Costa Rican nonagenarians: are they the longest living male humans?

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Abstract

This survival analysis of registry data on about 24,000 Costa Rican nonagenarians, 1983-2004, shows that they might be the longest living humans. To ensure that there are no age-misreporting errors, only individuals legally registered in a ledger of the year of their birth are considered. The analysis to some extent is of extinct cohorts, with little room for death under-registration error. Mortality at age 90 in Costa Rica is 13% lower than an average of 13 high-income countries. This advantage increases with age by 1% per year. Males have an additional 12% advantage. Age-90 life expectancy for males is 4.4 years, a half-year higher than any other country in the world with reliable statistics. Although this life expectancy is still below that of women, the difference is only 0.3 years, the smallest recorded at these mortality levels. The Costa Rican advantage comes mostly from lower cardiovascular mortality rates.

Introduction

That population ageing is a direct result of extended longevity is a very common misconception among the lay public. Conversely, large numbers of the oldest-old in a population are wrongly taken as proof of exceptional longevity. Demography teaches that relatively large numbers of very old individuals may be more a result of long-term low fertility levels or exceptional migration flows in the past than a result of extended life expectancy, not to mention that figures of very old are often inflated by bad data. For example, claims of exceptional longevity in communities in the Andes and in the Caucasus from casual observers have not resisted scientific scrutiny (Garson, 1991).

To tell how longevous a population is, one should look primarily at survival proportions at old ages or compute life expectancy for the elderly. Carrying out such observations is not that simple, though. Often, data are not tabulated beyond age 80 or 85, and data errors are pervasive. In particular, demographers know well that age exaggeration among the elderly in censuses leads to substantial inflation of old-age populations (Coale & Kisker, 1986; Preston *et al*., 1999). Data problems worsen in developing countries for lack of documents to validate age reports, poorly educated informants, and because of faulty vital statistics with under-recorded deaths. This paper assesses the validity of early data of exceptional old-age longevity in Costa Rica, a middle-income country in Central America. Academic circles in high-income countries may disregard, in a reflex way, this claim of exceptional longevity as just “bad data”. The availability of rich data sets in Costa Rica, however, allows us to take a second look at these claims. If, after scrutiny the claims hold, science would have an opportunity of looking in Costa Rica for clues to long-life determinants in the adverse conditions of a developing country.

Table 1 shows that a naïve observation of the percentage of nonagenarians (this paper refers to the population aged 90 and above as *nonagenarians*, although some are actually centenarians) in the total population does not show any exceptionality for Costa Rica, year 2000. To the contrary, that percentage is a modest fraction of figures from ageing populations such as France (less than one-fourth for women and one-half for men). The story, however, differs if one refines the observation by computing a “nonagenarian rate” as the percentage of nonagenarians in the population of the same cohorts 30 years earlier, i.e. with respect to the population aged 60 and over in 1970. In demographic analyses of centenarians, it is common practice to compute this kind of "rates" (Robine & Paccaud, 2005), under the assumption that migration after age 60 is nil. The nonagenarian rate is exceptionally high for Costa Rican males: more than twofold that in France, Italy, Sweden or the USA, and four-times higher than in Russia (where adult mortality is very high). The nonagenarian sex ratio is also exceptional in Costa Rica: there are 30% or 40% more women than men, compared with the 200% or 300% excess of women in the other countries in the table.

These population data suggest that survival at old ages in Costa Rica is exceptionally high; males, in particular, may be the most longevous in the world (considering national populations only, since some sub-national populations, such as Sardinia in Italy and Okinawa in Japan, may have better indexes than Costa Rica). Given that the observation is based on census data alone, it is error-free of under-registration of deaths. However, age exaggerations might be playing a role in the apparent Costa Rican advantage. In this regard, an evaluation of the 2000 census found that there was, indeed, age exaggeration especially among the oldest-old, by comparing the census-reported age to the age in the national identification card–the *cédula*– in a sample of 7,400 seniors. In the 90 and over age bracket, about 30% of the individuals exaggerated their age by more than 6 years on average, compared to 10% by those in their sixties (Rosero-Bixby *et al*., 2004). Although, the correction of these age-reporting errors reduces the nonagenarian rate from 6.9% to 5.6% in males (Table 1, second row), the figure continues to be more than twice as large as, say, France.

Official life tables built after correcting data on population and deaths for 1995-2000, confirm the exceptionality of Costa Rican elders. Figure 1 compares their life expectancy at age 80 with 13 high-income countries in the Kannisto-Thatcher database kept at the Max Plank Institute (Kannisto *et al*. 1994). Kannisto *et al*. judged that these countries, with the exceptions of the USA and Australia, have "highly reliable data." Costa Rica is the winner for males in this comparison and it is in the middle of this elite pack for females. Costa Rica has an age-80 life expectancy for males of 8.2 years, the highest of any country with reliable statistics. Japan and Iceland come second with less than 7.5 years.

Costa Rica has been known for years as a country with outstanding health indicators, although its level of economic development is not that high (Caldwell, 1986). It was, for example, included as one of the four study cases in the Rockefeller Foundation report on "Good Health at Low Cost" (Halstead et al. 1985). However, from having good health indicators to being the world-champion in longevity is a huge difference and there are grounds for skepticism.

According to the World Bank (2005), by 2003, Costa Rica had a per capita income of about USA$ 4,000 and a health expenditure of $300, figures based on purchasing power and not just exchange rates. These figures are about one-tenth those in high-income countries. For example, in the USA they are $38,000 and $5,300, respectively, and in Japan, $34,000 and $2,500. Other indicators of health services, such as per capita physicians and hospital beds are also substantially lower in Costa Rica (one-third of USA physicians and one-tenth of Japan beds). It seems hard to believe that a country with these modest levels of wellbeing, health investments, and infrastructure can be the one with the highest life expectancy among the elderly. Although, there are often exceptions to the rule that greater longevity comes from higher wellbeing, with the population of Okinawa being one of them (Cockerham and Yamori, 2001).

Some explanations of Costa Rica's health achievements are as follows. One is the orientation of the government toward equity and social development, with large social investments being possible in part, due to the absence of military expenditures (Rosero-Bixby, 1991). Its 1949 constitution abolished the armed forces! The investments in education and the very high coverage of health insurance are often mentioned as key factors (Caldwell, 1986). Health insurance, which is provided by the national social security system, covers 82% of the population, including 9% destitute individuals whose insurance is paid by the government (Rosero-Bixby, 2004). Provision of primary health care, especially to remote or poor populations, has proved to have a quantifiable impact on death rates, especially among children (Rosero-Bixby, 1986 and 2004).

However, challenging this explanation, a 17-year follow up of Costa Rican elderly in a community close to the capital city showed no meaningful differences in survival by socioeconomic condition (education or wealth) nor by being covered by the national health insurance (although there seems to be a selection bias here, since the frail may tend to seek out insurance coverage more frequently) (Rosero-Bixby *et al.*, 2005). That study suggests that the Costa Rican advantage at old ages may be present across the entire society, with no clear-cut health interventions or classic socioeconomic gradients to explain it.

This paper models mortality rates and estimates life expectancy with data from a national population registry containing about 24,000 Costa Rican nonagenarians in 1983-2004 (i.e. individuals aged 90 and more and alive at some point in that period). The main purpose of the paper is to determine mortality and life expectancy patterns for the oldest-old Costa Ricans, hopefully, with error-free data to validate early claims that elder Costa Rican males may be the longest-living humans. By using this registry and by double-checking birth dates and identifying extinct cohorts, the paper intends to avoid age misreporting and death under-registration, common data shortcomings in this kind of studies. The paper also explores geographic patterns of mortality and causes of death to draw clues for possible explanations of the Costa Rican advantage. In analogy to the "Mnm" Coale's fertility model (Coale, 1977), the paper models mortality with three basic parameters: one expressing its level, and the other two showing aging and sex effects. The parameters refer to a standard schedule of mortality of the elderly in high-income countries.

Data and methods

To avoid age misreporting and death under-registration errors, the estimates of mortality and longevity in this paper come exclusively from the Costa Rican national voting registry. No census data or population estimates are used. Vital statistics were used only to input cause of death after linking the databases to the individuals in the voting registry. With the voting registry we created a database of 24,400 nonagenarians, which includes all living Costa Ricans aged 90 and more in the period 1983 to 2004. The starting date of observation is January 1, 1983 or the 90th birthday of the individual if it is after this date. The closing observation date is at death or October 30, 2004.

The Supreme Electoral Court (*Tribunal Supremo de Elecciones* or *TSE*) provided the registry's databases of births and deaths, as well as the voting list (the *padrón*) for the elections every four years (the latest from 2002), from which the nonagenarian database was created. Individuals were linked using a unique identification number, which appears in the national identification card (the *cédula*), that all citizens must renew every ten years. That unique number is assigned to each individual at birth, and includes the number of the ledger and page where the person is registered. These ledgers are uniquely and sequentially numbered, since the establishment of the civil registration system by 1880 (previously, the church had been in charge of the registry). By knowing this volume number we were able to determine the year in which the person was registered. Overall, 83% of the nonagenarians in the database were registered in a timely manner. Those registered late may suffer age misreporting errors, a fact that will be considered in the analysis.

It is almost impossible for an older Costa Rican adult to have lived in the country without ever having his/her *cédula* and, thus, without ever being in the registry. The *cédula* is required everywhere for all kind of transactions, public or private. The possibility of selection bias by exclusion of individuals from the registry is thus, essentially, nil. A cross-section from the registry at the date of the 2000 census resulted in 5,900 people alive and with ages 90 and over. The census count was 7,000 Costa Rican nonagenarians or about 20% more than the registry (the percentage is similar by sex). This census over-count is entirely compatible with the aforementioned patterns of age exaggeration identified in the 2000 census evaluation. It seems that no meaningful numbers of people are excluded from our registry of nonagenarians. A similar comparison with the 1984 census resulted in a larger discrepancy: 1,870 nonagenarians alive in our registry compared to 2,900 in the census, or a 55% census over-count (47% males and 62% females). This higher over-count may be due to higher age misreporting errors in the earlier census. The official population estimates based on the 1984 census (which were prepared by CELADE for the Costa Rican government) assumed 50% census over-count for the population aged 80 and over (MIDEPLAN *et al*., 1988).

There is, however, a potential for inflation in the registry, if it failed to exclude some of the deaths. We addressed this possibility by looking at cohorts that should be extinct. Birth cohorts from 1880 to 1895 were indeed extinct by 2004 in the registry. The maximum age reached by any of our 24,000 nonagenarians was 109; three died at this age. If there were under-registration of deaths we would see individuals still alive at 120 or so, which is not the case. In any event, estimates for extinct cohorts are, by definition, error-free of death under-registration. Moreover, the analysis will test whether extinct cohorts have significantly higher mortality–a clue that in the non-extinct cohorts some deaths may be missing (and, perhaps, the TSE will correct the error when it is self evident because individuals reach suspiciously high ages).

We conducted a record linkage of the nonagenarians in our database with the deaths in the vital statistics databases 1983-2004 provided by the Statistical and Census Institute (INEC). The variables used for the linkage were age, sex, and date and place of death. The linkage was successful in 96% of the almost 18,000 deaths. The main purpose of this linkage was to retrieve from the vital statistics the information on cause of death, as well as the reported place of residence at death. This geographic data will allow us to check whether migration of the sick and residence misreports may be distorting geographical comparisons, since deaths in the vital statistics may be over-reported in communities close to hospitals or medical facilities.

We defined six broad causes of death groups, plus a residual category (in parenthesis the codes from the 9th International Classification of Diseases):

1. Communicable diseases (1-139, 460-490)
2. Cancer (140-239)
3. Cardiovascular diseases (390-459)
4. Chronic respiratory diseases (491-519)
5. Diabetes (250)
6. Accidents and violence (800-999)
7. Residual

For comparative purposes we computed standardized death rates for these groups of causes in the USA (white population only) and Sweden, 1994-96. Data disaggregated by age and cause were not available for individuals aged 85 and over in these or other countries. Our comparison thus refers to the group 85 and over and in Costa Rica it uses only information from Vital Statistics for the period 1990-99. We used the "indirect" procedure of standardization (Pressat, 1972), with the Costa Rican rates as the standard.

In modeling mortality we used the death rates in the Kannisto-Thatcher database for the oldest-old available at the Max Plank Institute (http://www.demogr.mpg.de/). We averaged the 1990s data for the 13 countries rated as having reliable statistics (Kannisto *et al*. 1994) to define an old-age standard mortality schedule for high-income countries (shown in the Appendix).

Drawing from the "Mnm" model proposed by Coale (1977) to fit marital fertility rates, this paper fits the Costa Rican morality rates by age and sex to a three-parameter model, which is a function of the aforementioned old-age standard schedule:

$$m_{xd} = V_{xd}\, exp(\beta_0 + \beta_1\,(x - 90) + \beta_2\, d)\ error$$

$$m_{xd} = V_{xd}\, M\, A^{(x\text{-}90)}\, S^d\ error$$

Where:

- x represents age, and d, the dummy variable for sex (1 for males);
- m_{xd} is the rate or hazard of dying at age x, sex d, in the study population;
- V_{xd} is the expected hazard according to a standard mortality schedule–the Kannisto-Thatcher series;
- β_i are coefficients estimated with a Poisson regression model (StataCorp, 2003), exponentiation of these coefficients resulted in the M, A, and S parameters;
- M is a parameter representing the Costa Rican mortality level relative to the standard schedule (the rate ratio or relative hazard at age 90),
- A is a parameter representing aging effects specific for Costa Rica, above and beyond the age effect implicit in the standard schedule;
- S is a parameter representing sex effects specific for Costa Rica; i.e. male over-mortality above and beyond the one implicit in the standard schedule.

Values of 1 for the parameters *M*, *A,* and *S* would indicate that Costa Rican mortality behaves identically to the standard schedule.

To estimate the regression model we first split each observation into age units. We used "robust" estimates of the regression coefficients and their standard errors to take into account this replication. To estimate the parameters for population subgroups defined by variables of interest one just needs to add those variables to the Poisson regression model as well as their interactions with *x* and *d*. The only additional variables available in our database were the calendar year, whether the individual was registered in a timely manner at birth (an indication that age is error-free), and the place of residence, which is a time-varying variable (for each segment we took the most recent voting place from the *padrón)*. After preliminary analyses we found that the only relevant geographic distinction was residence in the Central region, which includes the capital city.

To unveil geographic trends we also used the *x, y* geographic coordinates of the centroid of the approximately 1,900 voting districts in the *padrón*. We then enter the *x, y* coordinates as a third-degree polynomial ($x, y, xy, x^2, y^2, x^2y\ xy^2, x^3$ and y^3) in our regression equation. Geographers know this technique as "*trend-surface analysis*" (Cliff & Haggett, 1988). Its end product is a map with the predicted values of the dependent variable (the relative mortality rate in this case).

From the series of mortality rates we get estimates of life expectancy using conventional life table techniques (Wunsch *et al*., 2002). We arrived at two estimates: one corresponding to the observed rates and, another, for the predicted rates with the model for the population with more reliable data (Central region and timely registry).

Results

Our database of nonagenarians consists of about 101,000 person-years from 24,400 individuals born from 1878 to 1913 (Table 2). More than two-thirds of the observation segments correspond to the 1994-2004 period. Almost all individuals born before 1904 are deceased; we called these extinct cohorts. From those born in 1903-13, 43% were still alive at closing date in 2004. Each individual was observed little more than 4 years on average. The mean observed age is about 93. The female to male ratio is 1.28, with an increasing trend in more recent cohorts (in spite of these being younger), an indication that the sex gap in mortality is widening. The proportion of late-registered births is 17% overall and substantially higher (36%) in the cohorts born before 1893. Almost three-fourths of the observations correspond to the central region.

About 1,100 individuals, or 5%, in our database are centenarians; i.e. they were alive at their 100th birthday. Although this is a small figure, it is worth exploring its data reliability by checking the reliability criteria used by Kannisto in his 1988 article on centenarians. The two Kannisto indicators of data reliability in centenarians applicable to this data are (p.390):

1. Deaths of those aged 105 and over as percent of deaths at ages 100+ is expected to be less than 5% and to be smaller for men than for women. In our database this indicator is 5.2% for men and 5.9% for women when we exclude those with late birth registry. These

figures are borderline acceptable, and much better than, for example, the USA, Spain, or Portugal.

2. The risk of dying is expected to be higher at age 101 than at age 100 and the ratio of these two risks should be below unity. In our database this ratio was 0.94 for men and 0.79 for women, far lower than most populations in the Kannisto article.

Figure 2 shows the age-specific death rates in our database. The figure also shows the 95% confidence intervals of the female rates (those for males are similar) to illustrate that the rates become unreliable by age 98 due to random errors. As expected, the rates for males are higher than for females, and both increase with age, although there is some deceleration in the increases at advanced ages. This deceleration has been observed in other populations and species as well and it is subject of intense scrutiny (see, for example, Horiuchi and Wilmoth, 1998)

Figure 2 also shows the smoothed rates from our model. The adjustment seems reasonable. It is also mandatory in order to eliminate the random fluctuations in the rates.

Comparison with the set of rates from the Kannisto-Thatcher average for 13 high-income countries shows a clear advantage for Costa Rica, which increases with age. In addition, the mortality sex gap is strikingly smaller in Costa Rica. This is to say that the advantage is larger for Costa Rican men.

Table 3 presents the results of adjusting three regression models to the data. The first is a simple, age and sex model as described in the equation presented above. The M parameter resulted 0.83; i.e. Costa Rica has 17% lower mortality at age 90 than the Kannisto-Thatcher standard. The A parameter is estimated at 0.989; i.e. aging occurs more slowly in Costa Rica than in the standard, at a rate of about 1% slower for each year of age. The S parameter came out as 0.88; i.e. Costa Rican males have an additional advantage of 12% lower than expected death rates.

The second model includes four additional variables with no interactions and the third model includes only variables and interactions that showed significant effects. Extinct cohorts do not differ significantly in their mortality. There is a significant time trend of mortality reduction of 0.4% per year, which occurs mainly in the central region and increases slightly with age. The non-central regions had a 15% lower mortality by 1995. Given that those regions are the most remote and least developed, one wonders whether this apparent advantage comes from data errors. Being a late birth registry (a proxy for potential age-reporting error) reduces mortality by 6%, but this effect occurs only among women, as shown by the interaction effect with sex.

By restricting the analysis only to the Central region and timely registered births, one assures high-quality estimates, although these may be conservative. With these two restrictions, the parameters for aging (A) and sex (S) are about the same as in the simple model presented before. The parameter for mortality level (M) is a bit higher and the advantage for Costa Rica declines from 17% to 13%. The set of rates for the selected group is, however, only slightly higher than the observed set (Figure 3). We conclude that the exceptional longevity of Costa Ricans do not seem sensitive to this refinement.

Life expectancy

Life expectancy at age 90, corresponding to the observed set of rates is 4.8 and 4.5 years for women and men respectively. Using the smoothed rates did not change these figures. Restricting the estimate to the population with high quality data (Central region and timely registry) reduces these figures only slightly, to 4.7 and 4.4 respectively.

The comparison of age-90 life expectancy with the same 13 countries as in Figure 1 results in essentially the same ranking for males (not shown). Costa Rican males have the highest life expectancy, half a year higher than a group of four countries headed by the USA and including Japan, Australia and Iceland. Costa Rican females climb to second place, 0.1 year below Japan and with a figure similar to the USA.

Figure 4 shows that life expectancy from the model is a good adjustment of the original figure. It also shows that while Costa Rican females differ little from Japan and the USA, Costa Rican males have a half-year advantage in life expectancy at all ages in the nineties. By age 100, Costa Rican males have 2.5 years of life expectancy, while females have 2.6 years. The USA (whites only) is second with 2.2 and 2.4 years, respectively.

Cause of death

Figure 5 shows the age pattern in four groups of causes of death. Cancer at these ages does not show any aging effect—the curve is essentially flat. Other causes show hints of deceleration. Cardiovascular death rates are by far the highest rates. About 50% of deaths at these ages are of cardiovascular origin. Chronic respiratory (mostly "other chronic airway obstructive diseases") and communicable diseases (mostly bronchopneumonia and pneumonia) become more important than cancer at these ages.

The comparison with the USA and Sweden points out that the Costa Rican advantage is mostly due to its lower cardiovascular mortality (Figure 6). The Costa Rican rate ratio is 0.80 and 0.70 compared to the USA and Sweden, respectively. By contrast, Costa Rican elders have substantially higher mortality due to chronic respiratory diseases and accidents (huge rate ratios in the order of 200 to 400%). Cancer and diabetes are pathologies in which Costa Ricans have slightly higher mortality than USA and Swedish citizens (3 to 15% higher).

Geographic patterns.

In addition to cause of death, the data on geographic differences may provide some hints about the determinants of old age morality in Costa Rica. Preliminary regression analysis of the effect of the seven Costa Rican regions showed that the only significant distinction is that of the Central region (including the metro area of San Jose) against all the others together. The other regions have a mortality that is 10 to 15% lower than the Central's. This effect is slightly higher (less than one percentage point), when the place of residence is taken from the report in the vital statistics death records. Therefore, it seems there is no meaningful inflation of mortality for the Central region in the vital statistics due to misreported residence (or a move) to be closer to hospitals and health care facilities.

The trend–surface analysis shown in Map 1 confirms previous findings (only populated cells are colored in the map). The highest nonagenarian mortality occurs in a corridor that goes from the port of Puntarenas on the Pacific coast to the port of Limon on the Caribbean, which passes through the Central region and the capital city. This corridor is, by the way, the most developed in the country, with the goods and evils that modernity may bring. Mortality declines as one moves further away from this corridor. The relative risk of dying is 13% (or more) lower toward the borders with Panama and Nicaragua and at the northwest on the Pacific Ocean coasts of Guanacaste (a popular tourist destination nowadays). Mortality increases again at the extreme southern tip of the country, on the Osa Peninsula and Punta Burica, but this is a sparsely populated area.

A similar analysis for cardiovascular mortality shows a geographic pattern that resembles that of all-cause mortality, with one big exception (Map 2). The port of Limon and surrounding areas on the Caribbean coast has substantially higher cardiovascular mortality: about 10% higher than the Capital and about 20% higher than the borders. This area distinguishes itself for hosting an important Afro-Caribbean population that came to Costa Rica at the beginning of the 20th Century. This population has a different genetic endowment and somehow different lifestyles (for example, using coconut oil for cooking) than the rest of the country.

Geographic analyses for other causes of death were less reliable because of the small numbers involved. However, the following hot spots with significantly different mortality were singled out (maps are not shown):

- The northwestern corner (Guanacaste) with lower than expected cancer mortality
- Some small areas at the center with higher than expected mortality due to communicable diseases and diabetes, and
- A higher than expected chronic respiratory disease area toward the southwest, in the Valley of “El General” and the neighboring coast.

Discussion

Using data from a population registry kept in Costa Rica for voting purposes, this paper re-estimated mortality and life expectancy for the about 24,000 Costa Rican nonagenarians who lived during the period 1983-2004. To ensure that there were no age-misreporting errors, only individuals who were registered in an official ledger at the time of their birth are included in the final estimates. The analysis to some extent is of extinct cohorts, with little room for death under-registration error. Since individuals not living in the Central region present lower mortality and this may seem suspicious, they were also excluded from the estimates. Mortality at age 90 in Costa Rica is 13% lower than an average of 13 high-income countries with reliable statistics. This advantage increases with age by 1% per year. Males have an additional 12% advantage. Mortality decreased by an average of 0.4% per year during the studied period, with steeper declines at older ages. Age-90 life expectancy for males was 4.4 years, one-half year higher than any other country with reliable statistics in the world--elderly Costa Rican males may be the most longevous humans, at least when only national populations are compared. Although this life expectancy is still below that of women, the difference is only 0.3 years, the smallest recorded at these mortality levels. The superior longevity of elderly Costa Ricans comes mostly from lower cardiovascular mortality.

There are three points to discuss regarding these findings: (1) Whether these are for real or just a product of "bad data" as academic circles in developed countries will probably dismiss them; (2) How could they be real, especially considering that standards of living and health services are way behind those in high-income countries? (3) How sustainable is the relative advantage of Costa Rica considering the rapid changes that modernity is causing along?

This paper is mostly devoted to validating the estimates. We are not basing the estimates on self-reported age data, such as those from census, avoiding the inflation of old-age population that usually comes from age exaggeration. Moreover, we are discarding data from individuals whose birth date is fully documented in the national identification card but whose birth registration occurred late in life (this, of course, includes all citizens born in other countries). The only possibility of age error in our data is that there was massive identity supplantation of older and deceased individuals by younger ones. Such a massive fraud does not seem plausible however.

We then addressed the possibility of under-estimating mortality because some deaths are not registered. This error, however, is impossible in extinct cohorts. By definition, they were not extinct if some deaths failed to register! In addition, we tested whether mortality in extinct cohorts differs from non-extinct ones to check if the later may be under-registering deaths. There was no significant difference; the exceptionally low mortality in our nonagenarians is an attribute shared by both extinct and non-extinct cohorts.

Another hint that the exceptional survival of old-age Costa Ricans is not an artifact of missing deaths comes from the extremely high nonagenarian rate in the 2000 census. More than two-times higher than, say, France for males. This rate is computed comparing censuses 30 years apart--it is thus free of the death registration errors from vital statistics

Recent research in the United States has shown that adult mortality is lower among the population of Latin American descent—the so-called "Hispanics" (Elo *et al*. 2004). This advantage, that occurs in spite of the lower socioeconomic status of Hispanics and their reduced access to health care, in some ways tells that the exceptional longevity of Costa Rican elderly may not be that exceptional.

This paper does not have an answer to the question of why elderly Costa Ricans do so well. It could be some genetic factor, lifestyles, social factors, or the environment. It could also be just a selection process for the fittest. Costa Rican nonagenarians are true survivors of cohorts that underwent extremely harsh health conditions. For example, they survived infant mortality rates in the range of 250 per thousand prevalent in Costa Rica in the early 20th Century. Malaria, tuberculosis, and diarrheic diseases decimated these cohorts when they were young. In addition, modern evils like obesity, sedentarism, and smoking are rare among them. And finally, a reasonably good health care system is currently protecting them from dying of communicable diseases, as shown the comparison of causes of death with Sweden and the USA (the death rate ratio is about one). These explanations, however, say nothing regarding why the Costa Rican advantage occurs mostly among males, or why the sex gap in mortality is so small among elderly

Costa Ricans. The only thing we know so far is that it has to do with low cardiovascular mortality.

If the high longevity of elderly Costa Ricans is mostly a result of a selection process of the less frail, then it is possible that this is an ephemeral advantage that may disappear as more frail individuals reach old ages thanks to the rapid progress that took place in the past. Life expectancy at birth in Costa Rica rose from 46 to 63 years from 1940 to 1960, which means a gain of 19 hours of life every single day in a 20-year period. In the 1970's, there were again gains at the same staggering speed, which raised life expectancy to 73 years in 1980 (Rosero-Bixby, 1991: 31). These advances mean that probably there has been rapid change in the frailty composition of Costa Rican cohorts, coupled to a quick change in lifestyles with increasing sedentarism, obesity, and smoking. The country's public health might be riding a tiger that took it very fast through the epidemiologic transition but that could be dangerous when it stops moving.

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Table 1. Nonagenarians in the population in selected countries, circa 2000

Country	In population (%) Female	In population (%) Male	Cohort 30 yr. (%) * Female	Cohort 30 yr. (%) * Male	Female ratio**
CR census	0.22	0.17	9.2	6.9	1.4
CR-estimate	0.19	0.14	7.4	5.6	1.3
France	1.09	0.33	6.1	2.5	3.5
Italy	0.90	0.31	5.4	2.3	3.0
Japan	0.77	0.26	8.3	3.3	3.0
Russia	0.39	0.10	2.8	1.6	4.2
Sweden	1.05	0.37	5.6	2.2	2.9
USA	0.78	0.26	6.9	2.9	3.1

*Ratio of the population aged 90 & more in 2000 / pop. 60 & more in 1970
** ratio female / male, ages 90 & more.
Data sources for Costa Rica: 2000 Census and CCP & INEC, 2002
Data source for countries other than Costa Rica: Human Mortality Database, http://www.mortality.org/

Table 2. Selected data on Costa Rican nonagenarians 1983-2004

Data items	Total	Birth cohorts 1878-93	Birth cohorts 1894-03	Birth cohorts 1904-13
N Individuals	24,438	2,150	7,692	14,596
N Observed years				
Total	101,439	8,778	38,981	53,680
In 1983-93	33,409	8,611	24,798	0
In 1994-2004	68,030	167	14,183	53,680
Mean obs. years	4.15	4.08	5.07	3.68
Deceased	73%	100%	97%	57%
Mean obs. age	92.7	94.9	93.2	92.0
Female ratio	1.28	1.20	1.24	1.33
Late birth registry	17%	36%	17%	13%
Central region	71%	76%	71%	69%

Source: National Registry of the *TSE*

Table 3. Poisson multiple regression models on the relative mortality of Costa Rican nonagenarians

Explanatory var.	Coef.	Exp.	P>z	Coef.	Exp.	P>z	Coef.	Exp.	P>z
M Constant	-0.1875	0.829	.00	-0.1598	0.852	.00	-0.1413	0.868	.00
A Age (90=0)	-0.0108	0.989	.00	-0.0091	0.991	.00	-0.0109	0.989	.00
S Male	-0.1297	0.878	.00	-0.1187	0.888	.00	-0.1332	0.875	.00
Late registry				-0.0144	0.986	.48	-0.0645	0.938	.02
Year (1995=0)				-0.0086	0.991	.00	-0.0042	0.996	.04
Noncentral region				-0.1143	0.892	.00	-0.1612	0.851	.00
Nonextinct cohort				0.0054	1.005	.84			
Interactions									
Male-late reg.							0.0852	1.089	.03
Age-year							-0.0018	0.998	.00
Age-region							0.0124	1.013	.03
Year-region							0.0066	1.007	.03

Figure 1. Age-80 life expectancy in selected countries, circa 2000

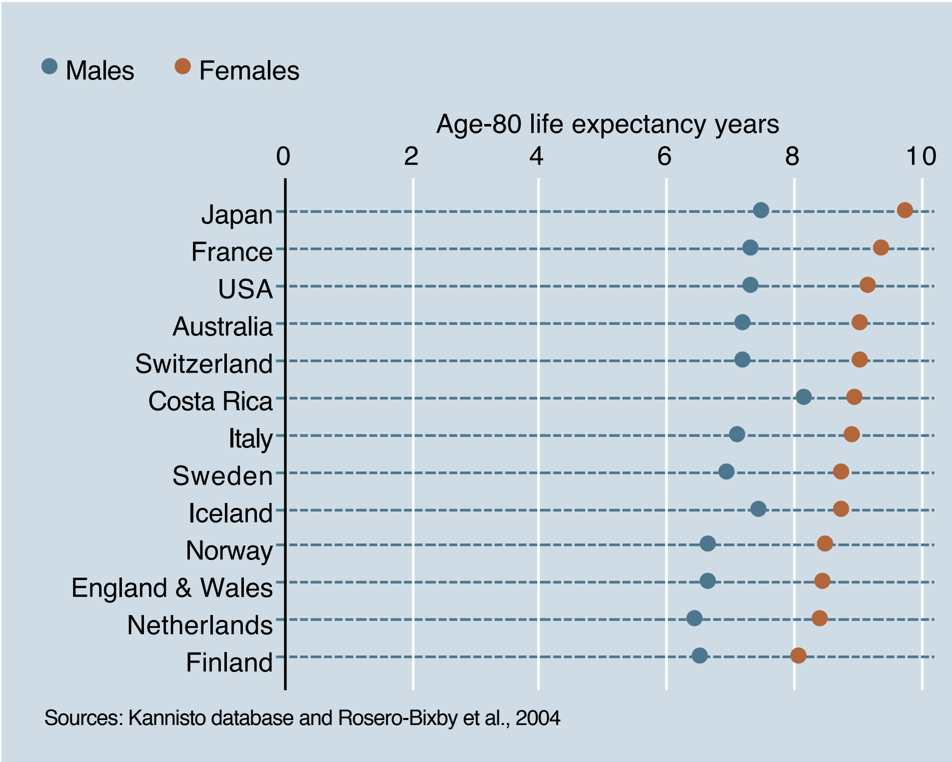


Figure 2. Observed and adjusted age-specific death rates. Costa Rica 1983-2004 and Kannisto-Thatcher average 1990-99

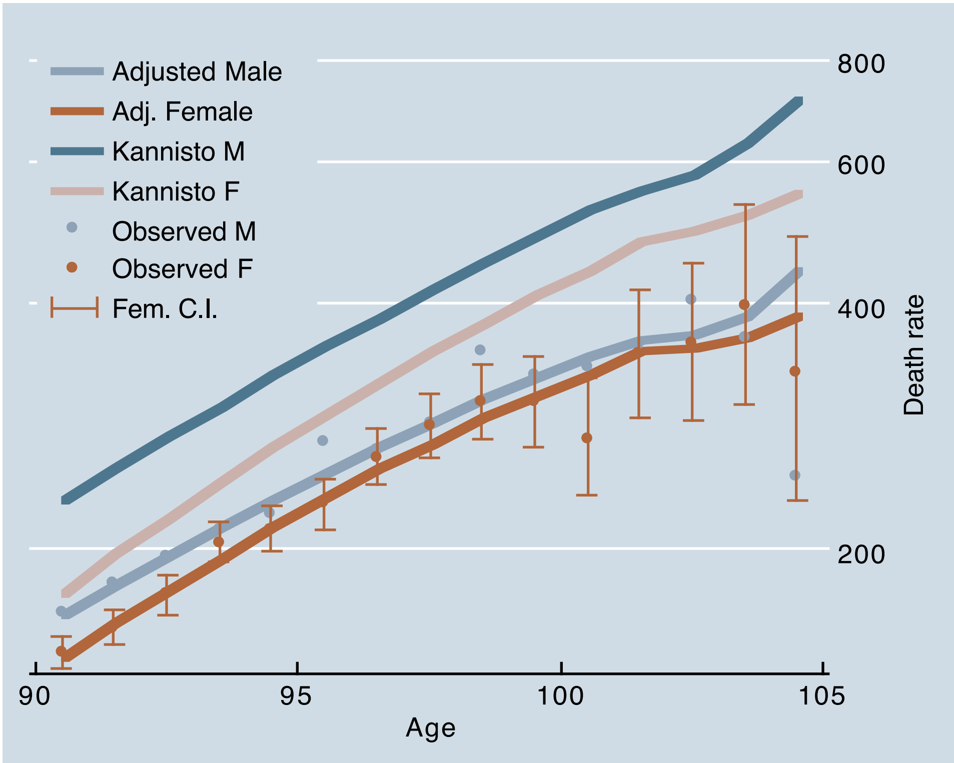


Figure 3. Correction in the age-specific death rates. Costa Rica 1983-2004

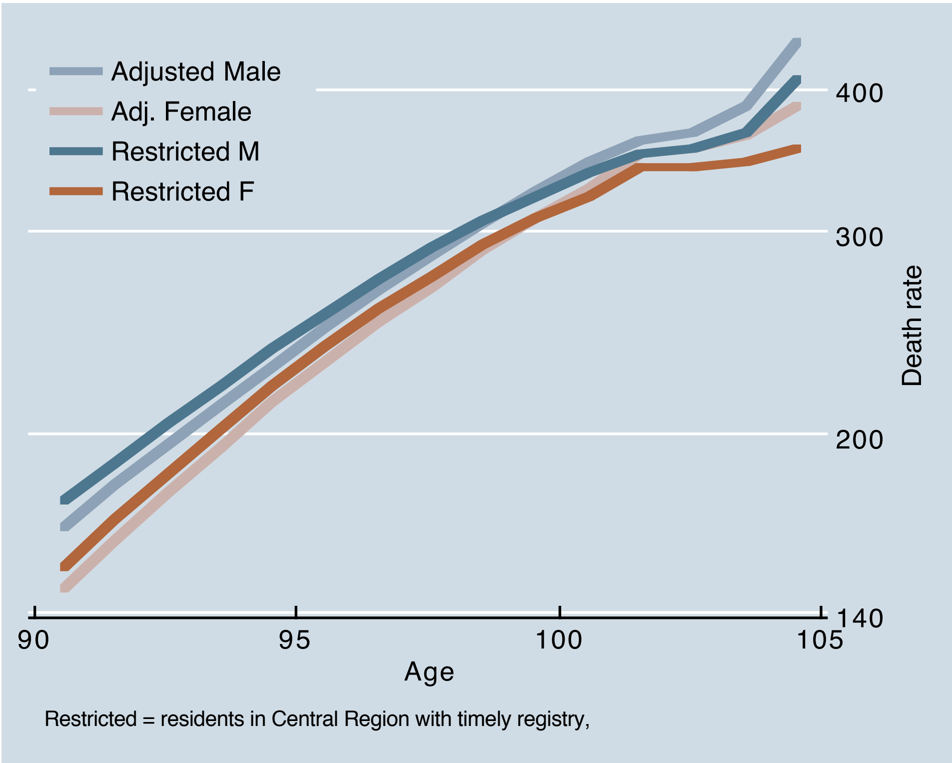


Figure 4 Life expectancy by age and sex. Costa Rican nonagenarians 1983-2004.
Japan and the USA 1990s

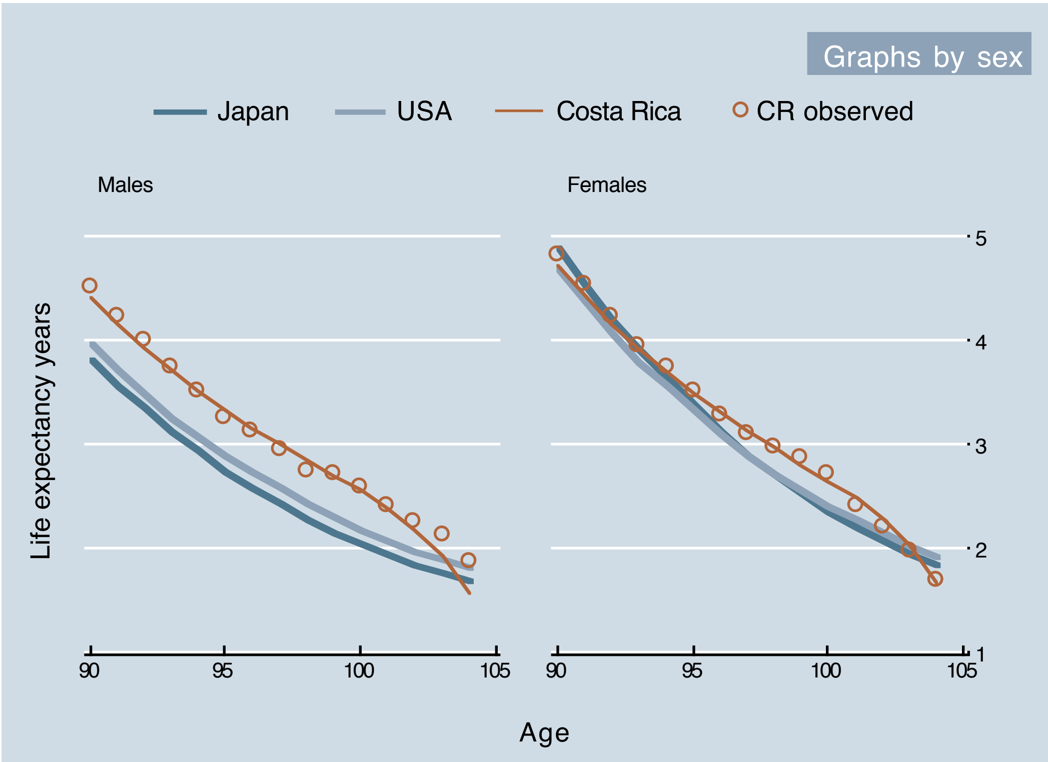


Figure 5. Age-specific death rates by cause of death. Costa Rican nonagenarians 1983-2004

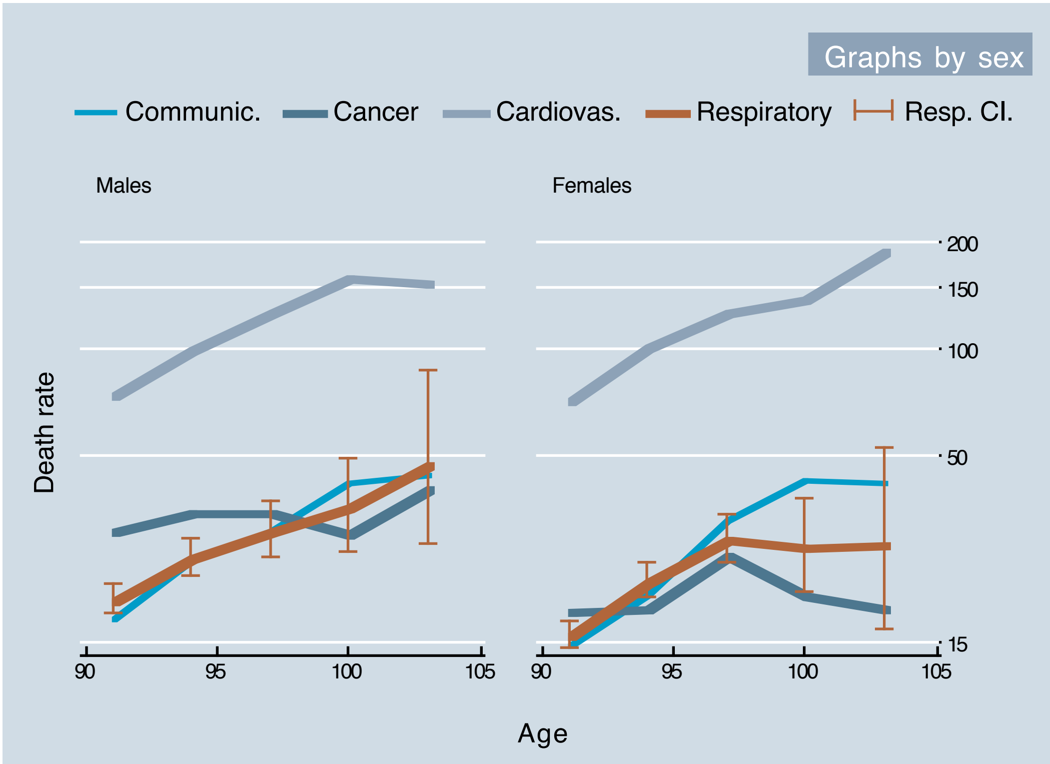
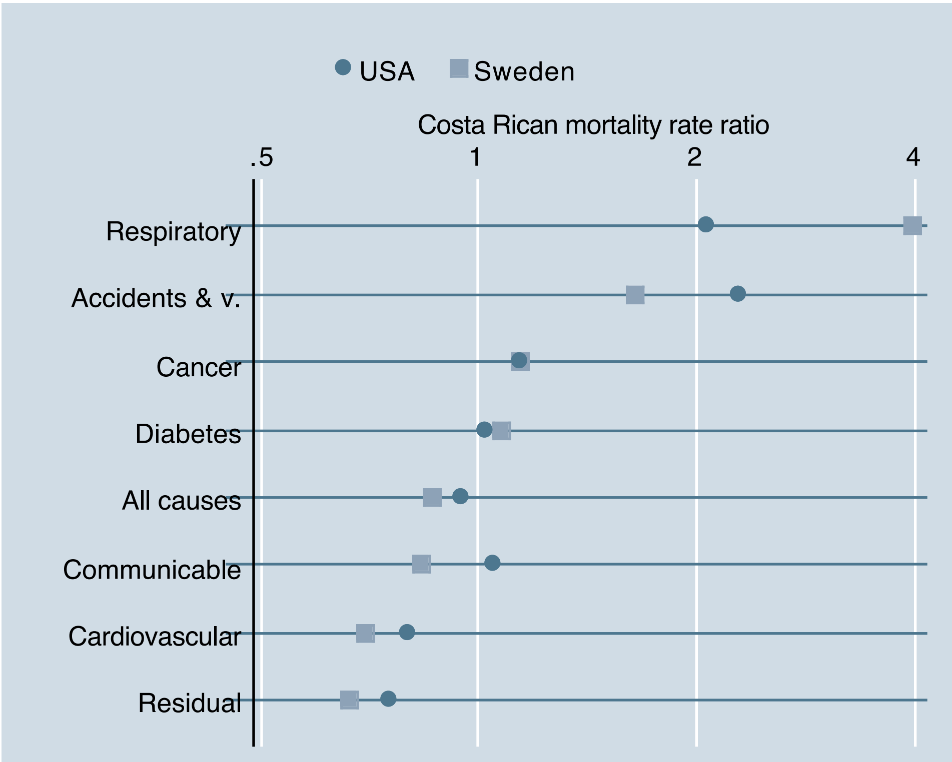
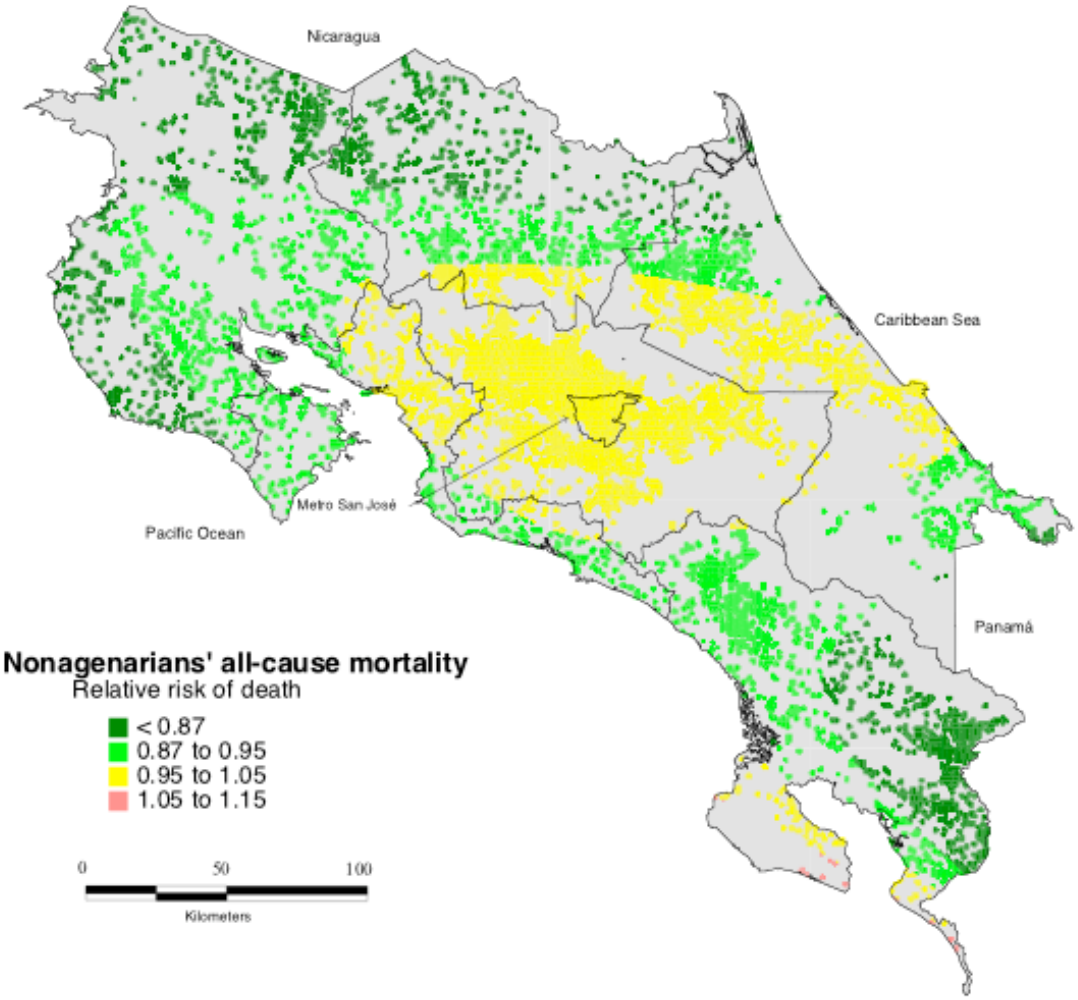
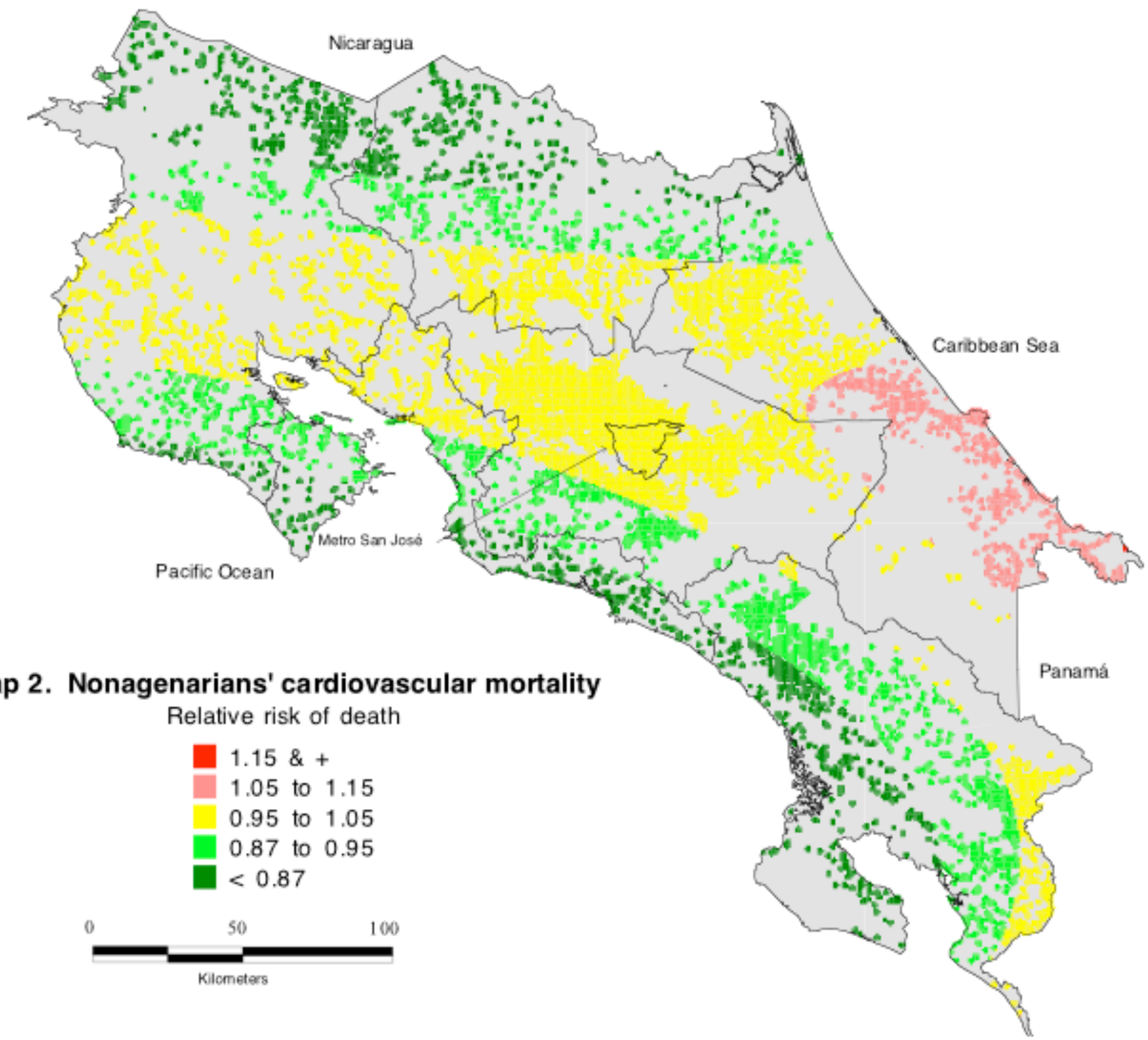


Figure 6. Costa Rican mortality rate ratio by cause of death, compared to the USA and Sweden 1990s decade, ages 85 and over, indirect standardization by age and sex.





Map 1. Nonagenarians' all-cause mortality
Relative risk of death



Map 2. Nonagenarians' cardiovascular mortality

Appendix

Age and sex specific mortality rates. Kannisto-Thatcher standard and observed in Costa Rica 1983-2004 (Rates per 1,000 population)

	Kannisto-Thatcher		Observed in Costa Rica			
Age	Males	Females	Males	(N)	Females	(N)
80	88	53				
81	97	60				
82	108	68				
83	119	78				
84	131	88				
85	145	99				
86	159	112				
87	175	126				
88	193	142				
89	211	159				
90	231	178	166	(9,391)	149	(11,780)
91	253	198	181	(7,704)	160	(9,790)
92	277	220	195	(5,925)	175	(7,652)
93	302	243	211	(4,529)	203	(5,891)
94	328	268	220	(3,430)	211	(4,419)
95	357	295	271	(2,505)	227	(3,286)
96	387	323	264	(1,781)	259	(2,359)
97	419	352	285	(1,236)	284	(1,656)
98	453	382	351	(844)	303	(1,123)
99	489	412	326	(561)	303	(756)
100	526	444	335	(362)	274	(515)
101	556	482	355	(236)	346	(344)
102	582	495	405	(146)	358	(218)
103	635	518	365	(77)	397	(128)
104	721	553	246	(49)	330	(79)
105	853	604	274	(29)	369	(49)
106	1,054	672	344	(17)	441	(25)

N = person-years observed