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Abstract

It is difficult to distinguish changes in health due to aging from those related to dying, because the two processes are highly related. Some potentially treatable conditions may mistakenly be dismissed as due to old age. The goal of this article was to examine the relationships of aging and of dying to changes in 10 health-related variables: self-rated health, depression, ADLs, IADLs, minimental state examination, body mass index, blocks walked per week, bed days, hospitalization, and walking speed (all coded so that higher values were better). We used longitudinal data from the Cardiovascular Health Study to estimate the changes in the variables associated with 5 years of aging and also in the 5 years before death, controlling for years from death and for age, respectively. All 10 health variables declined as death approached, and most of them also declined with age. The “effect” of the dying process was usually significantly larger than the effect of aging. Large declines in these health measures are probably not due to aging, and should be taken seriously by patients and their providers. © 2002 Elsevier Science Inc. All rights reserved.

Keywords: Self-rated health; Terminal drop; Normal aging; Aging process; Dying process; Failure to thrive; Sarcopenia

1. Introduction

A significant problem in caring for older people is distinguishing age-related changes from pathology, because treatable conditions are frequently passed off as “old age” [1]. However, changes due to aging can easily be confused with changes related to the imminence of death. Many human functions are not primarily related to chronological age, but tend to show marked decline prior to death during a period ranging from a few weeks to a few years [2,3]. Gerontologists have described a phenomenon called terminal drop, a determinant chain of functional changes that may be due to a “dying process.” Terminal drop has been studied with relation to cognitive function [3–11] and to physical function [3,12–20]. Methodologic concerns with such analyses include selection bias, cohort effects, missing data, and selection for the “biological elite” as persons age [8,11,12].

There are no generally accepted models to describe the process of aging. There is also no agreement on whether there is a dying process, or how it should be defined. In this article we use an operational definition of a dying process as systematic changes in health that occur close to death and are independent of age. The relationship of the aging process to the dying process is also unclear. Fries describes an ideal model in which a person’s health does not deteriorate substantially with age, but instead declines very rapidly close to death, at whatever age [21]. This “dying-only” model would have a small effect of aging, and a large change associated with imminent death. Another possible model is that people’s health worsens monotonically with each year of age, independent of how close they are to death. This “aging-only” model presupposes a large effect of aging, but a relatively small effect of imminent death. Some intermediate model is probably the case.

For this article we assume that an aging process and a dying process exist, and examine how the processes are associated with changes in various health-related measures. For purposes of readability, we will refer to such changes as the “effect” of the aging and dying processes; however, because this study is based on observational data, the “effects” are only associations, and it is not possible to assign the direction of causality. To study the effects of dying and aging we need data from people who are dying, and also from those who are not dying. Such a classification cannot be made prospectively. However, in a longitudinal study, once a person’s date of death is known, data collected long before death can be used to examine the effect of aging on the variable of in-
terest, independent of the dying process. We examined data for people collected an average of 15 years before their death to study the effect of aging in people who we define as “not dying.” To study the effect of dying independent of aging, we examined the health of people the same age (80) but who differed in the length of time before death (<1 year vs. 5 years from death). The goal was to use these data to estimate the effect of the aging and dying processes on these health variables, and to see which effect is larger.

2. Methods

2.1. Study design: the Cardiovascular Health Study

The Cardiovascular Health Study (CHS) is a population-based longitudinal study of 5,888 adults aged 65 and older at baseline, designed to identify factors related to the occurrence of coronary heart disease and stroke [22]. Subjects were recruited from a random sample of the Medicare eligibility lists in four U.S. counties. Persons who did not expect to remain in the area for the next 3 years, or who were institutionalized, using a wheelchair at home, or receiving treatment for cancer at baseline were ineligible. Extensive baseline data were collected for all subjects, including a home interview and clinic examination. After baseline, subjects had an annual clinic visit, and provided additional information by mail and telephone. Two cohorts were followed: one with 10 years of follow-up (n = 5,201), and the second (all African-American, n = 687) with 7 years of follow-up to date. Data collection began in about 1990, and follow-up is virtually complete for all surviving subjects in the year 2000 [23]. At baseline, the mean age was 73 (range 65 to 100); 58% were women, and 84% were White.

2.2. Health-related variables

Although CHS participants had a clinic visit every year, different data were collected in different years. To describe subjects’ health, we chose 10 health-related variables that were measured every year and were likely to change with age or nearness of death. These included body mass index (BMI)—measured weight in kilograms divided by height in meters squared; the Mini-Mental State Examination score (MMSE) [24]; self rating of health as excellent, very good, good, fair, or poor (EVGFp); activities and instrumental activities of daily living (ADL and IADL); the Center for Epidemiologic Studies Depression score (CESD) [25]; number of blocks walked in the past week; number of bed days in the previous 2 weeks; whether the person was hospitalized in the prior 6 months; and the time it took to walk 15 feet. We also looked at blood pressure and flu shots, which are mentioned only briefly.

We reversed the coding of some of the variables so that a higher value would always represent better health. We recoded the depression score as 30 minus the CESD score, so that a person with no depressive symptoms has a score of 30, and a person with severe levels of all 10 depressive symptoms has a 0. To remind the reader of this sign reversal, we refer to this new variable as “Cheer” rather than depression. (We could not find a better word to describe lack of depressive symptoms). For EVGFp we scored the categories excellent, very good, good, fair, or poor as 96, 93, 75, 45, and 19, respectively, which yields the estimated percent probability that the person will be healthy 2 years in the future [26]. We report the number of ADLs (or IADLs) that the person could perform without difficulty, the number of days in 2 weeks not spent in bed, whether the person stayed out of the hospital, and the number of feet per second walked in a 15-foot timed walk (Walking Speed). More detailed definitions of all the variables are in the appendix table.

Longitudinal data were collected for all people on each variable. Data that were missing between the first and last known measures were imputed from a person-specific regression of the variable on the log of time from the last known measure. For measurements that were missing just before death, we imputed values using the last observation carried forward, realizing that this approach would give a conservative estimate of the change in the health variables close to death. For people currently alive, approximately 5% of the relevant data had to be estimated. For persons who died, 20–29% of the data for Blocks walked and Walking Speed were estimated; 10–19% were estimated for depression, MMSE, EVGFp, BMI, ADL, and IADL; and <10% were estimated for Bed Days and Hospitalization.

2.3. Operational definition of aging and dying

We are unaware of any evidence on when the “dying process” actually begins. We wanted the data describing people who were “not dying” to be as far as possible from death, within the limitations of our data. We set the boundary at 7 years, labeling patients 7 or more years before death as “not dying” and patients within 7 years of death as “dying.” The potential effect of any misclassification caused by this labeling is mentioned in the Discussion section. For the 1,933 persons who had died by the year 2000 (dying), we used all data collected in the 7 years before their deaths. For persons still alive in 2000 (not dying), we used only the data from 1993, which were thus collected at least 7 years before their death. We used 1993 rather than baseline data (1990) because there was positive selection at baseline due to eligibility criteria and a likely healthy volunteer effect, which should have attenuated by 1993. This choice also permitted inclusion of the smaller cohort of African-Americans, for whom data collection began in 1993. Based on the sex and age distribution in the year 2000, the remaining life expectancy of persons who were still alive in the year 2000 averaged about 8 years [27]. We can thus consider the data for the not-dying group to have been collected an average of 7 + 8 = 15 years before death. For most of the analyses, we used all the longitudinal data within 7 years of death for the people who died, and only the 1993 data for those alive in 2000.
2.4. Analysis

We used linear regression to describe each health variable as a function of age, log age, sex, years from death at the time of this observation (dummy variables, with those alive in 2000 taken as the reference category), and first-order interactions among all of these variables. This model permitted relationships to be nonlinear in age, different for men and women, and different by time from death. Rather than report coefficients of these complex equations we graphed the predicted values, as a function of age and years from death, by sex. A variant of the model, in which time from death was ungrouped and used as a continuous variable, is explained in conjunction with Figure 5.

To summarize the effect of 5 years of aging near age 80, we calculated the predicted difference between a 77.5-year-old person >7 years from death and an 82.5-year-old person also >7 years from death. We call the difference in those predicted values the pure aging effect. Similarly, we calculated the pure dying effect as the difference in the predicted value for a person age 80 and 5 years from death (presumably before the dying process has started) and a person age 80 and less than 1 year from death. We present these estimated effects on the original scale, and also standardized so that the different health variables can be compared. Some potential biases in these estimates are noted in the Discussion section. We tested whether the aging and dying effects were significantly different from zero and from one another, and whether the effects were different for men and women.

In testing for significant differences we used generalized estimating equations to account for the dying persons having contributed multiple observations. Analyses were performed using the Statistical Package for the Social Sciences and STATA.

3. Findings

Table 1 shows descriptive statistics for each study variable. Cheer averaged 24.5 of a possible 30 points; EVGFP averaged 70 (slightly below “good”); on average persons were able to perform 5.5 of the 6 IADLs and 5.7 of 6 ADLs; the mean MMSE was 89 of a possible 100; average BMI was about 26; persons walked an average of 31 blocks per week; they were out of bed 13.8 days of 14; 89% were not hospitalized in the previous 6 months; and on the timed walk they averaged a speed of 2.9 feet per second. There were over 45,000 observations for each variable, because this table includes all available data. The numbers differ slightly among variables because of differences in the mode of data collection.

The number of years of “follow-back” for persons who died depends on how long they were in CHS at the time of death. For example, 101 persons died shortly after enrollment, and thus had only one measurement prior to death. There were 133 persons with two measurements, 160 with three, 179 with four, 231 with five, 204 with six, and 925 with seven or more measurements prior to death, for a total of 10,482 measurements made in the 7 years before death. (Data “missing” because the person died early may be considered missing completely at random, and will not cause bias). persons did not respond at exactly 12-month intervals, which led to some persons having more measures than expected, and some fewer. For example, although 1,933 persons died, there were 1,987 Cheer measures within 1 year of death.

Table 2 shows the number of observations of Cheer as a function of sex, age at time of the measurement, and years before death. For example, the column labeled “<1” shows that 1,987 measures were made less than a year before death. The 3,913 measures in the column labeled “>7 years” are the measures made in 1993 for persons who are currently alive (in the year 2000). In the primary analysis we will exclude the 33,264 observations made on persons who are currently alive, but collected in years other than 1993 (labeled “Other” in the table). The numbers of observations in most cells are large, but there were fewer for persons who were young and close to death, or old and far from death.

Table 3 shows the mean of each health variable in five age groups, based on all 45,000 observations. All the means declined monotonically with age, showing that age was associated with worse health. However, the older persons were also closer to death, which might have caused their values to be low. Table 4 shows the mean of each variable as a function of years from death (now excluding the 33,264 observations in column 1 of Table 2). The mean of each variable decreased as persons drew closer to death. However, the persons closest to death were on average older, which might have caused their values to be low. To look at the trends as a function of both age and time from death we fit the regression defined above to describe each health variable as a function of sex, age, and years from death. The graphs of the estimated values for men are shown here because there were more deaths among men. Graphs for women and more detailed graphs for men are available on the CHS web page (figures will be at http://chs3.chs.biostat.washington.edu/chs/ after article is published).

Figure 1 shows the mean fitted Cheer score for men by age and years from death. We will discuss it in some detail, and
then point out similarities between Cheer and the other health variables. There is a clear separation among the five lines. The highest line represents persons more than 7 years from death (not dying, by our definition). People far from death were thus more cheerful (had fewer depressive symptoms) than those who were dying. Cheer declined sharply with age in this group. The lower four lines represent measurements taken 4 to 6.9, 2 to 3.9, 1 to 1.9, or less than 1 year before death, respectively. For men aged 80, mean Cheer is about half a point lower on each line as death approaches. Each of the four lower lines declines with age, but the slopes are not as large as for the topmost “not-dying” line.

Figure 1 thus shows that Cheer is associated with both age and proximity to death, and also that these two effects interact (the slopes of the lines are not all the same). The top two lines are also separated, indicating that Cheer was reduced in persons who were dying, even 5 years before death. Because there were relatively few persons who were alive in 2000 but were age 85 or more in 1993 (see Table 2), the estimated effect of age in that oldest group may be imprecise. Other possible biases are addressed in the discussion section.

The five regression lines for the other nine health variables were also perfectly ordered by their distance from death, except that the top two lines coincided for Days Not in Bed and the bottom two coincided for Walking Speed. For this reason, we present their information in less detail, in Figure 2. The fitted lines do not all have the same shape. Some, like EVGFP, show an aging effect for the not-dying group but little aging effect for those who are dying. For IADLs and ADLs, the opposite is true; there is little aging effect for the not-dying group, but a steeper decline with age for those who are close to death. In some cases such as MMSE the distribution is fan-shaped, while for others such as BMI the lines are parallel. For Blocks Walked and Walking Speed the lines become closer together as death approaches, while for Days Not in Bed and % Not Hospitalized the year just before death is far from the others. The graphs for women (not shown) are similar, but not identical.

Note that Days Not in Bed in the previous 2 weeks is estimated as slightly greater than 14 at one point, which is not a possible value. This reminds us that these graphs are only regression estimates.

Table 2
Number of observations by age, sex, and years from death*

<table>
<thead>
<tr>
<th>Years from death</th>
<th>Alive in 2000</th>
<th>Died before 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gender</td>
<td>Age</td>
</tr>
<tr>
<td>Male</td>
<td>65–69</td>
<td>1272</td>
</tr>
<tr>
<td></td>
<td>70–74</td>
<td>3986</td>
</tr>
<tr>
<td></td>
<td>75–79</td>
<td>4260</td>
</tr>
<tr>
<td></td>
<td>80–84</td>
<td>2101</td>
</tr>
<tr>
<td></td>
<td>85+</td>
<td>817</td>
</tr>
<tr>
<td>Female</td>
<td>65–69</td>
<td>2392</td>
</tr>
<tr>
<td></td>
<td>70–74</td>
<td>6861</td>
</tr>
<tr>
<td></td>
<td>75–79</td>
<td>6754</td>
</tr>
<tr>
<td></td>
<td>80–84</td>
<td>3365</td>
</tr>
<tr>
<td></td>
<td>85+</td>
<td>1456</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>33264</td>
</tr>
</tbody>
</table>

*The number of observations for Cheer are presented. The numbers are substantially the same for the other 9 health-related variables.

†Alive in 2000, year of data not 1993.

‡1993 data for persons alive in 2000.

Table 3
Mean values of health variables by age (all n), not adjusted for years from death

<table>
<thead>
<tr>
<th>Health variable</th>
<th>Age</th>
<th>65–69</th>
<th>70–74</th>
<th>75–79</th>
<th>80–84</th>
<th>85+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheer</td>
<td>25.04</td>
<td>24.88</td>
<td>24.45</td>
<td>23.99</td>
<td>23.44</td>
<td></td>
</tr>
<tr>
<td>EVGFP</td>
<td>75.02</td>
<td>73.39</td>
<td>70.06</td>
<td>66.32</td>
<td>63.27</td>
<td></td>
</tr>
<tr>
<td>Ability (IADL)</td>
<td>5.73</td>
<td>5.65</td>
<td>5.49</td>
<td>5.27</td>
<td>4.71</td>
<td></td>
</tr>
<tr>
<td>Ability (ADL)</td>
<td>5.88</td>
<td>5.80</td>
<td>5.70</td>
<td>5.53</td>
<td>5.18</td>
<td></td>
</tr>
<tr>
<td>Mini mental</td>
<td>92.21</td>
<td>91.62</td>
<td>89.77</td>
<td>85.58</td>
<td>78.46</td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>26.62</td>
<td>26.49</td>
<td>25.95</td>
<td>25.25</td>
<td>24.51</td>
<td></td>
</tr>
<tr>
<td>Blocks walked</td>
<td>37.91</td>
<td>35.69</td>
<td>30.57</td>
<td>24.67</td>
<td>18.35</td>
<td></td>
</tr>
<tr>
<td>Days not in bed</td>
<td>13.89</td>
<td>13.82</td>
<td>13.76</td>
<td>13.71</td>
<td>13.55</td>
<td></td>
</tr>
<tr>
<td>% Not hospitalized</td>
<td>91.57</td>
<td>90.43</td>
<td>88.89</td>
<td>87.01</td>
<td>85.82</td>
<td></td>
</tr>
<tr>
<td>Walking speed</td>
<td>3.11</td>
<td>3.07</td>
<td>2.89</td>
<td>2.57</td>
<td>2.18</td>
<td></td>
</tr>
</tbody>
</table>

Table 4
Mean values of health variables by years from death (restricted n), not adjusted for age

<table>
<thead>
<tr>
<th>Years from Death (N)</th>
<th>&gt;7 years (3863)</th>
<th>4–6.9 (3420)</th>
<th>2–3.9 (3242)</th>
<th>1–1.9 (1833)</th>
<th>&lt;1 (1887)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheer</td>
<td>25.13</td>
<td>24.22</td>
<td>23.74</td>
<td>23.24</td>
<td>22.77</td>
</tr>
<tr>
<td>EVGFP</td>
<td>77.09</td>
<td>67.53</td>
<td>62.58</td>
<td>57.43</td>
<td>45.62</td>
</tr>
<tr>
<td>Ability (IADL)</td>
<td>5.69</td>
<td>5.38</td>
<td>5.11</td>
<td>4.81</td>
<td>4.53</td>
</tr>
<tr>
<td>Ability (ADL)</td>
<td>5.85</td>
<td>5.68</td>
<td>5.45</td>
<td>5.20</td>
<td>4.96</td>
</tr>
<tr>
<td>Mini mental</td>
<td>91.00</td>
<td>86.51</td>
<td>83.30</td>
<td>80.60</td>
<td>78.56</td>
</tr>
<tr>
<td>BMI</td>
<td>26.39</td>
<td>25.71</td>
<td>25.35</td>
<td>25.07</td>
<td>24.76</td>
</tr>
<tr>
<td>Blocks walked</td>
<td>34.29</td>
<td>27.63</td>
<td>23.10</td>
<td>19.87</td>
<td>18.26</td>
</tr>
<tr>
<td>% Not hospitalized</td>
<td>90.84</td>
<td>86.88</td>
<td>83.49</td>
<td>81.10</td>
<td>75.43</td>
</tr>
<tr>
<td>Walking speed</td>
<td>3.08</td>
<td>2.64</td>
<td>2.49</td>
<td>2.37</td>
<td>2.33</td>
</tr>
</tbody>
</table>
In summary, all figures showed a strong and consistent dying effect, and many also showed an aging effect. To quantify these effects, we used the regression equations to calculate the pure aging and pure dying effects described above. These effects can be calculated approximately from the figures. For example, in Figure 1, 80-year-old men who were 5 years from dying (second line from the top) had a mean Cheer score of about 24.9, while those within a year of dying (lowermost line) had a mean score of about 23.5. The pure dying effect (at age 80) is a loss of about 1.4 points (24.9 minus 23.5). Similarly, on the uppermost line, which represents persons who are not dying, a man aged 82.5 has about 0.5 fewer points than a man age 77.5. Thus, five years of dying is associated with a decrease of 1.4 points, while 5 years of aging is associated with a decrease of only 0.5 points, near age 80.

Table 5 shows the pure aging and pure dying effects for all of the variables, for men and women, respectively. The top line of Table 5 shows effects for the Cheer example that we calculated approximately from Figure 1. The aging effect is \(-1.10\) points (SD \(1.18\)) and the dying effect is \(-1.35\) points. Footnotes a through g indicate the statistical significance of various hypothesis tests (\(\alpha = .05\), two tailed). For example, for Cheer for men, there is a significant aging effect and a significant dying effect, and the dying effect is significantly larger than the aging effect.

All of the dying effects in Table 5 are negative, and 19 of 20 are significantly different from zero. The lone exception is BMI for women, which was nearly significant (\(P = .06\), two tailed). Most of the aging effects are also negative, and 14 of 20 are significantly different from zero. There was not a significant aging effect for Bed Days or Hospitalization for men or women, and no aging effect for ADLs or IADLs for men. We compared the relative size of the aging and dying effects, with results denoted by footnotes c and d in Table 5. The aging effect was significantly greater than the dying effect only for Walking Speed for women, but the dying effect was significantly greater than the aging effect for 14 of the 20 comparisons. The effects for men and women (footnotes e, f, and g) were fairly comparable. The effect of aging was significantly higher for women than for men for ADLs, IADLs, and Walking Speed. The effect of dying on Bed Days was larger for women than for men, and the effect of dying on BMI and Blocks Walked was larger for men.

3.1. Comparisons among variables

Table 5 shows the effect of aging and dying in their original units. To make it easier to compare the 10 health variables we divided each aging and dying effect in Table 5 by the variable’s standard deviation from Table 1. Figure 3 plots the standardized aging effect versus the standardized dying effect for the 10 health variables for women. For example, for women, Bed Days has a negative dying effect of about .9 standard deviations, but the aging effect is close to zero. The effect of aging 5 years on the health variables varies from \(+.02\) to \(-.25\) standard deviations. The dying effect varies from \(-.10\) to \(-.93\) standard deviations. Figure 4 shows a similar graph for men. In both figures the dying effect was largest for EVGFP, ADL, IADL, and Bed Days; medium for Hospitalization; and small for the remaining variables. In both figures the aging effect is largest for Walking Speed, BMI, MMSE, and Blocks Walked.

4. Summary and discussion

We described the effects of the aging and dying processes on 10 different health-related variables, using data from a longitudinal study of 5,888 older adults. If examined separately, both age and proximity of death were associated with lower values of the 10 health variables. When considered jointly, the aging and dying processes had separate effects on the health variables, usually in the directions expected. Aging and dying interacted, as shown by the differing slopes of the lines. Although the direction of effects was similar across variables, the sizes of the effects varied substantially.

4.1. Aging

There was a significant negative age effect in 14 of the 20 comparisons. Bed Days and Hospitalization never showed a
significant age effect, probably because they are direct responses to illness. The aging effect may be overestimated, for two reasons. First, there may be an age-cohort effect, in that persons currently 80 may be sicker than persons who will become age 80 in the future. If so, the same analysis performed 10 years later might yield a different age effect. Because we compared persons only 5 years apart in age, this should not be a major problem. Second, there may also be a confusion of comorbid conditions with aging because the older persons, even those far from death, have more health problems than the younger persons. If such conditions are prevented or
cured in the future, the aging effect will be smaller than presented here. The topmost curves may be thought of as an ideal or minimum expected change with age, because they describe the aging process in persons far from death.

4.2. Dying

We defined the dying effect as the difference between two persons of the same age, but who are different distances from death. Some of the decline in health near death might be caused by comorbid disease that is contracted closer to death. In our definition, such disease is part of the dying process. There was a significant negative dying effect for 19 of the 20 comparisons, and the 20th was significant based on a one-tailed test. The studies noted above also found evidence of a terminal drop in cognitive or physical function. Those studies did not estimate or compare the size of the aging and dying effects. Additional detail about self-rated health (EVGFP) near death, and before and after other serious health events, is shown elsewhere [20].

There are several reasons to believe that we have underestimated the dying effect. If there are secular trends toward improved health on a particular variable, then measures made 5 years before death would be made at a “less healthy” time than the measures close to death, and the differences between the 5 year and the <1 year measure would be too small. There may have been an increased emphasis over time on treating the elderly for depression, and managed care trends may have kept more persons out of the hospital. Secular trend is probably not a major factor for the other variables. If we had excluded deaths that involved no “dying” process, such as accidental deaths, the dying effect would also have been larger. The most important reason for underestimation of the death effect is that we estimated data missing just before death by substituting the last known value for the later missing values. Because all of the variables declined closer to death, this imputation method tends to underestimate the dying effect.

The strong and consistent dying effect that was observed for all variables raises the issue of the direction of causality in published research showing that drops in weight, depression, function, cognition, or self-rated health are predictive of mortality. The consistency of our results over all the variables suggests that the dying process may cause the drops, rather than the other way around, and care must be taken in interpreting such analyses. Survival analyses using these variables as time-dependent covariates would be especially prone to finding such associations, because the data closest to death would be emphasized. An analysis using these variables as time-dependent adjustments for confounding of a different variable of interest would essentially be adjusting the survival analysis for time until death, which would usually not be desirable.

4.3. Dying and aging

The most striking finding is how similar the graphs are for the 10 health variables. In every case there is a clear ordering of the lines in terms of time before death, and in most cases there is a visible aging effect as well. We considered three other variables that did not show this pattern: systolic and diastolic blood pressure, and having a flu shot (data not shown). For these three variables some of the lines overlapped or were out of order. This is likely due in part to secular trend, because flu shots and aggressive treatment of hypertension for the elderly have been stressed in recent years. A further complication was that systolic blood pressure increased with age but decreased closer to death (data not shown).

It is interesting that BMI behaved as the other measures, insofar as high (not low) values were associated with better health. This association of lower weight and weight loss with worse health in older adults has been detailed elsewhere [28]. The results for hospitalization are also of interest. Figure 2 indicates that for not-dying persons, hospitalization is independent of age, while for the dying the oldest are most likely not to be hospitalized. This trend is also evident in the raw data, but is not as strong as in the fitted data, and so should not be overinterpreted.

We had expected the top two lines in the graphs to coincide; that is, that a person 5 years from death would be about as healthy as a person the same age but >7 years from death (15 years on average). Except for Bed Days, this was not the case. This may be due to the positive selection in 1990 still being present in 1993 or to secular trend; or, possibly the dying process may have started (on average) as long as 5 years before death.

The estimates in Table 5 and in Figures 3 and 4 are useful ways to summarize the effects of aging and dying, but two numbers cannot describe all of the aspects of the various graphs. We considered a 5-year dying process and used age 80 as a reference age. There is no obvious choice for these parameters, and the reader is referred to the figures for the other situations of interest.

Results were usually similar for men and women, and may be thought of as replicates. Table 5 showed a few cases where men and women differed significantly, which may be of interest. We defined the aging effect with reference only to people who were “not dying”; the top line in Figures 1 and 2. The relationship of age to the study variables in persons close to death also shows considerable variation, which may merit further study.

4.4. Dying versus aging

Although there has been considerable discussion of the distinction (or lack thereof) between aging and disease [29–32], less has been written to compare the aging and dying processes and their relative effects. We found that effect of 5 years of dying was larger than the effect of 5 years of aging for 17 of the 20 comparisons, and the difference was statistically significant for 14. The aging effect was significantly larger than the dying effect for only one comparison. Large changes in these health variables are more likely to have been caused by the dying process than by the aging process.
4.5. The aging and dying processes

This article provides empirical support for the existence of a “dying process,” in the sense that there appear to be systematic declines in health that are independent of age. Whether this decline is a result of gradual, very long-term deterioration or to a more acute, biologically based distinct “dying process” remains unknown. Either process might be related to genes, environment, or the presence of chronic diseases. We have defined the process only in statistical terms, using an operational definition. We were unable to demonstrate when the “dying process” begins, and were surprised at evidence that it may begin (on average) as long as 5 years before death.

The data suggest a model of change over time in which a person’s health declines at one rate until the dying process begins, after which the decline becomes steeper. Figure 5 presents an estimate of this decline for Cheer, calculated from the variant of the regression equations in which we treated years from death as a continuous variable. This graph can be generated approximately from Figure 1, as follows. For a man who died at age 85, the average Cheer at age 84 can be obtained from the bottom line in Figure 1, his value at age 83 from the next-to-bottom line on Figure 1, and so on. Values for age 78 and lower are all taken from the top line, which represents persons far from death. Figure 5 shows that, on average, people who died at ages 85 and 90 had similar Cheer from ages 65 to about 73, after which their values diverged. For Cheer, the slope of decline near death is similar at all ages. The value of Cheer just before death is a little higher for those who died at 70 or 75, than for those who died at older ages. Plots for other variables (not shown) are fairly similar to that for Cheer.

Figure 5 is not useful prospectively, because it requires knowing the person’s age at death. Further, it represents only average values. For individuals, the value and the slope at varying locations on the aging/dying curve vary substantially (data not shown). This variability suggests that some of the people in the study may have been misclassified with respect to the dying process. A person whose dying process began 8 years before death might have been included with the not dying. If a person had begun the dying process in 1993 but been miraculously saved in 1994, the 1993 data would more properly belong in the dying group. A person who died of trauma at the age of 75 may not have begun the dying process at all, suggesting that his earlier data belonged in the not-dying category. These possibilities of misclassification do not invalidate our operational definitions, which clearly depend on the number of years from death, but point out that the resulting picture of the aging/dying processes can not be perfect. The usual effect of misclassification is to mask differences between groups. Because we found aging and dying effects that were strong and consistent, this may not be a large problem.

4.6. Potential limitations

We studied only older adults, emphasizing changes near age 80. Further, there was some positive selection due to CHS inclusion criteria and to volunteer bias. Based on plots (not shown), we think it likely that the selection bias had attenuated substantially by 1993, when the data for the not-dying group were collected. All of the findings are based on estimated curves. The regression model was rich enough to allow a variety of relationships with time and age, but the graphs are surely not exact. The standard deviations in Table 5 are large, indicating that the estimates of the effects are also inexact. It is likely that the aging effect was overestimated and that the dying effect was underestimated, for reasons noted above. The major finding, that the dying effect is usually larger than the aging effect, should be robust to these possible biases. We were not able in this article to present information on patterns of change for individuals. It is possible that the gradual changes shown in Figure 5 are the average of many abrupt changes in individuals. This topic deserves further exploration. We have used the word “effect” as a shorthand term for the association of the dying or aging process with the health variables. Because this is an observational study, we cannot be sure that the aging or dying process caused the observed decline.

4.7. Clinical implications

These results confirm prior work demonstrating that changes in health and functional status that are often attributed to the aging process may be indicative of underlying pathologic conditions and not simply “old age” [1,33]. The results are also in agreement with clinical impressions that such changes in older patients are, at first glance, similar to and in the same direction for both those who are dying and those experiencing potentially treatable acute or exacerbated chronic conditions [33]. What is unique about these results is the evidence that the magnitude of change in these measures is greater for those experiencing pathologic change than it is for those who are “simply” aging. These differences in the trajectory of decline in health status measures may be the basis for an approach to dif-

![Fig. 5. Mean Cheer by age and age at death (men).](image)
ferentiating aging from pathology, the latter of which ultimately may lead to premature disability and death.

The finding of more rapid decline in measures of health status for older people on the pathway to death is similar to the clinical syndrome of “failure to thrive” in older adults, which has been well described but is difficult to quantify [34,35]. These results lend support to a conceptual model proposed by Roubenoff and Harris that distinguishes between aging and failure to thrive, the latter being the result of disease and the former being the primary cause of sarcopenia, the progressive loss of muscle mass commonly seen in relatively disease-free aging adults [36]. Confounding attempts to differentiate and develop prevention and treatment strategies for these two syndromes or pathways is the underlying prevalence of chronic disease in the elderly and the fact that both aging and disease contribute to frailty and, ultimately, death.

These findings have clinical face validity in that marked declines in mood, function, and overall sense of well-being at any age are viewed by clinicians as indicative of a new or progressive condition. Another implication of these results is that longitudinal primary care that integrates observations from family, friends, and other care givers is critically important to the care of the older adult. Observations on the trajectory of decline must be factored into the plan of care for older adults. Failure to do so may result in subjecting patients near the end of life to fruitless and unwanted invasive diagnostics or, in other cases, the failure to aggressively pursue the diagnosis of conditions which, when treated, will reverse unexpected declines.

The dying process, as we have operationalized it, is clearly separate from aging, and is associated with declines in all of the variables that we examined. Some of these declines may be caused by treatable pathologic conditions that should not be passed off as “old age” [1,34], an occurrence that perhaps reflects perceptions that common chronic diseases and conditions are inevitable concomitants of aging, or that some changes in health and function are not germane to medical care [37]. Attribution of changes in health to aging could discourage older adults from raising concerns about the onset or progression of changes in their health. Our findings suggest that large changes on these (and probably other) health-related variables should be taken seriously and not simply dismissed as attributable to old age. Further study is needed to define the distinctions between age and disease-associated declines in health and functional status. The results of such investigations may lead to new interventions preventing premature death or loss of independence in older adults.

Acknowledgments


References

Appendix Table

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