HEALTHIER, WEALTHIER, AND WISER: A DEMONSTRATION OF COMPOSITIONAL CHANGES IN AGING COHORTS DUE TO SELECTIVE MORTALITY.

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ABSTRACT

Understanding the gradual changes in cohort composition that occur as a result of selective mortality is critical to aging research. We present a straightforward illustration of changes in the distribution of cohort characteristics that arise purely as a result of selective attrition. We use data on health, wealth, and education from 10 waves of the Health and Retirement Survey (N=16,233). Utilizing only baseline information, we calculate sample statistics but include only respondents who remained in the survey at each specific wave. This simple approach exposes substantial changes in the distribution of all examined cohort characteristics over time. For instance, the median wealth increases from about $90,000 to $130,000 among older cohorts. The selection process changes the composition of older cohorts considerably, suggesting that researchers focusing on the elderly need to be aware of the highly select groups they are observing and interpret their conclusions accordingly.

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Selective mortality is a process whereby disadvantaged individuals die at younger ages than their more advantaged peers. This process gradually changes the composition of cohorts in a systematic way: the cohorts appear healthier, wealthier, more educated, and generally better off than they would in the absence of the selection process -- that is, if the disadvantaged individuals did not die. The changes in the cohort composition over time resulting from selective mortality are of interest to a range of substantive areas, particularly those focused on older adults or the aging process.

Over the past three decades, formal demographers have provided the theoretical and mathematical foundations to understand mortality selection and its impact on aging cohorts (Keyfitz, 1985; Manton, 1999; Trussell & Richards, 1985; Trussell & Rodriguez, 1990; Vaupel, 1988; Vaupel, Manton, & Stallard, 1979; Vaupel & Yashin, 1985; Vaupel & Zhang, 2010). They primarily aimed to disentangle individual mortality hazards from average cohort mortality experiences. In many other fields, however, their work was used to understand how distributions of other characteristics in surviving cohorts, whether health, wealth, or education differ from the characteristics of the original cohort, and how changes over time at the cohort level differ from changes at the individual level. For example, health tends to decline with age at the individual level, but the average health in a cohort can remain stable or even improve as those who are the sickest die out, leaving a more robust group behind. The mortality selection process removes individuals from the disadvantaged 'tail' of the cohort distribution, which changes both the centers of distributions (means, medians) of many characteristics toward a more advantageous levels, and also decreases the variance of these distributions (i.e., Vaupel & Zhang, 2010).

Many applied fields had to address selective mortality, also referred to as selective survival, mortality selection, or selective attrition, as a part of their substantive investigations. In social demography, for instance, studies of racial differences in health and mortality among the oldest old turned up evidence of a ‘racial crossover’ whereby the health and longevity of black older adults appeared to gradually approximate or even exceed those of white adults (Coale & Kisker, 1986; Dupre, Franzese, & Parrado, 2006; Johnson, 2000; Manton, Poss, & Wing, 1979; Masters, 2012). In sociology and social epidemiology, the study of age patterning of social disparities in health needed to reconcile two opposing perspectives: “cumulative inequality,” which posits that disparities continue to widen with age, versus “age-as-leveler,” which suggests that disparities become smaller in old age. At the population level, the disparities indeed appear to decline at older ages (House et al., 1990; House et al., 1994). At the individual level, theory and some empirical evidence indicates further increases in the disparities (Dupre, 2008; Lauderdale, 2001; Lynch, 2003; Mirowsky & Ross, 2008). In both cases, the inconsistencies between individual-level patterns and observed cohort averages can be explained by selective mortality that removes more frail individuals from the socially disadvantaged groups, so that the advantaged and disadvantaged averages gradually become more similar (DiPrete & Eirich, 2006; Dupre, 2008; Ferraro & Farmer, 1996; Ferraro, Shippee, & Schafer, 2009; Willson, Shuey, & Elder, 2007).

Selective attrition processes clearly have major consequences for research in many aging-related fields because the surviving cohorts differ from the original cohorts, and the changes over time at the cohort level differ from changes at the individual level. Researchers in many disciplines have discussed the process and its effects but an interesting gap remains. On one hand, formal demography provided the understanding of the mathematics that drives the selection process. On the other hand, the consequences of the selection process have been used to explain *associations* between characteristics in cohorts, like race and health or education and health. To the best of our knowledge, however, no study described how the distribution of *specific* cohort characteristics such as health, wealth, education, or demographics change as a result of selective mortality. This is a critical gap because we should understand the changes that occur in the basic building blocks of our analyses before we study associations between such variables.

In the current study, we present a straightforward illustration of changes in the distribution of important cohort characteristics that arise purely as a result of selective attrition in nationally-representative cohorts of older adults who were followed for up to 16 years. We focus on measures of health, wealth, and education, three factors central to much aging research (Adams, Hurd, McFadden, Merrill, & Ribeiro, 2004; Elo & Drevenstedt, 2002; Elo, Martikainen, & Smith, 2006; Montez, Hummer, & Hayward, 2012; Zajacova & Hummer, 2009). We also show the changes in basic demographic and health-related characteristics of the cohort, specifically sex, race, marital status, as well as smoking and self-rated health. To isolate the consequences of the selection process, we only use information about these characteristics as reported at the baseline. We calculate the distribution of these baseline measures for surviving individuals at each wave. Thus there are no actual individual changes over time – we simply repeatedly use the same baseline information. As some individuals attrit over time, however, the distributions of these characteristics will change for the cohort as a whole. We examine the changes in two cohorts, the HRS cohort with adults averaging about 58 years at the baseline and the AHEAD cohort with adults about 20 years older than HRS respondents. These two cohorts differ widely in the rate of mortality selection (among other factors discussed below), with the older cohort experiencing a much faster selection process. We can therefore compare the rate of cohort composition changes occurring in different characteristics across two generations.

DATA AND METHOD

Data Source

The analyses are based on data from the Health and Retirement Survey (HRS) (Hodes & Suzman, 2007; Juster & Suzman, 1995). The HRS is a nationally representative panel study of older Americans, with interviews conducted every 2 years by the Institute for Social Research at the University of Michigan. The original HRS cohort study started in 1992 and included adults born between 1931 and 1941. During the second wave of interviews in 1994, the survey was joined by the Asset and Health Dynamics Among the Oldest Old (AHEAD) panel that comprised adults born before 1924. Because the 1994 wave is the first wave where both the HRS and AHEAD cohorts are present, we define the 1994 interview as the baseline in our analyses.

We use a version of the merged HRS-AHEAD data available from the RAND Corporation (RAND Corp., 2011). We utilize all 9 waves in which both HRS and AHEAD respondents have been interviewed, from 1994 to 2010. We restricted the AHEAD sample to adults born between 1910 and 1923 in order to obtain a relatively similar age range and sample size for both cohorts. Our analysis sample was defined as respondents with nonzero sampling weights at the 1994 interview from the AHEAD and HRS cohorts. The sample size is 16,233.

Measures

We used only information that was self-reported at the 1994 interview for all cohort characteristics except mortality tracking where we used information from every wave of the survey. The primary measure of health was the number of chronic conditions. The conditions included diabetes, cancer, hypertension, lung disease, heart problem, stroke, psychological problems, and arthritis; the summed index ranged from 0 to 8 conditions. Wealth captured total household assets including primary residence minus any debt or mortgage. Education was measured in completed years from 0 to 17 or more; the last attainment level included all respondents with post-baccalaureate schooling. We used this measure as continuous in some analyses, and also categorized it as less than high school, high school diploma or some college, and bachelor's degree or more.

Demographic information included year of birth (used for sample definition and descriptive analyses), gender, race (white, black, and other), and marital status (which we dichotomized as married or not). Smoking status was coded as current smoker, former smoker, and never smoker. Finally, self-rated health was ascertained on a 5-point scale from excellent to poor; we categorized it into three levels (excellent or very good, good, fair or poor) for descriptive statistics and dichotomized it as fair/poor versus good to excellent elsewhere.

The HRS provided an ongoing tracking of all participants' vital status. At each wave, vital status was ascertained for all nonrespondents by the HRS staff by gathering information from spouses or partners of the respondent. The nonrespondents were classified as alive or presumed alive, dead or presumed dead; all respondents were by definition alive. We used this wave-specific information to define the surviving sample at each wave. In addition to this wave-specific vital status information, we also categorized respondents into one of three groups: those who were alive and remained in the survey through the last 2010 wave, those who died at some point during the follow up, and those who attrited but whose vital status was unknown. This summary variable was only used in descriptive and sensitivity analyses.

Approach

We calculated sample statistics (means, medians, proportions, and variance) for key cohort characteristics for each wave from 1994 to 2010. We always used the information as it was reported in 1994, but we only calculated the wave-specific statistics for those respondents who remained in the survey at the specific wave. The results were graphed against time using line plots, which show how the baseline characteristics of the surviving cohort change across the 9 waves of the survey from 1994 to 2010. Since we plot values as they were reported in 1994, if no attrition occurred the lines would be perfectly horizontal; if the attrition was random or unrelated to the key covariates, the lines would be approximately horizontal. Any departure from the horizontal pattern is a consequence of mortality selection.

Sensitivity analyses were conducted to determine the robustness of the findings to three analytic choices. First, we examined the impact of survey weights by comparing results under three scenarios: unweighted results, results obtained when applying the baseline weight at each survey wave, and results obtained when wave-specific weights were applied. These wave-specific weights were calculated by the HRS to match the sample to the Current Population Survey distributions for the given year. There was almost no difference in substantive findings based on the two types of weights. The weighted and unweighted findings differed in the initial distribution of each characteristic but the rate of change over time, the main factor of substantive interest, was comparable for the weighted and unweighted estimates. Second, we compared results with and without inclusion of respondents who left the study but were either known to be alive based on the HRS tracking information, or whose vital status was unknown – in other words, respondents whose attrition could not be definitively attributed to mortality. The findings excluding this group were again substantively equivalent to those presented below that included the attriters. And finally, some respondents were not interviewed in some waves but were later interviewed again – they may have missed interviews because they were out of the country or could not be reached that year. We could either leave these respondents out for the missed waves when calculating the sample distributions (since they failed to participate during that wave) or we could add them to the calculations (since we knew they did not attrit or die). In other words, the sample could be summarized with or without these missing interviews. Again, there was little substantive difference in findings with or without this imputation; all results are available on request.

RESULTS

Table 1 summarizes the characteristics of the AHEAD and HRS cohorts at the 1994 interview and shows the attrition from each cohort through 2010 at the bottom of the table. The respondents from the AHEAD cohort were born on average in 1916, nearly 60% were female, 87% were white, their median household wealth was just under $92,000, and they reported about 1.5 health conditions at the start of the survey. The HRS cohort was about 20 years younger on average, 53% female, with a higher median household wealth of $128,000 and a smaller number of health conditions (1.2) at the 1994 interview.

---------- Table 1 about here ----------

Figure 1 shows how the distributions of health, wealth, and education change over time as a result of selective attrition. If no attrition occurred or if the attrition were random, all lines in the figure would remain horizontal because we are repeatedly summarizing the 1994 characteristics at each wave. A different way to think about this is that the individual ‘trajectories’ are necessarily flat – we just repeat the 1994 information for each individual. At the cohort level, in contrast, the characteristics change in a predictable manner: the average number of health conditions as reported in 1994 declines, median wealth increases, and the average educational attainment also grows. For all three characteristics, variance decreases steadily. The rate of change in both the measures of central tendency and in variance is considerably faster in the older AHEAD cohort than in the HRS cohort. This difference is primarily a function of the greater attrition of the AHEAD respondents, among whom fewer than 15% of the initial cohort remained in the study through 2010, compared to over 60% in the HRS cohort.

The changes in the distributions of these characteristics in the surviving cohorts are sizeable. For instance, the AHEAD cohort averaged about 1.5 health conditions in 1994; this mean declines to less than one condition by 2010. For the HRS cohort, the initial mean of 1.2 conditions decreases to about 1.0. In fact, a crossover is evident for this characteristic whereby by 2008 the mean number of health conditions of the older AHEAD cohort is lower than the mean of the younger HRS cohort. The median baseline household wealth appears to increase steeply by 45%, from about $90,000 to over $130,000 for the AHEAD cohort. The observed mean educational attainment rises by nearly one year in the AHEAD cohort during the follow up. The increases are more modest, but still appreciable, in the younger HRS cohort where median wealth increases from under $130,000 to over $140,000 and mean education grows from about 12.4 to over 12.6 years.

---------- Figures 1 and 2 about here ----------

Figure 2 shows changes in the distributions of other important cohort characteristics. The proportion of men drops from about 47% to 44% in the HRS cohort and from about 40% to 33% in the AHEAD cohort. The proportion of black respondents and adults with less than high school similarly declines in both cohorts, as does the percent who were not married in 1994. The proportion of respondents who reported that they were current or past smokers in 1994 decreases across waves, as the smokers are removed from the cohorts faster than never-smokers. The change over time in the proportion of respondents who reported fair or poor health at baseline is particularly steep, falling from over 35% to about 12% in the AHEAD cohort and from about 21% to less than 16% in the HRS cohort. Just as for the number of chronic conditions, there is a crossover by 2008 so by the last wave the older AHEAD cohort survivors appear better off than the HRS group.

DISCUSSION

Understanding the changes in cohort composition caused by selective attrition is important for all aging research. The selective attrition process is relatively well understood theoretically but empirical illustrations of its consequences for key characteristics of aging cohorts have been lacking. This study presented a simple demonstration of the changes in the distribution of health, wealth, education, and other characteristics in two nationally-representative samples of older adults over the course of 16 years. Our approach was straightforward: we used information provided by respondents at the baseline interview and summarized it at every subsequent wave, including only those respondents who remained in the cohort at that particular wave. In the absence of selective attrition, the means, medians, proportions, and variance of these measures would remain unchanged across all waves.

We found substantial changes in the distribution of all examined cohort characteristics over time. The direction of these changes was consistent with theoretical predictions: the averages of covariates associated with lower mortality, like wealth and education, increased over time. The averages of covariates associated with higher mortality, like poor health, or being male, black, not married, or a smoker, decreased over time. The variance of the distributions also decreased over time as those most disadvantaged and at the tails of the distributions died at faster rates.

The changes occurred both in the younger HRS cohort and the older AHEAD cohort. However, the rate of the change was particularly high in the latter group where high overall mortality---a function of the cohort's old age—resulted in a rapid selection process to a point of crossover with the younger cohort in some characteristics. In particular, while the younger HRS cohort reported fewer chronic conditions and better self-rated health than the older AHEAD cohort at the baseline 1994 interview, this distribution changed as those in poor health died. By the 2010 wave, these health characteristics appeared more advantageous in the older cohort, compared to the younger HRS group. With respect to economic well-being, the AHEAD cohort started with about $90,000 in household wealth; by the last interview the median of their 1994 value increased to over $130,000. The mean educational attainment increased by nearly a full year in the AHEAD cohort over the 16 year follow up, again purely due to selective attrition.

The primary factor that influenced the faster changes in the older AHEAD cohort as compared to the HRS group is the higher overall rate of attrition, mostly due to death. This attrition removed over 80% of the AHEAD sample; the more advantaged subgroups were more likely to remain alive and in the sample. However, several other factors are likely to play a role in the rate of change for different cohort characteristics.

First, the more strongly a characteristic is related to the likelihood of attrition, the more it will change over time. This is why the health measures (number of conditions and poor/fair self-rated health) changed so steeply in the AHEAD cohort, to a point of crossover with the younger HRS cohort: health is more closely linked to mortality than other characteristics. A related second factor pertains to the causes of attrition, in particular what proportion of attrition is due to mortality as opposed to other causes. This is because key cohort characteristics may be more strongly related to mortality attrition than attrition that occurs for various other causes, like moving to a different location or lack of interest in participating. In the AHEAD cohort, over 90% of attrition was due to death. In the HRS cohort, less than 60% of attrition was due to death. Thus, characteristics that predict mortality, like wealth or health, may be more strongly linked to the selection process in the AHEAD cohort and thus their average values for the cohort will change more over time in the older group.

Third, it is likely that the initial distribution of a characteristic in the cohort matters for the rate of its change over time. If a variable positively associated with mortality hazard is right-skewed, for instance, its initial mean is affected by this right tail; the count of chronic condition is a good example. The relatively small number of individuals in that tail, who have the highest values (most chronic conditions in our example), are by definition particularly disadvantaged and thus most likely to die, causing a relatively large decrease in the mean of that characteristic over follow up. A parallel situation could arise for a variable that is linked to lower mortality and has a long left tail; a good example is the distribution of educational attainment in current cohorts, where a very small proportion of the population is in the 0-8 years range but this group also has the highest mortality risk.

A fourth factor that may impact the changes in cohort composition over time is the age range of the initial cohort. Specifically, the wider a set of ages analyzed together, the larger is the variation in the mortality hazards across this differently-aged group. Thus the difference in the rates of selective mortality at the opposite ends of the age spectrum is large, meaning that the characteristics of the whole group gradually come to resemble those of the younger aged individuals as the older ones die out faster. For illustration, suppose we summarized a distribution of some characteristic for a group composed of an equal number of 20-year-olds and 80-year-olds. As this group would age, within a decade or two the proportion of the older group would dwindle to nearly zero, so the distribution would become nearly equal to the distribution of the 20-year-olds. If that characteristic were age, for instance, its mean would *decline* from 50 at the beginning to about 40 over the course of two decades, although obviously every survivor's age *increased* by 20 years. If the two groups instead comprised an equal proportion of adults who were say 80 and 81 years old at the beginning –a much smaller range of cohorts— the mean of the age distribution in the surviving cohort would in the two decades increase similarly to the individual-age increases, about 20 years.

Finally, the rate of change in the distribution of a characteristic may depend on secular changes in this characteristic across cohorts. If a distribution changes little between younger and older birth cohorts, then a group comprising different birth cohorts starts off with similar distributions of the characteristic. If, however, the distribution of a characteristic changes across cohorts then the differently-aged groups start with already different distributions. For instance, average educational attainment has increased steeply over time, so younger cohorts have a higher average attainment than older cohorts. Suppose we calculated the educational attainment in a joint HRS/AHEAD cohort; the initial distribution would be a weighted average of the two groups. As most of the AHEAD cohort died out while most of the HRS cohort remained in the sample, the overall education average would approach that of the HRS cohort. Thus the apparent change in the mean educational attainment in such a merged HRS/AHEAD cohort over time would be a function of the wide age range that causes the AHEAD cohort members to die out at much faster rates than the HRS respondents, combined with the higher educational attainment of the HRS cohort.

The main limitation of our descriptive analysis is that we could not systematically analyze the contributing impact of these five factors on the changes in the cohort characteristics. Not only are there multiple contributing factors, but these factors interact with one another in complex ways so it is difficult to isolate their effects just by observing the consequences of their interplay in a cohort. This is precisely where simulation analyses would be helpful. In a simulation, the analyst can impose control over the individual factors and hold some constant while changing others to observe their effects on characteristics of the cohort. A descriptive analysis like the current study can be used as a foundation to ensure that the outputs of the simulation correspond roughly to the patterns in actual cohorts.

Our study was based on longitudinal data. The implications of the findings, however, are relevant for both cross sectional & longitudinal research. A cross-sectional sample is a snapshot of the selected surviving cohort at one time point. In older cohorts, such a group may represent a highly select group of survivors. The focus on the survivors is a perfectly valid approach for many research questions – for instance, we may be interested hospital utilization among the oldest old and thus focus on only those who survived to the relevant ages. We need to be aware, however, of the implicit conditioning on survival to the point of the study (Kurland, Johnson, Egleston, & Diehr, 2009). Longitudinal studies typically are undertaken to describe changes in some characteristics over time. More precisely, researchers tend to be interested in *individual* changes over time but these individual changes are typically inferred from *cohort averages*. Our results highlight the differences between individual and cohort-average patterns over time and point to the need to take selective mortality into account when modeling longitudinal data collected from older adults.

Conclusion

As the world population ages, research on older adults is becoming increasingly critical to economic, health, and social policy planning. We showed that aging cohorts may appear to become healthier, wealthier, and wiser --or at least more educated—over time as selective mortality removes the more disadvantaged individuals from the population. The selection process changes the composition of older cohorts considerably, indicating that researchers focusing on the oldest old need to be aware of the highly select groups they are observing, and interpret their conclusions accordingly.

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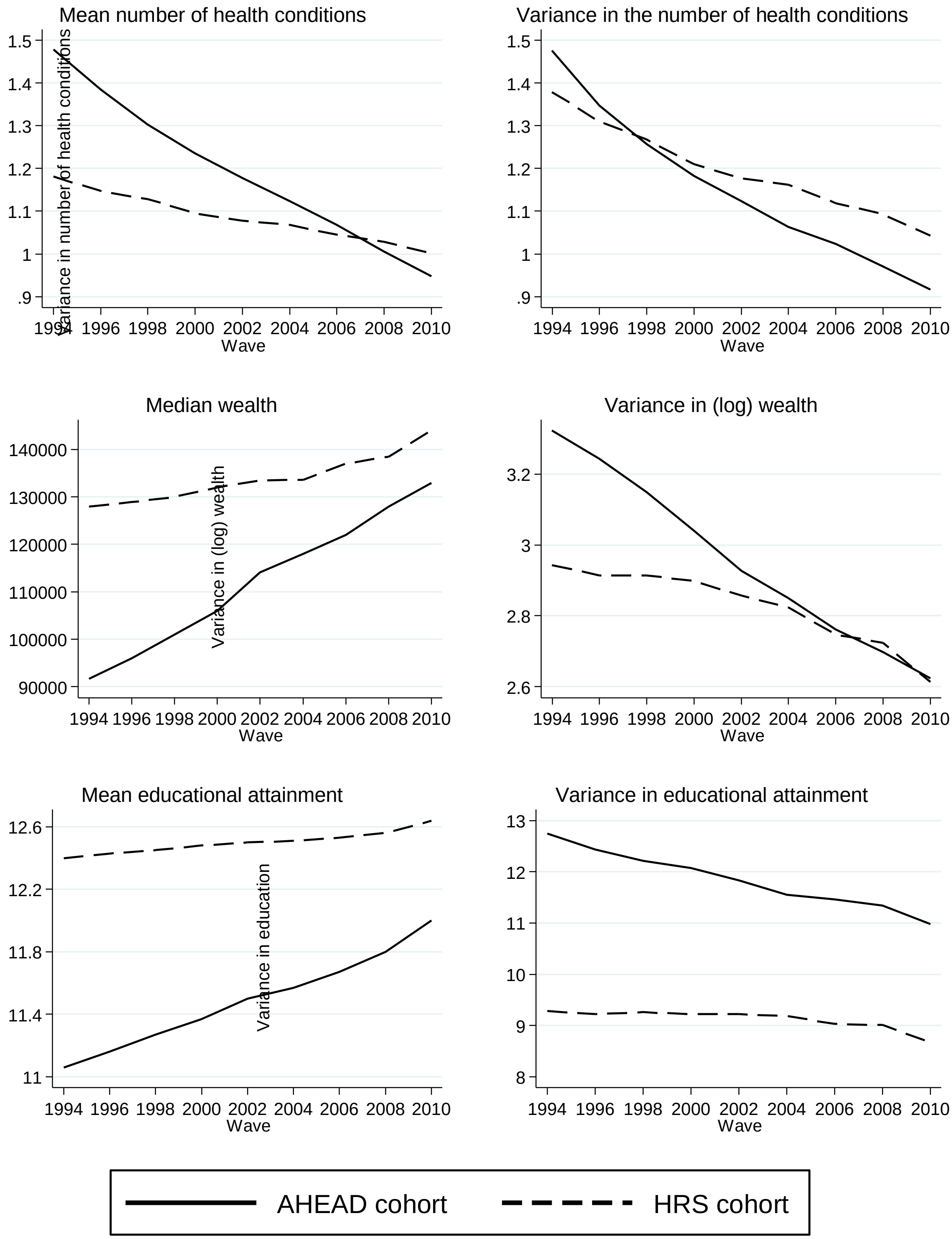
Table 1. Characteristics of the AHEAD and HRS cohorts at the 1994 baseline.

	AHEAD cohort (1910-23)	HRS cohort (1931-41)
Baseline characteristics		
N	7,352	8,881
Mean year of birth	1916	1936
Proportion female	59.7%	52.7%
Proportion married	52.9%	76.4%
Race		
White	87.2%	81.7%
Black	7.9%	9.6%
Hispanic or other	4.9%	8.6%
Educational attainment		
Less than high school	43.4%	27.3%
HS or some college	44.9%	53.8%
Bachelor's or more	11.8%	18.9%
Median wealth	$91,700	$128,000
Smoking status		
Never smoked	47.1%	36.2%
Former smoker	43.0%	39.8%
Current smoker	9.9%	24.0%
Self-rated health		
Excellent or very good	33.7%	50.5%
Good	30.8%	28.6%
Fair or poor	35.5%	20.9%
Number of conditions	1.48	1.18
Attrition during follow up		
Survived through 2010	14.8%	61.1%
Died during follow up	79.5%	23.2%
Attrited, vital status unknown	5.6%	15.7%

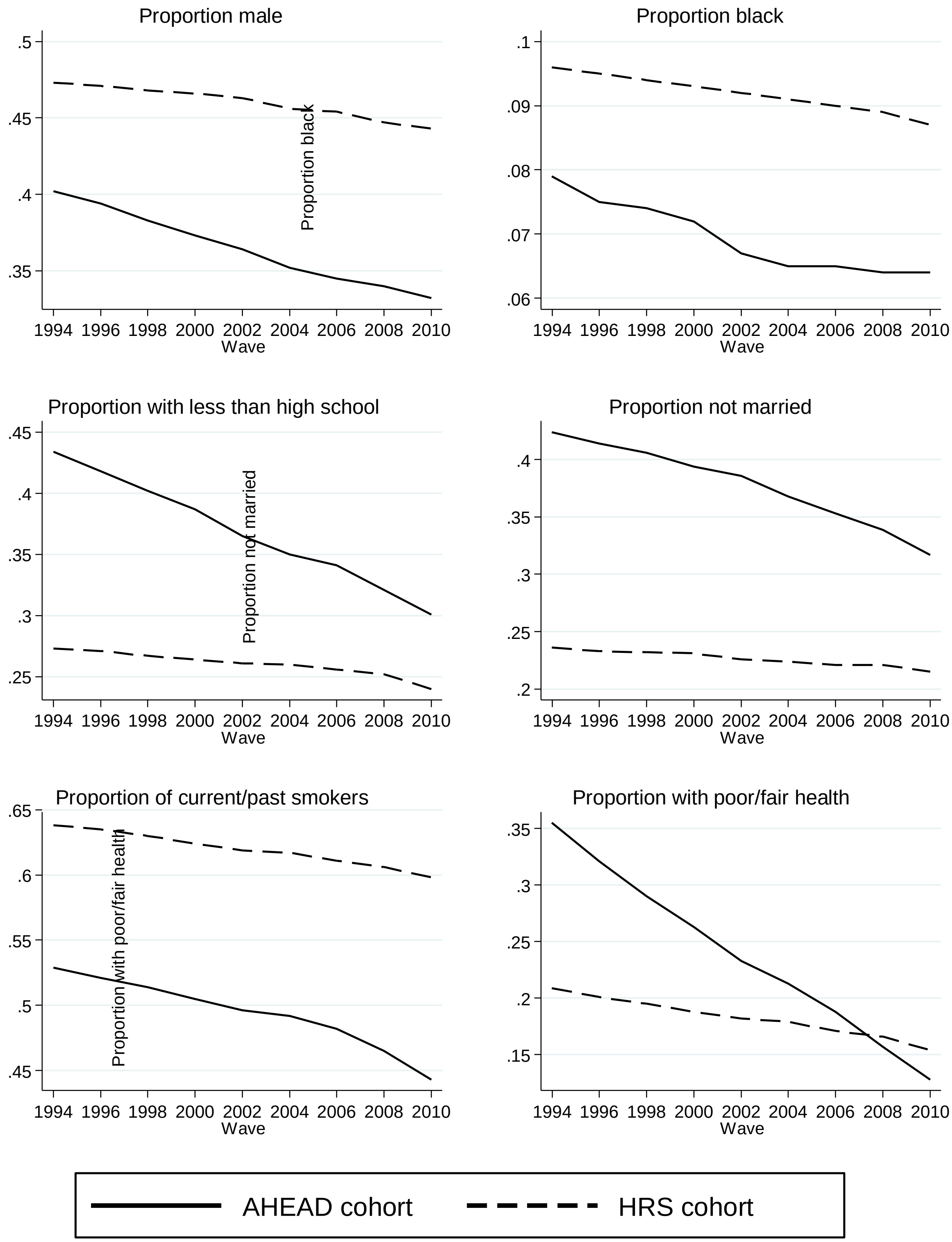
Adjusted for sampling design. Sample includes respondents who participated in the 1994 interview, had nonzero sampling weights and were born in 1910-23 or 1931-41.

Figure 1. Changes in cohort characteristics due to selective attition



Baseline weights applied. AHEAD includes 1910-23 cohorts; HRS includes 1931-41 cohorts.
Results are based on information reported in 1994 and summarized for survivors at each wave.
In the absence of selective attrition, the lines would be horizontal.

Figure 2. Changes in additional cohort characteristics due to selective attition



Baseline weights applied. AHEAD includes 1910-23 cohorts; HRS includes 1931-41 cohorts.
Results are based on information reported in 1994 and summarized for survivors at each wave.
In the absence of selective attrition, the lines would be horizontal.