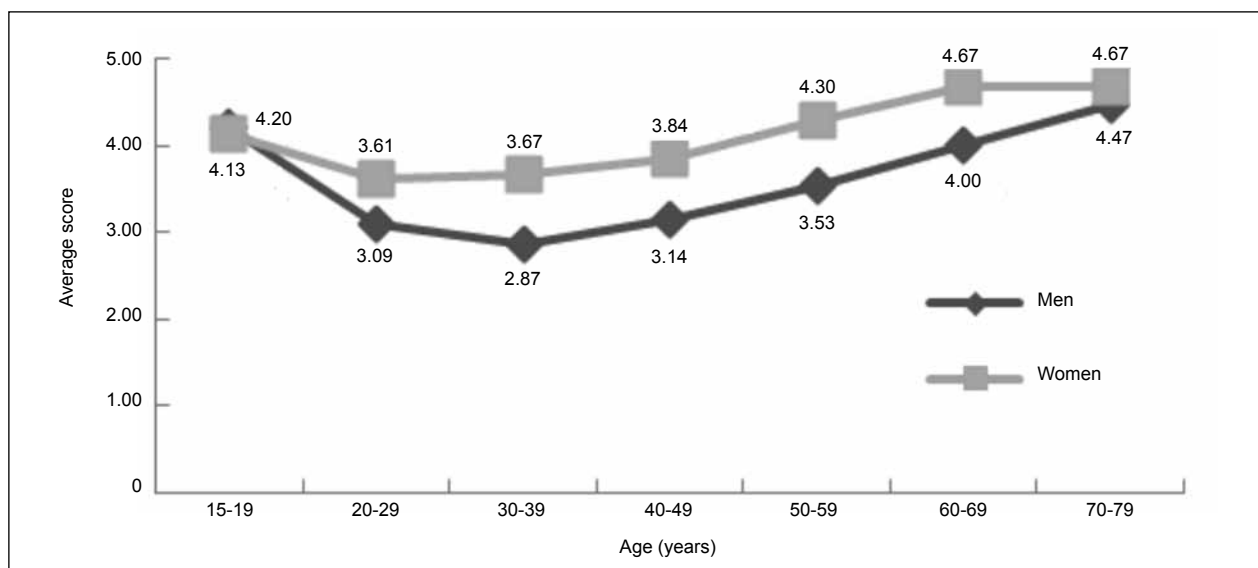


FIGURE 5. Breslow Health Practice Index scores for men and women in Okinawa. Higher score indicates healthier behaviour. One point is allocated for each of 7 health behaviours. Scores range from 0 to 7.

Source: Okinawa Prefecture, Department of Health and Welfare, 2008

lifetime exposure; over 40% of men in Okinawa become obese in their 20s, compared to only 10% of women.

Alcohol consumption

FIGURE 4 reveals the percentage of habitual drinkers (defined as more than 3 drinking days per week and more than 180 mL on those days) in Okinawa and mainland Japan.¹⁸ Men tend to drink habitually more than women throughout Japan. Both men and women in Okinawa show much higher habitual drinker rates than those in mainland Japan for every age category, with almost double for those aged <50 years. In Okinawa, the habitual drinker rates were much higher in men than in women: double for those aged <60 years, 7 times higher for those in their 60s, and 5 times higher for those aged ≥ 70 years.

Breslow Health Practices Index

FIGURE 5 shows the Breslow Health Practices Index for men and women in Okinawa. The Index is a validated tool for measuring the risk for age-associated disability and mortality.^{19,20} The Index assesses the risk using 7 health behaviours: adequate sleep, no smoking, healthy weight maintenance, moderate alcohol consumption, regular exercise, daily breakfast (not skipping breakfast), and no snacking between meals. The highest score is 7 indicating a healthy lifestyle. Men score lower in every age category than women, indicating that women on average have better health practices and fewer health risk behaviours.

Metabolic syndrome

Metabolic syndrome is characterised by the presence

of atherogenic risk factors and is associated with a substantially increased risk for diabetes and cardiovascular diseases, such as coronary heart disease.¹² In Japan, the definition of metabolic syndrome includes a constellation of risk factors such as abdominal obesity (waist circumference of ≥ 85 cm in men and ≥ 90 cm in women) and at least 2 of the following 3 components: (1) high-density lipoprotein (HDL) cholesterol of < 1.036 mmol/L or triglycerides of ≥ 1.695 mmol/L; (2) fasting blood glucose of ≥ 6.10 mmol/L; and (3) blood pressure of $\geq 130/85$ mm Hg.¹⁷ **FIGURE 6** indicates the high rates of metabolic syndrome among men in Okinawa, with approximately 30% of men between the ages of 40 and 74 years meeting the definition for metabolic syndrome and close to another 30% in the pre-metabolic syndrome stage. Except for men in their 40s, men in Okinawa show far higher rates than the mainland Japan average. Women in Okinawa have about half the male rates, with about 17% showing full-blown metabolic syndrome and another 17% at high risk for developing metabolic syndrome (pre-metabolic syndrome stage). Apart from women in their 30s, women in Okinawa also show higher rates than the Japan average.

Biomarkers of cardiovascular risk and overall unhealthy lifestyle

High levels of gamma glutamyl transferase (GGT or GTP or γ -GTP) have been used as an indicator of alcohol abuse, hepatobiliary disorders, fatty liver disease, and hepatitis. Longitudinal and cross-sectional studies have associated GGT with an increase in all-cause mortality, as well as common age-related causes of morbidity and mortality, including coronary heart disease, congestive heart failure, stroke, and some cancers. GGT has also been associated

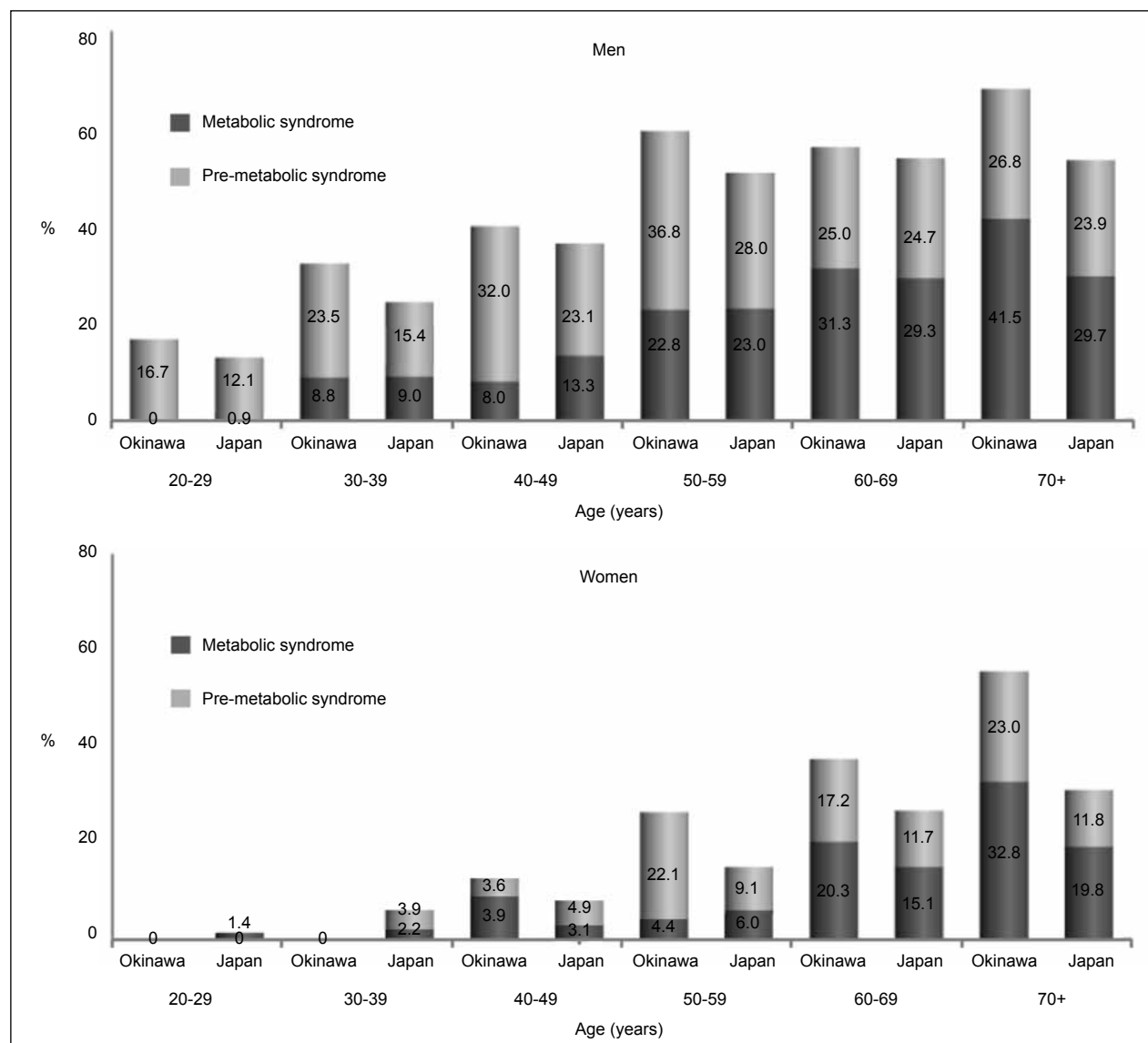


FIGURE 6. Metabolic syndrome in men and women in Okinawa and Japan.

Source: Okinawa Prefecture, Department of Health and Welfare, 2011

with specific components of the metabolic syndrome (abnormal body mass index and levels of HDL cholesterol, glucose, triglycerides, and systolic and diastolic blood pressure) and increased oxidative stress.^{21,22} Therefore, GGT has been increasingly touted for its applicability in primary and secondary prevention of cardiovascular disease.²¹ Other cardiovascular disease risk factors (obesity, smoking, lack of exercise) have also been associated with raised GGT levels.¹⁴⁻¹⁷ FIGURE 7 shows the percentage of the population in Okinawa and Japan with elevated (>51 IU/L) GGT liver enzymes. Over 40% of men under 50 years of age show elevated GGT liver enzymes according to prefectural health screening exam (tokutei kenshin) data, with every age category under 50 years showing higher levels than the Japan average. More women in Okinawa also show higher GGT levels than women in Japan, in accord with the higher rates of habitual drinkers,

obesity, and metabolic syndrome in Okinawa than the Japan average. Men in Okinawa aged <50 years also show almost double the rates of elevated GGT versus women in Okinawa, suggestive of less healthy lifestyles overall and the potential negative influence of multiple potential risk factors (smoking, obesity, alcohol consumption, Breslow Health Practice Index score, metabolic syndrome).

Closing the gap in life expectancy for men in Okinawa

FIGURE 8 reveals the gains in life expectancy if particular causes of death are eliminated for men and women in Okinawa and Japan.²³ Comparing men and women throughout Japan, the largest gains in life expectancy can be accomplished by eliminating cancer, which accounts for the highest share of mortality in both men and women. Men in general have more years (4 vs. 3 years) to gain by

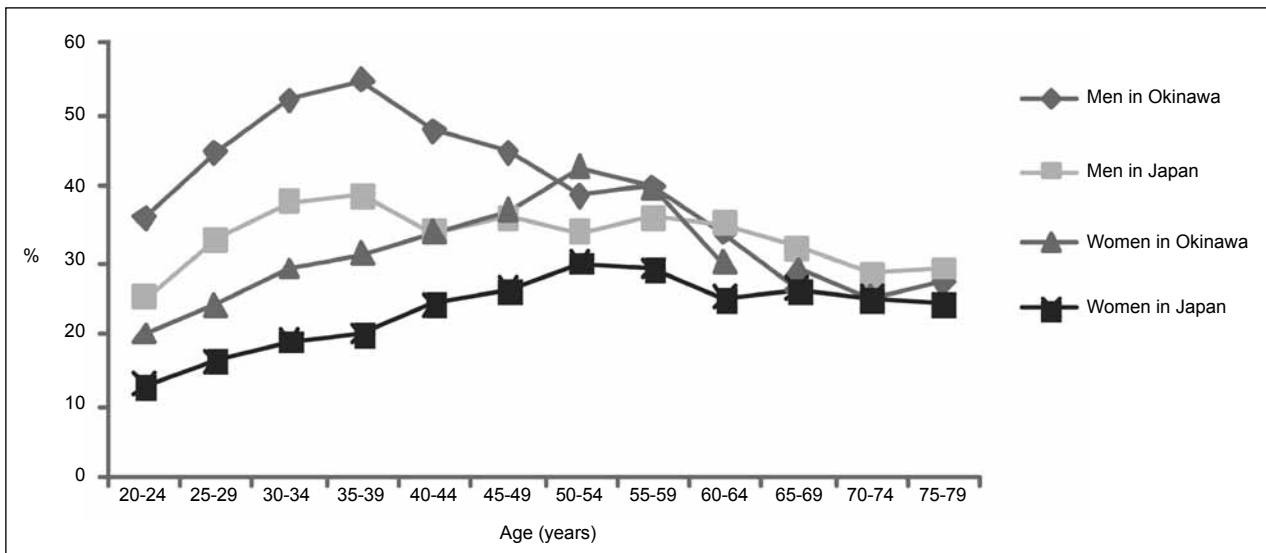


FIGURE 7. Percentage of population with elevated (>51 IU/L) gamma glutamyl transferase.

Source: Okinawa Prefecture, Department of Health and Welfare, 2007

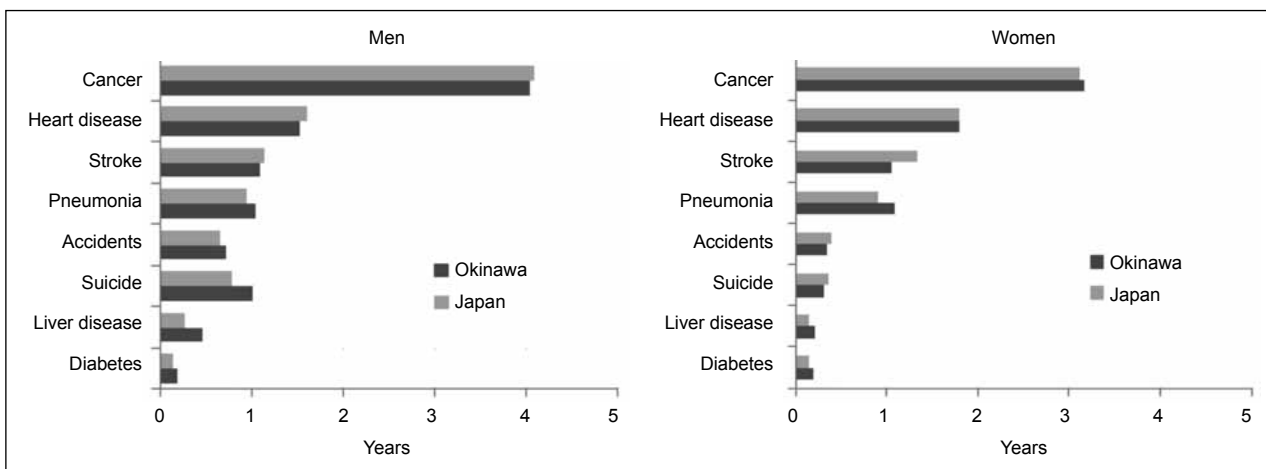


FIGURE 8. Growth in life expectancy by eliminating particular causes of death.

Source: Okinawa Prefecture, Department of Health and Welfare, 2008

eliminating cancer, as their mortality rates from this cause of death are higher. For men in Okinawa, elimination of preventable, violent causes of death (accidents and suicides) will overtake stroke and compete with coronary heart disease (currently number 2) as the second leading potential area where gains could be made for increased life expectancy. Moreover, the potential gains that could be achieved through the elimination of deaths due to liver disease (almost half a year increase in life expectancy) are notable for men in Okinawa.

DISCUSSION

Women usually outlive men in almost all nations although the magnitude of this gender gap varies

considerably.²⁴ In developed nations, women have lower mortality at all ages. Although there are more males at birth, the number of women gradually catches up and then exceeds the number of men such that by the age of 100 years, women comprise 80 to 90% of the centenarian population.^{3,25}

Some gerontologists suggest that biological differences between sexes explain why women live longer than men. Despite the potential importance of biological mechanisms, historical and paleo-demographic data indicate that the gender gap in longevity did not become pronounced in favour of women until fairly recently. For example, mortality data from European countries from the 19th and early 20th centuries reveal a mortality disadvantage for younger women, due mainly to higher death rates from

infectious and parasitic diseases, such as tuberculosis, and from the high mortality risk associated with childbirth.^{3,26} Various factors related to gender inequalities of the times include inadequate nutrition, poor housing and hygiene, lack of access to education and medical assistance, and poorer working conditions.^{3,26} The 20th century witnessed a rapid improvement in life expectancy in the developed nations that benefited women more than men. The higher pace of improvement peaked mainly in 2 age-groups: young adulthood, with mortality from accidents and violent behaviours (including self-inflicted violence such as suicide) being lower for women, and then again during late adulthood when cardiovascular diseases and cancer begin to take their toll on men.^{3,4,26} These gender gaps increased in most developed nations from the post-war period until stabilisation and narrowing of the gender gap began to take place.⁴⁻⁶

Stabilisation and/or closing of the gender gap in most developed countries began mainly with a decrease in cardiovascular mortality for men.^{4,5} In recent years, the reduction of the gender gap has been mainly due to the reversal in the trend for male cancer mortality, which is decreasing in most developed nations, in particular lung cancer mortality, which is associated with the decrease in smoking rates for men.^{4,5,27} Other contributing factors, depending upon the country, are decreasing rates of male mortality secondary to accidents, violence and/or suicide.^{5,6} However, in Japan, the gender gap is still increasing, mainly owing to high rates of male mortality from cancer (especially lung cancer) and respiratory disease, and a less impressive decrease in cardiovascular diseases for Japanese men, which is likely associated with much higher rates of smoking in men.^{4,5,11,13} Also, suicide rates for Japanese men have risen in recent decades, whereas rates for women have declined.

Despite the increasing gender gap in Japan, during the last 3 decades the growth in life expectancy for both men and women has been remarkable, with Japanese women outpacing both men and other women throughout the world.²⁸ Okinawa prefecture has been placed at or near the top of common longevity indices (life expectancy at birth, life expectancy at older ages, and centenarian ratios) since comparative data became available in 1975.²⁹ However, during the period examined (1975 to 2005) the growth in life expectancy for men in Okinawa was slower, and male life expectancy began to equalise between Okinawa and the Japan average in the mid 1990s.^{7,11,29} Nonetheless, women from Okinawa had a larger initial advantage in life expectancy than women from other prefectures and therefore remain in top ranking, although the growth in life expectancy has become slower.^{11,29} Detailed analyses according to age-group show that the remaining mortality advantages for women (and men) are among those in the older age-groups, indicating that if the currently middle-aged and younger cohorts move through time without significant departures from present health and mortality

trends, further drops in life expectancy rankings are inevitable.^{7,11,29}

The analysis of differences in causes of death between 2 time periods (1975 and 2005) revealed that the decrease in age-adjusted death rates from cardiovascular diseases (mainly coronary heart disease and stroke), especially that of stroke, contributed most to gains in life expectancy. Gains for women from Okinawa and Japan from reduced mortality from stroke have been even more impressive than for men, and this has helped to widen the gender gap, with women aged ≥ 75 years gaining most in terms of added years.^{11,29} Although reduction in death rates from cardiovascular diseases has played the largest role in the growth of life expectancy over the past few decades, these causes of death have gradually played a less important role in the gender gap than has cancer, which in 2005, accounted for the largest share of mortality.^{11,29} Moreover, men had approximately double the overall cancer mortality rates of women in 2005, and therefore cancer is currently the single most important cause of mortality in bringing about the gender gap in life expectancy in Okinawa. These findings are similar for Japan as a whole.¹⁰ Suicide, from which Okinawan men are >4 times more likely to die than Okinawan women, has increased since 1975, currently the 5th leading cause of death for men in Okinawa, following pneumonia. Combining mortality rates from violent causes of death (accidents and suicides) would result in it ranking the 3rd highest cause of mortality for men, overtaking stroke and competing with heart disease for 2nd place.

Both cancer and cardiovascular mortality are strongly associated with smoking. Recent rising rates of lung cancer deaths among women in most developed countries are in direct contrast with declining rates among men and are a cause of much concern among public health officials. Smoking rates between men and women have been moving towards parity and are playing a strong role in the reversal in the direction of change in overall gender differences in life expectancy.³⁰⁻³² Smoking is the single largest cause of cancer in the world and is responsible for most lung cancers and is a major risk factor for liver and other cancers, as well as ischaemic heart disease, chronic obstructive pulmonary disease, emphysema, bronchitis, and other causes of early mortality.^{30,31,33} Male smoking rates in Japan have declined in recent years, but almost half of younger Japanese men (age < 50 years) still smoke and declines are too recent to confer drops in tobacco-related mortality rates for Japanese males which are likely to be slowing life expectancy gains for years to come.^{6,11,13,18} Although smoking has been shown to be the number one determinant of adult mortality from non-communicable diseases in Japan,¹³ public health interventions have lagged behind and smoking remains widely accepted in homes, restaurants, some workplaces, and many other public spaces, contributing not only to a higher risk for smokers, but also for passive smokers.³⁴⁻³⁶ Trivial increases

in cigarette taxes and a permissive legal framework may reflect the conflict of interest faced by the Ministry of Finance because of the large tax revenue from the sale of tobacco.³⁷ The Japanese government has traditionally been a major shareholder in Japan Tobacco, and this is a potential conflict of interest and a major public health challenge.^{34,37} Further resistance comes from local civic business interests with fears of impact on their customer base. Multiple, overlapping public health policies, including a substantial increase in tobacco tax, may be needed in order for Japan to reduce smoking rates to the levels of other developed nations.^{34,35,37,38}

Negative contributions to life expectancy and the increasing gender gap are also resulting from increases in deaths from liver disease for men aged ≥ 35 years in Okinawa (and throughout Japan), with men showing twice the risk of women.^{7,11,23,29} Alcohol consumption is a well-known risk factor for diseases of the liver and Okinawa prefecture suffers from the ignominious distinction of having the highest rates of alcohol-related liver disease for both men and women, approximately double that of the Japan average.³⁹ However, smoking and obesity are also independent risk factors for mortality from liver disease. Smoking and obesity may also interact synergistically with alcohol consumption, thus increasing the risk for liver cancer, other cancers, and other diseases of the liver.⁴⁰

Following cancer, heart disease and stroke are the 2nd and 3rd leading causes of death in Japan for both men and women. Impressive gains in life expectancy have been made over the past 3 decades by reducing mortality from these diseases in developed nations, particularly in Japan where the most impressive contribution to life expectancy gains over the period from 1975 to 2005 came from the decrease in stroke mortality.^{11,29} In contrast to the trends for Japanese men overall, recent cardiovascular disease mortality trends for men in Okinawa (especially those aged 35 to 64 years) have negatively impacted on life expectancy gains.¹¹ Surely, there is much more that could be accomplished through greater public health efforts. According to the World Health Organization, at least 80% of premature deaths from cardiovascular diseases could be prevented through a healthy diet, regular physical activity and avoiding the use of tobacco.⁴¹ Recurrence rates for stroke have been reported to be high in Okinawa compared to mainland Japan, suggesting the need for increased compliance with treatment regimens, or better yet, the need for participation in follow-up health screening exams, as well as a return to the traditional Okinawan diet that has been shown to be low in calories and glycaemic load yet nutrient-dense and antioxidant-rich, and an ideal dietary pattern to reduce risk for age-associated diseases.^{11,39,42}

A focus on men's health in Okinawa should be a public health priority, and progress in bridging the gender gap in life expectancy in Okinawa could be made by reducing mortality from cancers in men that are showing upward

trends (such as lung, liver, and intestinal cancers) and that respond well to lifestyle interventions, such as smoking cessation and dietary change (especially increased vegetable intake and reduced sodium intake). Metabolic syndrome and obesity respond well to diet and exercise programmes⁴³ if adhered to, and violent causes of death (suicide and accidents) and alcohol-related liver diseases require psychosocial interventions that focus upon the male working age population where stress, depression, and related psychological disorders, and economic reasons such as unemployment, debts, or business failure, are major contributing factors.³⁴ Healthier lifestyles by men in mid-life or earlier would no doubt help to reduce the risk for age-associated diseases and early mortality and therefore reduce the gender gap, as can be seen in other populations, such as long-living Japanese American men in Hawaii.⁴⁴

The Ministry of Health, Labour and Welfare recognises the challenges and employs a punitive approach of reduced government subsidies for health insurance to municipalities that fail to meet participation targets in health screening examinations.⁴⁵ However, this 'stick' approach would be more effective if supplemented by a 'carrot' approach that relies upon non-governmental organisations, small groups, families, communities, and other social units that utilise supportive relationships and that help 'fill the gap' between health care providers and local populations. Indeed, the very success of Healthy Okinawa 21, the prefectural health promotion plan, may depend upon who takes the initiative.^{39,46}

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REFERENCES

1. Yanagishita M, Guralnik JM. Changing mortality patterns that led life expectancy in Japan to surpass Sweden's: 1972-1982. *Demography* 1988;25:611-24.
2. Japan Ministry of Health Labour and Welfare. *Age-adjusted death rates by prefecture for 2005, Special Report on Vital Statistics* [in Japanese]. 2008.
3. Gjonca A, Tomassini C, Vaupel JW. Male-female differences in mortality in the developed world. *Max Planck Institute for Demographic Research* WP 1999-009:1-9. Available at www.demogr.mpg.de.
4. Trovato F, Lalu N. From divergence to convergence: the sex differential in life expectancy in Canada, 1971-2000. *Can Rev Sociol Anthropol* 2007;44:101-22.
5. Mesle F. Gender gap in life expectancy: the reasons for a reduction of female advantage [in French]. *Rev Epidemiol Sante Publique* 2004;52:333-52.

6. Trovato F, Heyen NB. A divergent pattern of the sex difference in life expectancy: Sweden and Japan, early 1970s-late 1990s. *Soc Biol* 2003;50:238-58.
7. Okinawa Prefecture, Department of Health and Welfare, Division of Health Promotion. 26 *Shock!* 2005 [in Japanese]. Available at <http://www.kenko-okinawa.jp/kankobutu/26shock>.
8. Watahiki N, Nishida S. Sex differential in life expectancy at birth in Japan: (2) trends in sex differential in life expectancy at birth from 1920 to 1990 [in Japanese]. *Minzoku Eisei* 1996;62:139-53.
9. Mizushima Y, Mizuno H, Urada Y. The influence of the top cause of death on life expectancy among prefectures in Japan [in Japanese]. *Gerontology* 2004;16:65-9.
10. Yoshinaga K, Une H. Contributions of mortality changes by age group and selected causes of death to the increase in Japanese life expectancy at birth from 1950 to 2000. *Eur J Epidemiol* 2005;20:49-57.
11. Willcox DC. Why do women live longer than men? A demographic analysis of male-female mortality differences in Okinawa and Japan. *Okinawa Int Univ J Sci Res* 2007;11:1-16.
12. Okinawa Prefecture, Department of Health and Welfare, Division of Health Promotion. 2008 *report on health screening for metabolic syndrome* [in Japanese]. 2011.
13. Ikeda N, Inoue M, Iso H, Ikeda S, Satoh T, Noda M, et al. Adult mortality attributable to preventable risk factors for non-communicable diseases and injuries in Japan: a comparative risk assessment. *PLoS Med* 2012;9:e1001160.
14. Mukaiya M, Nishi M, Miyake H, Hirata K. Chronic liver diseases for the risk of hepatocellular carcinoma: a case-control study in Japan. Etiologic association of alcohol consumption, cigarette smoking and the development of chronic liver diseases. *Hepatology* 1998;45:2328-32.
15. Rantala AO, Lilja M, Kauma H, Savolainen MJ, Reunanen A, Kesaniemi YA. Gamma-glutamyl transpeptidase and the metabolic syndrome. *J Intern Med* 2000;248:230-8.
16. Yokoyama H, Ohgo H, Hirose H, Moriya S, Hibi T, Saito I. An inverse association between serum gamma glutamyl transpeptidase activity and Breslow's Lifestyle Index: its practical application for screening of subjects with unhealthy lifestyles. *J Occup Health* 2006;48:198-206.
17. Taki K, Nishio K, Hamajima N, Niwa T. Metabolic syndrome defined by new criteria in Japanese is associated with increased live enzymes and C-reactive protein. *Nagoya J Med Sci* 2008;70:1-9.
18. Okinawa Prefecture, Department of Health and Welfare, Division of Health Promotion. *Report on health and nutrition research in Okinawa for 2005* [in Japanese]. 2007.
19. Breslow L, Breslow N. Health practices and disability: some evidence from Alameda County. *Prev Med* 1993;22:86-95.
20. Okinawa Prefecture, Department of Health and Welfare, Division of Health Promotion. *Citizen survey on health consciousness* [in Japanese]. 2003.
21. Mason JE, Starke RD, Van Kirk JE. Gamma-glutamyl transferase: a novel cardiovascular risk biomarker. *Prev Cardiol* 2010;13:36-41.
22. Okinawa Prefecture, Department of Health and Welfare, Division of Health Promotion. 2004 *report on health screening* [in Japanese]. 2007.
23. Okinawa Prefecture, Department of Health and Welfare, Division of Health Promotion. *Healthy Okinawa 2010* [in Japanese]. 2008.
24. Barford A, Dorling D, Davey Smith G, Shaw M. Life expectancy: women now on top everywhere. *BMJ* 2006;332:808.
25. Willcox DC, Willcox BJ, Poon LW. Centenarian studies: important contributors to our understanding of the aging process and longevity. *Curr Gerontol Geriatr Res* 2010;2010:484529.
26. Tabutin D, Willems M. Excess mortality of girls up to 1940: a good example of sexual inequalities in western history. In: Masuy-Stroobant G, editor. *Sante et Mortalites des Enfants en Europe: Inegalites Sociales D'hier et Aujourd'hui* [in French]. Louvain-la-Neuve, Belgium: Academia-Bruylant; 1996:129-77.
27. Pampel F. Cigarette use and the narrowing sex differential in mortality. *Popul Dev Rev* 2002;28:77-104.
28. Christensen K, Doblhammer G, Rau R, Vaupel JW. Ageing populations: the challenges ahead. *Lancet* 2009;374:1196-208.
29. Kuwae N, Shimoji A, Kinjo K, Sakiyama H. Trends of life expectancy, age-adjusted death rates and death rates by sex, age and leading cause of death in Okinawa 1973-2002 [in Japanese]. *Okinawa Prefecture Health and Environment Research Institute Report* 2006;40:121-7.
30. Medalia C, Chang VW. Gender equality, development, and cross-national sex gaps in life expectancy. *Int J Comp Soc* 2011;52:371-89.
31. Pampel FC. Declining sex differences in mortality from lung cancer in high-income nations. *Demography* 2003;40:45-65.
32. Lopez AD. The lung cancer epidemic in developed countries. In: Lopez AD, Caselli G, Valkonen T, editors. *Adult mortality in developed countries: from description to explanation*. Oxford, England: Clarendon Press; 1995:111-43.
33. Trovato F, Lalu NM. Contribution of cause-specific mortality to changing sex differences in life expectancy: seven nations case study. *Soc Biol* 1998;45:1-20.
34. Ikeda N, Saito E, Kondo N, Inoue M, Ikeda S, Satoh T, et al. What has made the population of Japan healthy? *Lancet* 2011;378:1094-105.
35. Kotani K, Osaki Y, Kurozawa Y, Kishimoto T. A survey of restaurant smoking restrictions in a Japanese city. *Tohoku J Exp Med* 2005;207:73-9.
36. Kurahashi N, Inoue M, Liu Y, Iwasaki M, Sasazuki S, Sobue T, et al. Passive smoking and lung cancer in Japanese non-smoking women: a prospective study. *Int J Cancer* 2008;122:653-7.
37. Tanaka K, Johnson NE. What Japan can do to push its longevity envelope. *Population Reference Bureau*. 2006. Available at www.prb.org.
38. Kayaba K, Wakabayashi C, Kunisawa N, Shinmura H, Yanagawa H. Implementation of a smoke-free policy on school premises and tobacco control as a priority among municipal health promotion activities: nationwide survey in Japan. *Am J Public Health* 2005;95:420-2.
39. Okinawa Prefecture. Department of Health and Welfare. Division of Health Promotion. *Healthy Okinawa 21*. Available at <http://www.kenko-okinawa21.jp/>
40. Marrero JA, Fontana RJ, Fu S, Conjeevaram HS, Su GL, Lok AS. Alcohol, tobacco and obesity are synergistic risk factors for hepatocellular carcinoma. *J Hepatol* 2005;42:218-24.
41. World Health Organization. *World Health Report* 2008. Geneva: 2008.
42. Willcox DC, Willcox BJ, Todoriki H, Suzuki M. The Okinawan diet: health implications of a low-calorie, nutrient-dense, antioxidant-rich dietary pattern low in glycemic load. *J Am Coll Nutr* 2009;28(Suppl):500S-516S.
43. Willcox BJ, Willcox DC, Suzuki M. *The Okinawa diet plan*. New York: Random House; 2004.
44. Willcox BJ, He Q, Chen R, Yano K, Masaki KH, Grove JS, et al. Midlife risk factors and healthy survival in men. *JAMA* 2006;296:2343-50.
45. Ministry of Health, Labour and Welfare. *Standard health examination and guidance program* [in Japanese]. Tokyo: Ministry of Health, Labour and Welfare; 2007.
46. Ogawa S, Boostrom E, Nakasone T. *Healthy Okinawa: a problem and a program*. Available at http://webistem.com/psi2009/output_directory/cd1/Data/articles/000528.pdf.