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They Really Are That Old: A Validation Study of Centenarian Prevalence in Okinawa

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Long-lived individuals, such as centenarians, may harbor genetic or environmental advantages important for healthy aging. Populations with high prevalence of such individuals offer fertile ground for such research. However, precise phenotypes are required, particularly accurate age. Okinawa has among the world's highest reported prevalence of centenarians but, despite extensive study, no systematic validation of centenarian prevalence has been published. Therefore, we performed comprehensive age validation of a subset (8%) of the total centenarian population and assessed the reliability of the age registration system. Self-reported age was validated with several common methods and found to correlate well with documented age. Demographic methods, including assessment of age heaping, maximum age at death, centenarian proportions, and male to female ratios of centenarians indicate that the age registration system is reliable. We conclude that the high reported centenarian prevalence in Okinawa is valid and warrants further study for its genetic and environmental correlates.

Key Words: Longevity—Centenarian—Age Validation—Okinawa.

THE National Institute on Aging (NIA) Advisory Panel on Exceptional Longevity (APEL) (1) and the NIA strategic plan (2) have identified healthy aging as a research priority. However, few individuals survive to exceptional ages in robust health. Centenarians possess genetic and/or environmental attributes that allow them to survive to exceptional ages, and many appear to delay or avoid major age-related diseases and disability (3,4). Okinawa, the southwesternmost prefecture of Japan, is an isolated island population that possesses the longest life expectancy and the lowest risk for major age-related, chronic diseases in Japan, the world's longest-lived country (5–7). Geriatric studies of the older population also demonstrate that Okinawans appear to have high physical and cognitive function at older ages (3,8,9). Consistent with these studies, the Japanese government's Annual Centenarian Report ranks Okinawa as having the highest prevalence of centenarians of any prefecture within Japan (10). Therefore, the Okinawan population may be important for further study of genetic and/or environmental traits that lead to exceptional longevity, including longevity with good health. However, studies of exceptionally aged persons require precise definitions of phenotypes, the most important of which is accurate age for the study participant.

Early centenarian studies had major challenges with age validation (11,12). In the majority of studies of exceptionally long-lived populations, the most pressing concern has been with age exaggeration as compared with errors in the opposite direction (i.e., reporting of ages as being younger than they actually are). Factors that have been associated with age misreporting include: lack of an age registration system to record births and deaths, destruction of records by war or natural causes, artificially inflating one's age to avoid military service or to qualify for admission to a country or work at the time of immigration, widespread illiteracy within a population, and cultural traditions that place little emphasis on dates of birth or have different calendar systems for recording age (11–16).

Countries that rely on census records to estimate prevalence data for centenarians are particularly prone to inflation of actual numbers of centenarians through practices of age heaping and age rounding, where the majority of ages appear to fall at easily remembered major ages such as age 100 years. The 1980 U.S. Census for example, reported approximately double the actual, realistic prevalence rates of centenarians (11,17). Therefore, in studies of exceptionally long-lived individuals, or populations that claim to have high numbers of centenarians, careful scrutiny of birth records, death records, and other age-related documents is necessary to support longevity claims.

One of the most comprehensive databases on oldest-old mortality is the Kannisto-Thatcher Oldest-Old Database within the Odense Archive of Population Data on Aging (18). The database documents ages for most countries for

the oldest-old (defined as age 80 years and older) beginning in the year 1950. Numerous demographic tests of the data set have been carried out to assess the quality of international data on the oldest-old. From these various analyses, Kannisto (18) categorized countries into four categories according to the quality of their data: *Good*—Japan and 19 European countries; *Acceptable*—Australia, New Zealand non-Maori, Portugal, and Singapore Chinese populations; *Conditionally Acceptable*—Estonia, Ireland, Latvia, Poland, and Spain; and *Poor*—Canada, Chile, New Zealand Maori, and the United States. Thus, Japan has long been considered to have among the highest quality data for the oldest-old.

The high quality of age-reporting data from Japan is due largely to its extensive, cross-referenced, and overlapping system for age registration. In fact, as early as 1872, a national birth registration system (which encompassed the entire population) called the *koseki* (family register) was implemented based on place of residence at birth. Various additions have been made to the *koseki* system since its inception. For example, in 1914, a complementary resident registration system (*jumin daicho*), based on municipality of residence, and providing names, dates of birth, and address of household members was added. Japanese resident registration law requires each citizen to report his or her current address to the local municipality, which compiles the information for purposes of tax, national health insurance, and census matters. Deaths are recorded after reporting the death to the municipality of current residence, which then sends the information to the municipality of permanent residence where it is recorded in the *koseki*. The birth and death registration system is supplemented by a census (*kokusei chousa*), undertaken first in 1899 and every 5 years since 1920. Since 1963, the Ministry of Health, Labour and Welfare has also compiled a list of centenarians based on data supplied by municipalities from the resident registration system. However, the core of the age registration system is the *koseki*.

Japanese *koseki* law requires that all households report births, deaths, marriages, divorces, and criminal convictions to their local municipality, which compiles the information into the *koseki*. It is a testament to the importance of this document that if such events are not recorded in the *koseki*, they might not be officially acknowledged by social or governmental institutions. For example, a copy of the *koseki* may be required as a legal document on many occasions, such as application for a passport, application for certain jobs, or entrance to schools or universities. The information contained within the *koseki* is detailed, sensitive, based on the family rather than the individual, and continually updated. The *koseki* includes the permanent address (*honseki*) of the family, the name of the family head, his or her date of birth, birth order (e.g., first son, second daughter), names and dates of birth of his or her parents, and names of spouse and children, their dates of birth, their sex, their birth order, their parent's names if they are other than the head and his wife, and their relationship to the family head.

In addition, the actual age of the *koseki* document can be checked, including the date when the document was filed, whether it is an original or a copy, and if a copy, then the date that it was copied, and the name and location of the official who sealed the copy. Any changes to the original information require prior approval from municipal public officials and a seal by an official registrar, and usually (depending on the details) require a decision in family court. The *koseki* can therefore be said to contain the history of its own evolution and perhaps even to fulfill the role that birth certificates, death certificates, marriage licenses, and the census play in other countries, all in one document—although these other documents (birth, death, and marriage certificates) also exist, they are not, by law, required to be kept on file at the local municipality after the information is entered into the *koseki*. When recorded, these documents are transferred to the local office of the Ministry of Justice (*houmukyoku*).

Formerly, the *koseki* was kept in each municipality as a paper record, but the system has been computerized and cross-referenced with other databases since 2002. Laws governing access to these documents and related personal privacy laws have been strengthened in Japan since cross-referencing of the system. Thus, records are held in strict privacy and are usually only issued to family members, the police, lawyers involved in legal proceedings, or a proxy officially designated by a family member.

Despite the extensive age registration system that ensures high quality, age-reporting mistakes have occurred, particularly in the early years of the system. This is illustrated by the case of Shigechiyo Izumi from Kagoshima prefecture, who was once regarded as the world's oldest man at 120 years of age. Although the *Guinness Book of World Records* (19) continues to regard him as the oldest man ever documented, deeper investigation of this case by Japanese gerontologists has revealed that, in all likelihood, Mr. Izumi had ''inherited'' the name and *koseki* of an older deceased sibling. More likely, he was born around 1880, which would have made him 105 years old at the age of death (20). Likewise, a common practice in the early part of 20th century Japan was to delay reporting of births to municipalities until there was greater certainty that the child would actually survive. Therefore, under-reporting of infant mortality was rampant, and many children did not become registered as ''new births'' in the *koseki* of their household until they were 1 or 2 years of age, or even older.

The *koseki* system has gone through regular revisions with the Japanese government replacing previous versions on no fewer than five occasions since the inception of the system in 1872. Updates occurred in 1886, 1898, 1915, and 1948 throughout Japan. Every replacement of existing records incurs risk of copying error. Moreover, the Second World War led to extensive damage throughout Japan's major cities leading to loss of many documents such as *koseki*. Therefore, regions such as Okinawa, which suffered extensive war-related upheaval, had to rebuild large parts of their age registration infrastructure. The above historical circumstances have led some demographers to question the validity of age reporting in Japan at the regional level, particularly in Okinawa and other areas of the nation that have suffered heavy war damage (21). However, questioning the age-reporting data of these regional areas has been largely a theoretical issue based on conjecture, and despite

studies of the quality of the Japanese data at the national level, there have been no systematic age-validation studies carried out at prefectural (state) levels reported in the gerontological literature.

Because the prefecture of Okinawa has what may be the world's highest prevalence of centenarians and appears to be an area of exceptional longevity, it is important to validate this phenomenon by epidemiologic, anthropologic, and demographic criteria. Therefore, in this study we asked three questions: (1) What is the accuracy of self-reported ages of centenarians in Okinawa? (2) What is the reliability of the age registration system in Okinawa? (3) If the age registration system is reliable, what is the true centenarian prevalence in Okinawa for the year 2006?

Methods

Identification and Recruitment of Study Participants

The Okinawa Centenarian Study (OCS) began in 1975, recruited its first study sample in 1976 (22), and is currently the world's longest continuously running study of centenarians (7). It is population based and focuses on the prefecture (state) of Okinawa—the southernmost of 47 prefectures within Japan. All studies, including the current study, are undertaken with Institutional Review Board approval from Okinawa International University. To minimize selection bias, the OCS yearly locates all centenarians who reside on Okinawa's main island, where the majority (84%) of the prefecture's population resides, and examines a subset of these individuals. To locate and validate potential study participants, we use the resident and family registers. In usual circumstances, these documents are not publicly available, and access is restricted to family members or government officials who maintain the records. However, in special circumstances, permission can be acquired from families or government officials to view the documents. We were able to obtain special permission from government officials to access these documents in the company of government officers. We were therefore able to access the names, dates of birth, and addresses of every centenarian reported to official centenarian lists in Okinawa from April 1976 through March 2004.

Validation Procedures: Self-Reported Age

During the years 1976 through 2004 the date of birth, as recorded in the *koseki,* was accepted as the main proof of age, as it is the equivalent of the birth certificate in the West. These documents were checked by the public officials at the level of the municipality of the (currently 41) cities, towns, and villages in Okinawa and reported back to a prefectural government official collaborating with our study, who then reported the names, dates of birth, and addresses to us.

After receiving the date of birth of the centenarians, we then contacted the centenarian and/or the proxy to arrange a visit to the place of residence where we requested further corroborative evidence indicating the centenarian's age such as medical records, school records, military certificates, certificates celebrating important (Okinawan) cultural coming of age milestones (at ages 88, 97, and 100), or other documents that listed the centenarian's age. We also performed family reconstruction to note dates of birth and/or birth order of parents, siblings, children, and grandchildren. Participants whose ages, as verified through the above multiple procedures, were in doubt were excluded from the study.

Although these validation procedures are considered adequate to establish age as a phenotype (23), growing interest in the study of long-lived populations as a means to understand human aging (1) has resulted in increasingly stringent efforts at age validation. Therefore, in 2005, to gain a more precise measure of the prevalence, size, and direction of discrepancies between reported age and age recorded in the *koseki*, we carried out an intensive age validation study on a subset of the total centenarian population in Okinawa prefecture. Because most of the centenarians in our previous work (1976–2004) were deceased, we chose all centenarians living in three representative cities, towns, and villages of Okinawa. This subsample represented approximately 8% of the total reported number of centenarians and encompassed both urban and rural areas.

Verbal substantiation of *koseki* records (dates of birth) from participants themselves and/or their family members as well as neighbors were solicited and cross-checked with the other age validation procedures reported above. In addition, we also systematically checked, in a face-to-face interview, the Chinese animal year of birth. In Asian cultures, an important tool for age verification comes from identifying the year of birth based on the Chinese zodiac (16). Every Japanese person is also keenly aware of the Chinese animal year in which they were born, and this was an extremely valuable device for cross-checking the accuracy of the birth year as recorded in the *koseki*. When discrepancies were found, they were noted and further probing was carried out to find out the source of the error and which date of birth was correct. Neighbors were also consulted because, in the Okinawan cultural context, endogamy (practice of marrying only with specified social groups, classes, or ethnicities) within the village was a common practice during the prewar period, and villagers have remained part of the same age grade throughout their lives and celebrated coming of age ceremonies every 12 years as a group (12 years is the period of time required for one complete cycle of the *Eto* or Chinese animal year zodiac). Therefore, villagers have a keen awareness of their age, their animal birth year and, in particular, their age in relation to other members of the community. Finally, we also requested an official copy of the centenarian's *koseki* from family members.

Validation Procedures: Demographic Validation of the Age Registration System

Another method of validation of centenarian prevalence is to assess the accuracy of the age registration system by demographic means. Therefore, we used seven separate demographic methods to assess the reliability of the age registration system in Okinawa.

Interprefectural validation.—Centenarian prevalence can be compared within a country to assess whether unusual

regional variations exist. The population distribution of centenarians by region may vary with some regions having high numbers and others having low numbers, depending on a number of different factors that affect population structure (such as immigration, emigration, birth cohort size, death rates); however, centenarian numbers in prefectures should not stand out so far from others as to be implausibly high (or low). To see if Okinawa's centenarian rates were highly unusual compared to other prefectures, we tabulated officially reported centenarian prevalence rates in the top 10 and bottom 10 prefectures.

Intraprefectural validation.—We also assessed potential *koseki* damage during wartime, because loss of some original *koseki* documents during World War II may have led to mistakes when documents were reconstructed in the postwar period. We surveyed all 41 cities, towns, and villages in Okinawa prefecture to identify which of them had original prewar *koseki* and which had only postwar reconstructed *koseki;* we then compared centenarian prevalence. If centenarian prevalence in areas where the *koseki* was reconstructed was markedly different from areas where the prewar *koseki* was still intact, this may indicate a source of age bias in the postwar reconstructed *koseki*.

Assessment of total number of centenarians over time.—Past research on quality of population age data has shown that the effects of age overstatement within a population can be assessed by counting the total number of centenarians year by year in a population. Given that most populations have increased in size over time and mortality rates have decreased, centenarian numbers should, on average, show increasing numbers over time. Observing lower numbers of centenarians over time in a growing population should engender suspicion of age overstatement. For example, in the United States, the absolute number of centenarians reported in decennial censuses actually fell between 1920 and 1940 despite both population growth and mortality improvements. This counterintuitive finding has been reported to be a result of more accurate age reporting because the resultant decline in census-recorded centenarians more than made up for the expected increase in centenarians due to population increase and cohort mortality reductions (24). To assess whether similarly poor reporting or record-keeping affected centenarian numbers in Okinawa, we plotted absolute numbers of centenarians since 1972, exactly 100 years after the initiation of the original *koseki* system throughout Japan. The growing size of younger birth cohorts and more favorable survival rates should have resulted in steady increases in centenarian numbers in Okinawa over time, as in most industrialized countries (25).

Assessment of maximum age at death.—The reliability of centenarian mortality data in Okinawa can also be tested by analyzing the maximum age at death in Okinawa versus other populations. Kannisto (25) has shown that such comparisons can be undertaken to measure reliability of data on centenarians. For example, age overstatement can be estimated by analyzing the maximum age at death for men and women in a population. If the ages appear implausibly high, then it is likely that age exaggeration has taken place. To test for age overstatement, we examined the maximum age at death reported for centenarians in Okinawa and compared these data with those from countries known for having reliable mortality data at advanced ages.

Assessment of centenarian age proportions.—Another method for examining whether age exaggeration has taken place in a population is to tabulate the proportion of centenarians 105 years old or older among all centenarians. The expected proportion should appear as a reasonable number, usually between 5% and 10%, and should in all likelihood be smaller for men than for women (25). Furthermore, due to rapid depletion of the population at these extreme ages, the percentage of centenarians 110 years old or older among those 105 years old or older (110+/105+) should be smaller than the first indicator (105+/100+).

Assessment for potential age heaping.—Another demographic sign of age misreporting is *age heaping*—that is, the preference for choosing certain numbers divisible by 2, 5, or 10, and fewer at other ages. This often takes place in census data where more persons are listed at round ages such as age 70 years than at ages 71–79 years, inclusive. Age heaping can be assessed in centenarians. The risk of dying is expected to be higher at age 101 years than at age 100 years; therefore, the ratio of mortality risks at age 100 divided by 101 years should be below unity ($q100/q101 < 1$). If it is not, then it is likely that age heaping has taken place at age 100. We also used Whipple's Index for Centenarians, another measurement for evaluating age heaping among centenarians, developed by Wang and colleagues (16).

Assessment for sex differences in total centenarian deaths.—In all industrialized countries, centenarian women outnumber men, usually by a large margin, and deviations from this pattern are cause for further investigation (26). Therefore, it is expected that similar results will be found in Okinawa, and total deaths for female centenarians should be greater than that observed for male centenarians.

Evaluation of Japan Ministry of Health, Labour and Welfare Methods to Calculate Centenarian Prevalence

Methods to calculate centenarian prevalence could also be a source of error. Therefore, we assessed how this occurs in Japan. Briefly, on obtaining information on dates of birth, the public officers in the municipalities (cities, towns, and villages) count the number of people who would be reaching the age of 100 years between April 1 and March 31, which is considered the fiscal year in Japan. During the final two weeks of August, the numbers are checked again by public officers to determine how many persons still alive would be reaching 100 years of age by September 30 in a given year. These are the official centenarian prevalence numbers reported by each prefecture to the Japan Bureau for Health and Welfare of the Elderly, a branch of the Japan Ministry of Health, Labour and Welfare. The numbers are subsequently announced to the public every year in mid-September, on Respect for the Elders Day. However, this method slightly overestimates centenarian prevalence num-

bers for each prefecture as the counts include an excess consisting of those who die in September (before September 30) having already reached the age of 100 years or more, and those who die in September in the last month of their 100th year (aged 99 years) before actually reaching their 100th birthday. To get a more accurate prevalence, these deaths must be subtracted from the overall count.

Therefore, we estimated mortality for 99-year-olds born in the month of September and for centenarians 100 years old or older for 2006. This was calculated by extrapolating recent mortality trends (average of the 6 years 1998–2003). Mortality rates of approximately 30% per year were found for centenarians during this period (for ages 100–104). Because 1/12 of total yearly mortality could be expected to take place in September, the resultant number was subtracted from the total count reported by the Ministry of Health, Labour and Welfare.

Results

Total Number of Centenarians and Study Participants

Local municipalities in Okinawa reported that 2644 persons were to have reached 100 years of age between April 1, 1976 and March 31, 2004. We were able to enroll 706 (27%) of those 2644 persons into our centenarian study. This occurred during a visit to their place of residence, where we also conducted additional age validation mainly through life history and family pedigree reconstruction. This protocol has been reported briefly (see ''Methods'' section) and elsewhere in more detail (22). The vast majority of these study participants had died by the time of the current validation study, so further validation with additional methods was performed on a subsample of 52 participants, as described below, in the year 2005. Table 1 presents summary data for participant recruitment from 1976 to 2004, including the highest attained ages or current age if alive on September 30, 2003. Recent mortality rates were also calculated for male and female centenarians between the ages of 100 and 104 (data not shown). Men had higher mortality rates at approximately 35% per year, whereas women had lower rates at 27% per year. Mortality above age 105 years was unstable due to small numbers and therefore is not reported here. These rates are comparable to those reported for Japanese centenarians as a whole (27).

Table 1. Total Number of Centenarians in Okinawa and OCS Participants, 1976–2004*

	Total Centenarians†		OCS Participants‡	
Age	Men	Women	Men	Women
112	1	1	1	1
111	1	5 (2)	—	4 (1)
110	—	5	—	2
109	—	11 (4)	—	6 (2)
108	3 (1)	10 (3)	3 (1)	7 (3)
107	3 (2)	14 (3)	2 (1)	9
106	6 (1)	50 (11)	1 (1)	32 (6)
105	14 (4)	80 (20)	6 (2)	40 (8)
104	23 (2)	121 (30)	14 (1)	55 (9)
103	28 (4)	178 (42)	13	66 (8)
102	63 (10)	273 (93)	25 (3)	90 (19)
101	75 (13)	473 (127)	21 (2)	125 (12)
100	131 (27)	605 (169)	26 (1)	113 (4)
99	82 (26)	389 (111)	9	36
Subtotal	430 (90)	2214 (615)	121 (12)	585 (72)
Total	2644 (705)		706 (84)	

Notes: Exact date of death not available for all subjects. Centenarian data derived from prefectural lists based on the highest attained ages counted yearly on September 30, 1976 to 2003. Supercentenarian (110+) data based on actual data of death from official public records.

*Numbers in parentheses indicate number of centenarians alive as of September 30, 2003.

†Total centenarians include 471 persons aged 99 years and were calculated from official lists from Ministry of Health, Labour and Welfare covering period from April 1, 1976, through March 31, 2004 (10).

‡OCS participants calculated from OCS database.

OCS = Okinawa Centenarian Study.

Validation Results: Self-Reported Age

During the year 2005, to assess the accuracy of self-reported age with further corroborative evidence, we were able to recruit an additional 52 individuals (population-based sample of all centenarians from three municipalities in Okinawa). Consistent with our past observations, we found that errors in the system tended to be small (as little as 1 day) and random in direction. Forty-nine of fifty-two participants were verified as centenarians (94.2%). Three of fifty-two participants (5.8%) had ages on their *koseki* document that indicated an error of > 1 year and could not be definitively validated as centenarians. All errors indicating age overstatement were within 1 year except for three cases (2, 3, and 6 years) and ranged from 1 day to 6 years. All errors indicating age understatement (four cases) ranged from 1 to 2 years. We found no evidence of systematic age exaggeration.

Demographic Validation of the Age Registration System

Interprefecture validation.—Okinawa leads a southwestern longevity belt within Japan. The population distribution of centenarians by region varies within Japan, with northeastern and central prefectures (Tohoku to Kanto) tending to show lower prevalence and southwestern prefectures (Chugoku to Kyushu/Okinawa) showing higher prevalence of centenarians. Therefore, a ''southwestern longevity belt'' can be said to exist. Officially reported centenarian prevalence rates in Okinawa prefecture do not appear to be unusually high when considered within the context of the Northeast to Southwest gradient. In fact, Kochi prefecture (51.88 centenarians per 100,000 population) has only a slightly lower reported centenarian prevalence ratio than Okinawa prefecture (54.37 centenarians per 100,000 population). There was a reported range of 34.26–54.37 centenarians per 100,000 persons for the top 10 prefectures and 10.8–17.17 centenarians per 100,000 persons for the bottom 10 prefectures (see Table 2).

Intraprefectural validation.—We were able to survey all 41 cities, towns, and villages in Okinawa prefecture to

Table 2. Reported Prevalence of Japanese Centenarians by Prefecture* and Region, 2006†

Rank	Top 10 Prefectures	Region	Centenarian Population (*n*)	Centenarians per 100,000	Rank	Bottom 10 Prefectures	Region	Centenarian Population (*n*)	Centenarians per 100,000
1	Okinawa	SW	740	54.37	38	Shiga	Central	237	17.17
2	Kochi	SW	413	51.88	39	Osaka	Central	1449	16.43
3	Shimane	SW	379	51.08	40	Ibaraki	NE	481	16.17
4	Kumamoto	SW	790	42.89	41	Miyagi	NE	378	16.02
5	Kagoshima	SW	659	37.59	42	Kanagawa	NE	1378	15.68
6	Kagawa	SW	377	37.22	43	Tochigi	NE	315	15.62
7	Saga	SW	315	36.37	44	Aichi	Central	1057	14.57
8	Ehime	SW	524	35.69	45	Aomori	NE	207	14.41
9	Yamaguchi	SW	526	35.23	46	Chiba	NE	850	14.04
10	Miyazaki	SW	395	34.26	47	Saitama	NE	762	10.08

TOTAL NUMBER OF CENTENARIANS PER 100,000 PERSONS (PREVALENCE), ALL JAPAN: 22.23

Notes: *From 47 total prefectures. Note that there exists a trend of increasing centenarian prevalence from NE to SW prefectures.
†Data Source: Calculated from Japan Ministry of Health, Labour and Welfare official centenarian count for 2006 (10).
NE = northeastern; SW = southwestern.

assess whether those that had original prewar *koseki* were different from those that had only postwar reconstructed *koseki* in terms of centenarian prevalence. A comparison of centenarian prevalence in areas where the *koseki* was reconstructed to areas where the prewar *koseki* was still intact revealed no significant differences in centenarian prevalence (see Figure 1). Furthermore, in our analysis, ''*koseki* intact areas'' included municipalities with both *wholly* intact systems and *partially* intact *koseki* systems. A further analysis that excluded the partially intact municipalities resulted in non-significantly higher centenarian prevalence rates in ''*koseki* intact areas'' when compared to areas where the *koseki* was reconstructed (data not shown). Therefore, there appears to be no significant effect of destruction/reconstruction of age registration records on centenarian prevalence.

Assessment of total numbers of centenarians over time.—Centenarian numbers in Okinawa showed steady increases over time. Past research on the growth trajectories of centenarian populations has shown that the growing number of births at the time that older cohorts were born, and the more favorable survival rates since birth of the latter cohorts, should result in fairly steady increases in centenarian numbers over time given reliable data sets (24,28). By plotting absolute numbers of centenarians since 1972, we can see that, except for a few small dips, common when dealing with small populations, centenarian numbers have been progressively increasing in Okinawa since the early 1970's. (see Figure 2).

This increase is to be expected because, despite the widespread underreporting common for the times, the size of birth cohorts in Okinawa (and throughout Japan) increased steadily during the latter decades of the 19th century and early decades of the 20th century, more than doubling during this period (27,29). As in most industrialized nations, larger birth cohorts coupled with better survival of later cohorts, largely account for these steady increases over time (27,28).

Assessment of maximum age at death.—Maximum age at death appears credible. The reliability of centenarian ages in Okinawa can be estimated by analyzing the maximum age at death reported for men and women and comparing this number to numbers in countries known to have high-quality data. Table 3 shows that the highest age at death (112 years) is similar to that of other long-lived countries with good mortality data, such as Sweden and France. It is considerably lower than that reported for countries appearing in Table 3 that are known to have problems with age inflation at older ages, such as the United States and Canada

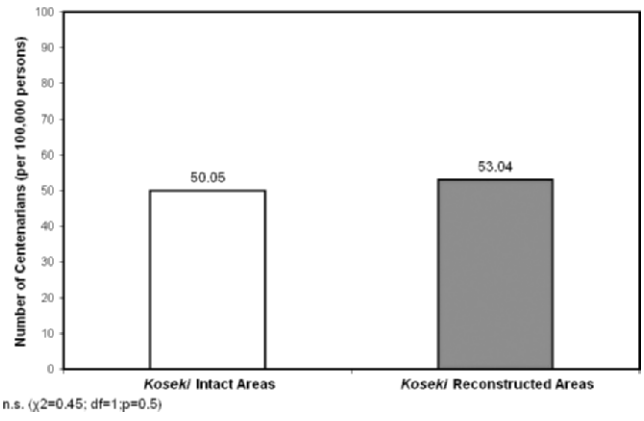

Figure 1. Prevalence of centenarians in regions of Okinawa with intact age registration documents versus areas with reconstructed age registration documents in 2005.

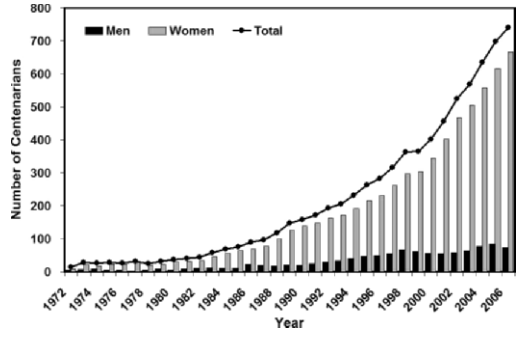

Figure 2. Number of centenarians in Okinawa from 1972–2006.

Table 3. Life Expectancy and Highest Ages at Death in Okinawa, All Japan, and Other Countries

		Men				Women			
Country or State	Years	e_0	1st	2nd	3rd	e_0	1st	2nd	3rd
Okinawa	1966–70	71.1 (1970)	102	101	100	77.5 (1970)	105	105	103
	1971–80	74.5 (1980)	105	105	105	81.7 (1980)	105	105	104
	1981–90	76.7 (1990)	106	105	104	84.5 (1990)	109	106	106
	1991–2004	77.6 (2000)	112	111	108	86.0 (2000)	112	111	111
All Japan	1960–70	69.3 (1970)	107	106	105	74.7 (1970)	118	116	109
	1971–80	73.4 (1980)	110	108	108	78.8 (1980)	113	112	110
	1981–90	75.9 (1990)	120	111	110	81.9 (1990)	111	111	110
	1991–2002	77.7 (2000)	112	112	111	84.6 (2000)	116	114	114
Canada	1961–70	69.3 (1970)	110	110	109	76.4 (1970)	109	109	109
	1971–80	71.7 (1980)	114	112	111	78.9 (1980)	114	113	112
	1981–90	74.4 (1990)	118	116	113	80.8 (1990)	113	111	111
	1991–95	76.7 (2000)	112	112	111	81.9 (2000)	116	113	113
United States	1960–70	67.1 (1970)	127	127	125	74.7 (1970)	128	128	127
	1971–80	70.0 (1980)	127	127	126	77.4 (1980)	127	126	125
	1981–90	71.8 (1990)	127	127	127	78.8 (1990)	128	125	125
	1991–2001	74.1 (2000)	128	126	126	79.5 (2000)	128	128	125
England and Wales	1960–70	68.7 (1970)	111	107	106	75.0 (1970)	111	109	109
	1971–80	70.2 (1980)	109	107	107	76.2 (1980)	111	111	111
	1981–90	72.9 (1990)	109	109	109	78.5 (1990)	113	111	111
	1991–2003	75.5 (2000)	109	109	109	80.2 (2000)	115	114	114
Sweden	1961–70	72.2 (1970)	105	105	105	77.1 (1970)	109	107	107
	1971–80	72.8 (1980)	107	107	106	78.8 (1980)	109	108	107
	1981–90	74.8 (1990)	107	106	106	80.4 (1990)	111	109	109
	1991–2003	77.4 (2000)	111	109	109	82.0 (2000)	112	112	111
Finland	1960–70	66.5 (1970)	103	102	102	75.0 (1970)	111	107	105
	1971–80	69.2 (1980)	103	103	103	77.6 (1980)	107	105	105
	1981–90	70.9 (1990)	106	104	103	78.9 (1990)	110	109	108
	1991–2002	74.2 (2000)	107	106	105	81.0 (2000)	112	109	109
France	1960–70	68.4 (1970)	109	108	107	75.9 (1970)	109	108	108
	1971–80	70.2 (1980)	109	108	108	78.4 (1980)	109	109	109
	1981–90	72.8 (1990)	114	114	114	80.9 (1990)	116	114	114
	1991–2002	75.3 (2000)	113	112	111	82.7 (2000)	122	117	116
New Zealand									
Maoris	1960–70	68.3 (1970)	110	108	107	74.6 (1970)	120	118	115
	1971–80	70.0 (1980)	112	106	105	76.3 (1980)	120	119	117
	1981–90	72.4 (1990)	106	105	105	78.3 (1990)	112	109	109
	1991–2003	76.3 (2000)	110	108	108	81.1 (2000)	110	110	109
Non-Maoris	1960–70	68.3 (1970)	104	104	104	74.6 (1970)	107	106	105
	1971–80	70.0 (1980)	120	104	104	76.3 (1980)	107	107	107
	1981–90	72.4 (1990)	106	105	105	78.3 (1990)	109	107	107
	1991–2003	76.3 (2000)	110	108	107	81.1 (2000)	110	110	109

Notes: e_0 = Average life expectancy at birth.

Data sources: Okinawa data: 1966–1970 data calculated from United States Civil Administration of the Ryukyus (43), 1966–1970 data for Okinawan men are highest ages attained as of September 1970; 1972–2004 data for Okinawa from Japan Ministry of Health, Labour and Welfare (10); Canada data: Table 1, Mortality Statistics for the Oldest-Old: An Evaluation of Canadian Data. Robert Bourbeau, André Lebel. Demographic Research, Volume 2, article 2, March 2000 (30); Other data: Calculated from K-T Database (42). Cut off time: Okinawa: September 30, 2004; K-T Database: January 1, 2004.

(24,25,30). In fact, the highest age at death in the European countries and Japan observed over a long period of time rarely exceeded 110 years for men. Similarly, only two men were reported to have ever lived this long in Okinawa. Women seem to break this barrier more often with the top three ages reported for Sweden, France, and Japan ranging from 112 to 122 years. The top three ages for women in Okinawa all fall between 111 and 112 years.

In the reference countries in Table 3, maximum age at death tended to increase over time, as more and more individuals survived to older ages. In Okinawa this trend can also be witnessed, with maximum age at death growing from approximately 105 years in the 1960s to 112 years by 2005. In countries with unreliable data at these older ages (such as Canada), this trend cannot be witnessed. Rather, maximum ages appear earlier, and these ages are likely to be overstated.

Furthermore, the oldest ages at death in Okinawa were observed to be more common in the female population. This is to be expected given mortality patterns observed for developed nations, such as higher mortality at middle and older ages for men than women, and therefore a much lower absolute number of male centenarians compared to female centenarians. Countries with reliable data (Sweden, France, Japan) also show this finding, but the oldest age at death in Canada (118 years) can be seen in the male population, suggesting that age overstatement may have taken place.

Similarly, Table 4 shows that the second and third highest

Table 4. Indicators of Data Reliability for Deaths of Centenarians

Country or State	Years	Deaths 105+/100+ (%)		Deaths at Age 110+/105+ (%)		q100/q101		Death at Age 100+
		Men	Women	Men	Women	Men	Women	Women/Men
Okinawa	1966–2004	7.0	9.6	—	5.3	1.08	0.94	4.8
All Japan	1950–69*	5.3	4.4	—	13.8	1.10	1.02	3.5
	1970–82*	3.9	4.2	2.6	3.1	1.13	0.97	3.8
	1994–2002†	4.4	6.2	1.8	2.5	0.94	0.93	3.8
Canada	1961–70*	10.7	6.7	3.0	—	1.15	1.00	2.1
	1981–90*	6.7	8.7	6.9	5.5	0.98	0.93	3.0
	1991–2000†	7.5	9.8	—	4.0	0.94	0.94	4.4
United States								
White	1970–79*	7.8	7.4	10.0	6.0	—	—	3.0
Non-White	1970–79*	28.9	28.6	22.2	25.8	—	—	1.9
All	1991–2001†	8.1	9.8	9.1	6.2	0.96	0.95	5.0
England and Wales	1950–83*	3.0	5.1	9.4	2.0	0.93	0.94	5.9
	1991–2003†	4.5	6.5	—	2.0	0.91	0.95	7.6
Sweden	1920–83*	2.4	3.7	—	—	0.88	0.96	2.1
	1994–2003†	3.9	5.7	3.1	4.7	0.94	0.93	4.6
Finland	1920–83*	1.0	3.5	—	0.2	0.93	0.90	4.2
	1991–2002†	4.1	4.9	—	2.2	1.04	1.00	5.5
France	1970–83*	3.2	4.6	—	—	1.07	0.97	4.4
	1994–2002†	4.3	5.6	4.0	2.0	0.96	0.93	6.7
New Zealand								
Maoris	1947–84*	30.4	42.1	21.4	35.6	1.40	3.73	2.3
	1991–2003†	5.1	8.7	8.3	1.6	1.01	0.89	6.1
Non-Maoris	1947–84*	4.9	5.3	33.3	—	1.16	0.93	2.8
	1994–2003†	4.8	8.7	9.1	1.6	0.97	0.88	6.2

Notes: Data sources: For Okinawa, 1966–1971 data from United States Civil Administration of the Ryukyus (43); 1972–2004 data for Okinawa from Japan Ministry of Health, Labour and Welfare (10). Cut-off time: Okinawa: September 30, 2004; K-T Database: January 1, 2004.

*Data from Table 1, Mortality Statistics for the Oldest-Old: An Evaluation of Canadian Data. Robert Bourbeau, André Lebel. Demographic Research, Volume 2, article 2, March 2000 (30).

†Data calculated from K-T Database (42).

ages at death were also not considerably higher for men and women in Okinawa when compared to other countries. This situation can be contrasted with the United States, where both Medicare data (two persons) and Vital Statistics data (five persons) report ages of 122 years or more. As the oldest documented age ever reliably recorded was that of Jeanne Calment of France, who was aged 122 years at time of death (31), these extreme ages reported in the United States are highly likely to represent age exaggeration.

Assessment of centenarian proportions.—Due to rapid depletion of the population at extreme ages and the increasing size of successive birth cohorts, the proportion of centenarians 105 years old or older among all centenarians should appear as a reasonable number, usually between 5% and 10%, and should be smaller for men than for women (25). Furthermore, the percentage of centenarians 110 years old or older among those 105 years old or older (110+/105+) should be smaller than the first indicator (105+/100+). Data for Okinawa are presented in Table 4. In countries with reliable data, such as Japan, England and Wales, Sweden, Finland, France, and New Zealand (non-Maori), the proportion of deaths at 105 years old or older among the centenarian population falls between 5% and 10%. As seen in Table 4, Okinawa also falls within this range at 7% for men and 9.6% for women, respectively. However, in countries with less reliable data at these extreme ages, the proportion falls between 10.7% (Canadian men in the 1960s) and 42.1% (New Zealand-Maori women 1947 to 1984).

In countries with the best data, trends can also be observed toward increasingly higher percentages in the 105+ survival range, indicating trends toward increasing maximum life span, as reported earlier. Unfortunately, the very small total numbers in Okinawa do not permit definitive study, but preliminary analysis of these data suggests that they too follow this pattern (data not shown). Furthermore, numbers of supercentenarian deaths (110 years old or older) among semisupercentenarian deaths (105 years old or older) should be smaller than those of semisupercentenarians among all centenarians (105+/100+ years) (25). On this point as well, at 5.3% the Okinawa data fulfill this assumption for women, although so few cases are reported, conclusions are tentative. Even smaller numbers for men (two cases) do not permit any conclusions to be made. Countries with reliable data report percentages of supercentenarian deaths from approximately 2% to 5%. Countries with less reliable data have percentages that range from 6.9% (Canadian men in the 1980s) to 35.6% (New Zealand-Maori women 1947 to 1984).

Assessment for potential age heaping.—The Okinawa data do not indicate age heaping. The risk of dying is expected to be higher at age 101 years than at age 100 years; therefore, the ratio of mortality risks at 100 years divided by 101 years should be below or close to unity (16,25). If it

is not, then it is possible that age heaping has taken place at age 100. A number significantly higher than 1 indicates a tendency to declare death at the exact age of 100 years, which suggests age heaping. Data on age heaping are presented in Table 4. Tendencies toward this type of error can be seen in Canadian men during the 1960s, Japanese men through the 1970s, New Zealand (non-Maori) men during the 1940s through the 1980s, and strongly in New Zealand (Maori) men and women during the same period. The Okinawa data appear reliable in this regard with both men and women showing indicators of close to 1 and data improvements since the 1970s in line with Japan as a whole (data not shown).

Whipple's Index for Centenarians, adapted to test age heaping among centenarians by Wang and colleagues (16), was also used to test for age heaping among centenarians in Okinawa. It was found that the Okinawa data compared favorably when tested against the Swedish data as a standard (See Table 5). Data are considered ''very accurate'' or ''relatively accurate'' if they deviate <5% or between 5.0% and 9.9%, respectively, from the standard (16). Deviations from 10.0% to 24.99% are considered ''acceptable,'' but deviations beyond this are considered ''inaccurate'' and of questionable validity. These values should be regarded as an indication that reported ages for Okinawan centenarians do not show signs of age heaping when compared with the Swedish data, which are known for their high reliability, according to the United Nations' standard cited by Wang and colleagues (16).

Assessment for potential sex differences in centenarian ratios.—In all industrialized countries, centenarian women outnumber men, usually by a large number (21,25,26). Similar results were found in Okinawa, and total female centenarian deaths were much higher than total male centenarian deaths, at a ratio approximating five deaths for women to one death for men (Table 4).

Evaluation of Japan Ministry of Health, Labour and Welfare Methods to Calculate Centenarian Prevalence

According to official data supplied to us by Okinawa prefectural government officials, the numbers of centenarians in Okinawa prefecture grew from 14 in 1972 to 740 in 2006. However, as indicated earlier, the Japan Ministry of Health and Welfare Bureau for the Elderly methodology fails to account for mortality during the month of September.

Therefore, we estimated total excess mortality and subtracted it from total centenarian numbers to obtain a more accurate estimate of centenarian prevalence rates. There were 20 ''new centenarians'' (99-year-olds becoming 100 years during the fiscal year) who were born during the month of September. Based on earlier calculations (not shown here) recent mortality rates for centenarians in Okinawa (100–104 years old) were found to be approximately 27% per year for women and 35% per year for men. If we take 30% mortality as a standard and assume that 1/12 of that mortality could be expected to take place in September, 2.5% of the ''new centenarians'' or approximately one person could be expected to die in the month of September before reaching his or her 100th birthday.

Table 5. Whipple's Index for Centenarians*

Region	Okinawa†	Sweden‡	Difference (%)
Men	0.903	0.880	2.5
Women	0.957	0.908	5.1
Both sexes	0.945	0.901	4.6

Notes: A relative deviation of <5% or 5%–9.99% indicates very accurate or relatively accurate data quality by United Nations standards (16).

*Whipple's index for centenarians = (sum of numbers of deaths at ages 95, 100, 105)/total number of deaths between ages 93 and 107 years.

†The index for Okinawa is based on year 2000 data from Japan Ministry of Health, Labour and Welfare (10).

‡The index for Sweden is based on data supplied by Wang and colleagues (16).

This result needs to be subtracted from the original Ministry of Health, Labour and Welfare data. If we then use the same formula to subtract those who had already reached the age of 100 years but who could be expected to have passed away during the month of September, approximately 18 of the 720 remaining centenarians would need to be subtracted from official counts. Adding these 18 centenarian deaths to the 99-year-olds results in 19 centenarians that we expect to be deceased centenarians who appear on the ''official'' list. Subtracting these 19 persons from the official count for 2006 resulted in a prevalence number of 721 persons 100 years old or older who could reasonably be assumed to be still living as of September 30, 2006. This gives a true centenarian prevalence of 52.97 centenarians per 100,000 persons versus an official estimate of 54.37 (per 100,000 population), which is a negligible difference.

This prevalence is quite high compared to that found for other developed regions of the world, which have been reported to range from approximately 10 to 20 per 100,000 population (15,21,26,32) but reasonable when considered within the reported regional distribution of centenarians within Japan (reported earlier).

Discussion

As the world's population ages, increased research emphasis has been placed on identification of populations with high prevalence of healthy, older individuals for the study of healthy aging and exceptional longevity (1,2). Precise phenotyping, particularly accurate age, is required. This is especially important for genetic studies of human longevity; therefore, age validation has become an important part of such research (7,15,16,23,33,34). Thus, the purported high prevalence of centenarians in Okinawa has been a subject of keen interest and some controversy (8,21,32,34,35).

Previous centenarian studies have been faulted for not verifying the ages of their participants or checking the quality of age-reporting data in the areas where studies are undertaken (11,13,25,33,34). However, most research on exceptional human longevity is hampered by the difficulty in locating and enrolling long-lived individuals, in part, because a suitable population age registration system is lacking. Very few countries possess an extensive, cross-referenced, age registration system, such as that of Japan

(18,25). Thus, most centenarian studies must rely on census data, local obituary listings, councils or clubs for the elderly, features in newspapers, nursing homes, and veterans or medical insurance databases to locate and enroll their participants before they can even begin the process of age validation.

Typically, census data has poor sensitivity and specificity (15,25). Moreover, with the high annual mortality for centenarians, a large percentage of centenarians listed in the census may have already died by the time researchers obtain the census data. Therefore, locating and enrolling participants for centenarian studies in countries such as the United States is laborious and time consuming, and inevitably results in missing some potential candidates.

In contrast, different challenges exist in Okinawa. These challenges do not come from the lack of sensitivity or specificity of census databases but mainly from lack of access to the resident and family registers due to extremely strict privacy laws. Fortunately, we were able to receive special research permission and gain access to names, dates of birth, and contact information (including addresses) of every person reaching 100 years of age during the years 1976 to 2004.

After a potential study participant is located, before enrolling him or her in a centenarian study, obtaining proof of birth is extremely important (33,34). We were able to obtain proof of birth for every study participant that we enrolled between the years 1976 and 2006. This was possible because we had previous access to their birth records, via the *koseki*, before we contacted them. This proof of birth consisted of the participant's name, address, and date of birth. Upon visitation, further proof of birth was sought, as indicated earlier.

The reason that proof of birth is so vitally important in studies of exceptional longevity is that the age data are vulnerable to error—particularly age exaggeration. This tendency is most apparent in populations for which there was no birth registration system at the time that the candidate centenarian was born. Reliable recording of ages exceeding 100 years today presupposes the existence of complete registration of births since at least the late 1890s. This condition is met in only a few countries around the world (18,25). For example, some parts of Europe, where compulsory registration at birth began in the 1860s to 1870s (i.e., Sweden 1861, England 1874, Germany 1876) or in Japan, where birth registration began in 1872, are considered to have reliable data on centenarians. Thus, in countries such as the United States, where there was no nationwide birth registration system until 1940, birth certificates become the *sin qua non* of proof of age. Unfortunately, in some places such as the United States, Canada, and some European countries, high numbers of immigrants or refugees (some from countries at war) and/or poor record-keeping by some provinces or states, make for challenges in obtaining birth certificates or other documents that provide for proof of age.

Okinawa does not suffer from that particular challenge as there was no substantial immigration at the turn of the century into Okinawa from other nations or prefectures, nor has there been a large influx of older people not originally born there, such as one would find in retirement locales such as Florida. That being said, Okinawa, as well as other areas of Japan that suffered extensive war damage during World War II, lost many documents pertaining to age. The postwar reconstruction process in Japan included reconstruction of the *koseki* system in war-torn areas. This reconstruction has led some researchers to question the accuracy of *koseki* documents and the validity of the high centenarian prevalence in the prefecture of Okinawa (21,35). For studies of human longevity, validation of areas of exceptional longevity is important prior to investing extensive time and resources investigating the etiology of such longevity (1). However, until this current age validation study, questioning of the high centenarian prevalence in Okinawa has been based largely on conjecture. Nevertheless, despite past validation of centenarian ages as part of the OCS protocol, no systematic study of centenarian prevalence or validity of the *koseki* system in Okinawa (or in other regions of Japan) has been published in the gerontological literature.

We found that, in general, our study supports prevalence data from the Japan Annual Centenarian Report (10) and is consistent with past work from the OCS. For example, perhaps the most serious potential issue that might affect the credibility of the Okinawa longevity phenomenon is the destruction of large parts of the *koseki* during World War II and the subsequent potential for age misreporting during its postwar reconstruction (21). Therefore, our comparison of areas where the *koseki* remained intact to areas where it was destroyed is particularly important. This comparison revealed no significant differences in centenarian prevalence between areas that were destroyed and reconstructed, versus those areas left intact. This finding lends support to the validity of the *koseki* system in Okinawa despite the war damage.

Data reliability, although not perfect, was found to be high in comparison to those in countries with known high-quality centenarian data. Demographic assessment of the data revealed few signs of common age-related reporting errors such as age heaping, exaggeration of maximum age at death, variation in expected centenarian proportions, or unusual male to female ratios of centenarians.

Our age validation study also showed the importance of cultural background in verifying centenarian ages, similar to another validation study in East Asia (16). Our study required that the centenarians and their family members verbally corroborate the centenarian's age through stating actual age as well as animal birth year according to the Chinese (animal year) zodiac. Although we found that family members were successful at remembering the day, month, and year of birth of the participant, the participants themselves were less so, usually due to cognitive impairment. However, the majority of centenarians (unless severely cognitively impaired) were able to clearly state animal birth year according to the Chinese zodiac. We found this to be an extremely helpful way to cross-check whether the birth years were consistent with the birth year reported in the *koseki*. Thus, we found that rather than accepting birth certification as the *sin qua non* of proof of age (as in most studies of exceptional longevity), it is important to cross-check birth certification with other sources of corroborative

evidence—for even birth certification or age registration systems can show error.

Our rigorous check of the family registration system or *koseki* in Okinawa revealed that there was some error in the system. However, that being said, the error appeared to be small and random in direction. That is, there was no large systematic age exaggeration, in contrast to past studies of purported regions of exceptional longevity, such as the Caucasus, Vilcabamba, or Hunza Valley (11–14).

A particularly interesting finding was that part of the error was attributable to age underestimation. In other words, in several cases the centenarians were actually *older* than the age reported in their *koseki*. That being said, presently only a few countries can provide accurate data about the ages of their oldest citizens, particularly ''supercentenarians'' (those 110 years or older). Although Japan appears to be one of the few countries with accurate data at these exceptional ages, mistakes have also been discovered, as the case of Shigechiyo Izumi illustrates (20). Further validation of the age reporting system in other areas of Japan should be carried out, particularly with regard to supercentenarians. Although exceedingly challenging, ideally, the *koseki* of each participant should be brought alongside the *koseki* of the family head (usually the father) from whence it originated and cross-checked to ensure that no copying errors are present.

Our age validation study also examined the official method for calculating centenarian numbers in Japan used by the Japan Bureau for Health and Welfare for the Elderly, the branch of the Ministry of Health, Labour and Welfare responsible for this task. This examination revealed that the data reported by their methodology overestimates centenarian prevalence throughout Japan by a small percentage because it fails to account for mortality during the month of September. These numbers are widely quoted and should be used with caution when making international comparisons. Our validation study reported a slightly lower but more accurate prevalence number. However, this lower validated number was still much higher than the rates that have been reported from other industrialized nations. We were also able to show that the high centenarian prevalence in Okinawa is not an outlier within the 47 Japanese prefectures, but rather the leading prefecture in a Southwestern longevity belt.

The high centenarian prevalence found for Okinawa can be largely explained by the long life expectancy at older ages (after age 65); this, in turn, is mainly accounted for by very low mortality risk from cardiovascular disease (coronary heart disease and stroke) and certain cancers (32). The Okinawa findings are thus highly plausible and expected within the context of such mortality patterns. These findings stand out sharply from those in countries that demonstrate patterns of high mortality and short average life expectancy, yet also purport to harbor high numbers of centenarians in certain so-called ''longevity regions'' (11–14,24).

The above notwithstanding, prevalence of centenarians can be affected by many factors such as size of birth cohorts, war, or migration patterns. No doubt (as indicated earlier), increasing size of birth cohorts in Okinawa explains part of the reason for increasing growth in centenarian numbers as throughout Japan as a whole (27). However, as Robine and colleagues (27) indicate, the proliferation of centenarians in Japan (centenarian numbers are doubling every 5 years) appears to be due mainly to changes in society rather than the increase in birth rates. Furthermore, previous research indicates that 2/3 or more of the increase of centenarians in industrialized countries is due to improved survival at older ages (from age 80 to 100) (28,34,36). Because there has been little influx of seniors to Okinawa from other areas of Japan (all centenarians reported in the 2006 survey were native born), coupled with an emigration (out-migration) movement beginning with the current centenarian cohort (starting in 1900) as well as an expected net decrease due to war deaths, it would appear extremely likely that the high prevalence of centenarians in Okinawa is due largely to the exceptionally low mortality risk at older ages. Deeper inquiry into this issue is warranted.

We hypothesize that the Okinawa longevity phenomenon is due to a number of factors that have coalesced to decrease the risk for both age-associated disease and mortality among older people. For example, there appear to be important genetic aspects to Okinawan longevity (7,37,38) that merit further investigation. The traditional diet, low in calories but high in nutrition, may have also led to a population-wide caloric restriction phenomenon, among other dietary and lifestyle factors (8,39–41). A superior public health system and other social and psychological factors may have also contributed to this longevity phenomenon (32). These factors deserve further investigation. Discovering the basis for the longevity advantage in Okinawa may have important potential implications for human health.

Conclusion

Japan is one of the few countries with a centralized and reliable age registration system that is old enough to provide information on dates of birth of exceptionally long-lived individuals. Although the system was not found to be completely free from error, and extreme caution should be exercised when accepting *koseki* ages older than 110 years, the age registration system was shown to have excellent reliability in Okinawa, particularly when used in conjunction with other age validation tools.

Reliance on census data for measuring centenarian prevalence, as is the custom in most countries, routinely results in overestimates of centenarian prevalence rates. The low sensitivity and specificity of census data is testament to the importance of performing population-based studies using extensive age validation techniques when determining centenarian prevalence rates, as was done in the current study.

Centenarians are a valuable resource for the study of factors associated with exceptional longevity and healthy aging (7). However, most centenarian studies take place in European or North American countries, and few studies include minorities. As an ethnically distinct, isolated population of Japan with a very high prevalence of centenarians, a long life expectancy, and a highly functional elderly population, the Okinawans are an important population for studies of the genetic and environmental correlates of exceptional longevity. Further study of this population is warranted.

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