ROM AN ACTUARIAL POINT OF VIEW, it might be interesting to know whether it's possible to predict the likelihood of a person living to 100 and beyond based on general personal data taken at some point in young adulthood.

Say, at age 30.

Who has a better chance to become a centenarian—a taller or a shorter person? Is it better to be slender or stout? We know that most centenarians are both short and slender in their body build, but these measurements made at older ages could be misleading because they might only reflect body shrinkage as a result of aging. We were also intrigued by other possible predictors of long life. Is it better to be a farmer or an actuary in order to survive to 100? Does



the number of children people have affect their chances to celebrate their 100th birthday? Is it better to have dark eyes or light eyes? All these personal characteristics could be useful for actuaries if a strong association between them and exceptional longevity were to be established.

Biologists vs. Demographers

Interestingly, scientists currently disagree on whether a small or a large body size is conducive to exceptional longevity. Historical demographers are confident that small body size is associated with increased mortality, while biologists are firmly convinced that a small body size is preferable for longevity.

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Numerous historical studies have found that body height in young adulthood is a good indicator of a past history of nutritional and infectious diseases. Infectious diseases (and diarrheal diseases in particular) that were highly prevalent in the past clearly led to growth retardation and a shorter body height, making shortness a marker of an unhealthy childhood and impaired health. For example, early 20th-century military conscripts from highmortality districts of New York were shorter than those from health-

ier districts. It could be expected that shorter people raised in a less healthy environment would have higher death rates at older ages as well. In his pioneering study published in 1984, Norwegian demographer Hans Waaler found a negative relationship between body height and mortality later in life. Waaler's initial findings were reproduced in many other studies, including a famous study of U.S. Union Army Civil War veterans. According to these studies, future centenarians should be taller than their peers.

Not true, say the biologists. Studies of different strains and breeds of dogs, rats, and mice have found that smaller animals live longer on average within a given species. Biologists believe that rapid "catch-up" growth may be harmful and that somewhat delayed maturation is beneficial for longevity. It's well known that dietary restriction that interferes with normal growth can dramatically extend life spans in laboratory animals. These biological findings are consistent with recent studies on the adverse effects of obesity on human health and survival in later life. In some studies, daughters of centenarians have been found to be somewhat shorter than their peers, sugOdds ratios (and 95 percent confidence intervals) of exceptional longevity (survival to age 100) for certain physical and sociodemographic characteristics of men at 30. Results of data analyses were obtained by multivariate conditional logistic regression.

CHARACTERISTIC	ODDS RATIO (95 PERCENT CI)
Stout build	Reference level
Slender or medium build	2.63* (1.13 - 6.12)
Farmer by occupation	2.20* (1.16 - 4.19)
Native born (vs. foreign born)	1.13 (0.63 - 2.05)
Married by age 30	0.68 (0.35 - 1.34)
No children	Reference level
1 to 3 children	1.61 (0.87 - 2.98)
4 or more children	2.59+ (0.92 - 7.28)
Short height	Reference level
Medium or tall height	1.35 (0.80 - 2.29)
Blue/gray eyes (vs. dark eyes)	1.71 (0.99 - 2.95)
Light hair (vs. dark hair)	0.64 (0.31 - 1.32)
Having any reported disability	0.68 (0.28 - 1.66)

^{*} $p \le 0.05$

gesting that the familial factors of longevity may also be associated with a shorter body height (interestingly, sons of centenarians haven't been found to be similarly affected). Accordingly, future centenarians should be shorter and more slender than their peers. In fact, there are reports that Japanese centenarians are shorter than their countrymen whose life span is average. But as we already have mentioned, these studies measured centenarians when their body height had already decreased with age.

For the purpose of longevity prediction, we decided it was necessary to consider the effects of height and weight from when future centenarians were young adults. Surprisingly, such simple studies were never done before, possibly because of the lack of available data.

Better Data, Intriguing Results

With the idea of using better data to explore all these interesting questions on longevity predictors, we initiated a small pilot study of American centenarians using personal characteristics measured when they were young adults. This study employed a random representative sample taken from a Social Security Administration database (SSA Death Master File) of 240 centenarian men born in 1887. These records were then linked to the World War I draft registration cards collected in 1917 when the same men were 30 years old.

In 1917 and 1918, draft registration cards were completed for approximately 24 million American men born between 1873 and 1900. The registration was amazingly complete, with about 98 percent of

year, race, and county of draft registration to use as matched controls. This approach allowed us to eliminate the effects of birth cohort, race, and place of draft registration on survival. Using controls from the same geographical area (county) allowed us to mitigate a possible geographically related subjectivity in height and build estimation and relative ranking. According to the 1900 U.S. cohort life table, living beyond 100 can be expected for around two or three men in every 1,000 born, so it was unlikely that the selected control men could become centenarians by chance.

Finding centenarians in the Social Security database was a relatively easy task. However, it was more difficult to find the same persons in the World War I draft registration cards when they were young. This process (known as data linkage) had an overall success rate of 72.5 percent. In other words, we succeeded in finding 174 linked records for centenarians; three records in Spanish from Puerto Rico were later dropped from the analysis because we couldn't read the handwriting.

Fortunately, the linkage of centenarian records to draft registration wasn't subject to significant bias regarding foreign-born status or race. The proportion of immigrants was similar among centenarians (20 percent) and controls (22 percent) and close to the officially reported proportion of immigrants (18 percent) in the 1920 cen-

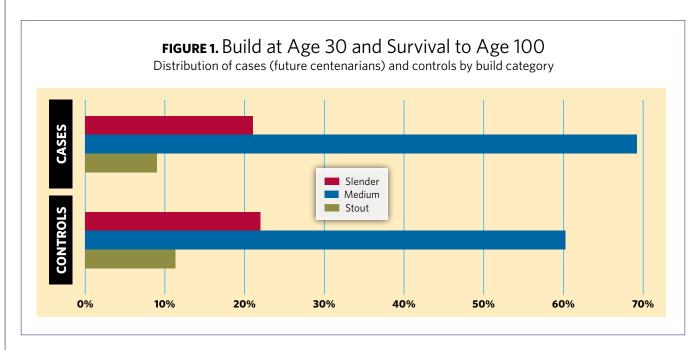
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all adult U.S. men from the ages of 18 to 46 years participating. The registration cards contain information on important socioeconomic characteristics (occupation, marital status, immigration status, number of children) and some physical characteristics, including height, body build, eye color, hair color, and any disabilities.

We randomly selected shorter-lived men matched with centenarian men by birth sus (for ages 20 to 44). The proportion of African-Americans among centenarians (5 percent) was lower than the proportion in the 1920 census (9 percent), but this could be due to higher mortality of blacks compared to whites at certain ages and hence their lower survival rate to age 100.

The first striking observation of our study was that a "stout" body type at age 30 seems to be negatively correlated with survival to

[•] p = 0.07



age 100 (See Figure 1). Only 7 percent of future centenarians fell into the "stout" category, compared to 15 percent of the control group. The overall difference in distribution in build between cases and controls demonstrated a borderline significance in univariate analyses (p=0.07). It's interesting to note that centenarians are not among the tallest or the shortest men at age 30. In fact, most of them tend to be of medium height, although these differences weren't statistically significant.

Multivariate analyses using conditional logistic regression (and controlling for demographic and socioeconomic characteristics) confirmed that a stout body has a statistically significant correlation with lower survival rates to age 100 (see Table 1).

Our study confirmed that obesity at young adult age (being stout at 30 years) is detrimental to attaining exceptional longevity, while height is a far less important factor. The findings that a stout build predicts much lower survival rates to age 100 were consistent with existing knowledge that particularly high body mass indexes (BMIs) and obesity are associated with increased mortality. Our findings also expanded our knowledge about centenarians in three ways:

- 1. The detrimental effects of obesity may have an exceptionally long time range. Obesity as a young adult is still predictive of decreased chances of survival to age 100;
- 2. The significance of build as a predictor of exceptional longevity is much higher

than other variables such as height, immigration status, and marital status;

3. Contrary to expectations based on biological studies (including life extension of dietary-restricted animals), a slender build doesn't improve chances of survival to 100 years when compared to a medium buildit's better not to be stout, but there's no need to starve in order to become slim.

Another interesting finding of our study was the positive effect of a farming lifestyle at age 30 on survival to age 100. In addition to farming, several other broad occupational groups were studied: white-collar occupations (clerks, bankers, etc.), blue-collar skilled occupations (repair mechanics, machinists), service occupations

LIVING TO 100 WAS AN EXCEEDINGLY RARE EVENT

in the past, but now centenarians represent one of the fastest-growing segments of the American population. According to some estimates, the number of centenarians in the United States has reached more than 84,000 and is climbing at an astonishing rate. If this trend continues, how many U.S. citizens will survive into their second century in the future? What will be their health status and health care needs? What will be the costs of this longevity revolution, and who will cover these costs and how?

To address some of these pressing issues, the Society of

Actuaries (SOA) has organized a number of international conferences on living to 100 and beyond and published the proceedings of these meetings in the form of online monographs. The SOA has also sponsored pilot research projects on predictors of exceptional human longevity. This paper represents a brief overview of the authors' study "Physical and Socio-Economic Characteristics at Young Age as Predictors of Survival to 100—A Study of a new Historical Data Resource (U.S. WWI Draft Cards)," conducted with support from the SOA and published online at www.soa.org/livingto100monographs.

(grocers, barbers, salesmen), and unskilled occupations (laborers, kitchen hands, etc.). None of these non-farming occupational groups showed any significant effect on longevity in our study. This result was consistent with our earlier findings (published in the North American Actuarial Journal in 2007) suggesting that children raised on farms (boys in particular) had higher chances of becoming centenarians. Similar results were obtained by other authors who studied childhood conditions and survival to advanced ages and found the beneficial effects of a farm childhood on longevity much stronger for men than women. American demographer Samuel Preston and his

colleagues suggested a hypothesis that the effect of farm childhood on longevity is stronger for men, as compared to women, because men raised on farms often became farmers themselves and continued to live in healthier environments, while women often moved away when they married.

Being married by age 30 had no statistically significant effect on survival to age 100. However, the number of children born to a man by age 30 had a positive effect on his chances of exceptional longevity (see Table 1). The draft registration cards recorded all de-

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pendent children under the age of 12. Since it's unlikely for a father to have children older than 12 by his 30th birthday (corresponding to fatherhood before 18), we believe that the registration cards reported almost all living children born to the men by age 30. It's interesting that a large initial number of children born by the time a man reaches 30 increases his chances of attaining exceptional longevity by a factor of 2.6 (Table 1). The positive correlation of the number of children with longevity seems to contradict predictions in some evolutionary theories of aging (notably, the disposable soma theory) that longevity comes at the cost of impaired reproduction. On the other hand, this finding may have

several reasonable explanations, both of a social and a biological nature. First, fathering a large number of children earlier in life may provide the parent with necessary care and material support in old age. Second, high fertility at young age may be a marker of a man's overall good health and attractiveness in the marriage market (on average, the earlier you marry, the more children you should have by age 30). Third, it was common for farm families to have a larger number of children to help on the farm. Further studies of centenarians, including studies of genealogical data, may shed more light on the mechanisms of this interesting phenomenon.

The effects of immigration status, marital status, and height on longevity appeared less important, and their impact on longevity was statistically insignificant in the studied data set.

This study provided the first estimates of the impact of height, build, and other vital characteristics at a young adult age on future exceptional longevity. It showed that the detrimental effects of obesity may have an exceptionally long time range and that obesity as a young adult is predictive of almost three times lower the chance of living to 100. The results of this study also demonstrated the usefulness of World War I draft registration cards as a new and promising source of information for finding factors associated with lower mortality and better survival.



Additional Reading

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