TRANSACTIONS OF SOCIETY OF ACTUARIES
1981 VOL. 33

RECENT TRENDS IN THE MORTALITY OF THE AGED

JOHN C. WILKIN

ABSTRACT

This paper presents central death rates for persons aged 65 and over based on medicare data covering the period 1968–78. These rates are compared with the corresponding rates published by the National Center for Health Statistics (NCHS). The age-adjusted rates from medicare data are generally lower, but they follow the same trend as the NCHS rates. Since 1968 there has been an increase in the rate of improvement in the mortality of the entire population. The aged are participating in this improvement more fully than in the past because much of the recent improvement has resulted from increased control of diseases of the heart and of the circulatory system. Since 1968 the rate of improvement of mortality has been greater for females than for males, and hence the relative difference between male and female mortality rates is continuing to widen. This paper also presents probabilities of death within one year, for each age from 65½ to 99½, from medicare data. After about age 90, the mortality curve increases at progressively smaller rates until it becomes essentially flat near age 100.

1. INTRODUCTION

TRENDS in the mortality of the aged is a topic of much interest, but the data available are sparse. Most published data are combined into five-year age groups up to the age group 85 and over.[1] One reason for not presenting more detail by age is the suspected unreliability of the data, attributed mainly to misstatement of age and net underenumeration of population [6]. Unreported deaths could be a problem in the study of some groups; in the United States, however, the registration of deaths is believed to be virtually complete. There are strong incentives for filing a death certificate—obtaining burial permits, settling estates, and collecting insurance benefits. In a few studies it has been possible to secure highly reliable data, but only for a small number of observations over a relatively

[1] For example, National Center for Health Statistics, *Vital Statistics of the United States*, Vol. II: *Mortality, Part A*, which is published every year.

long period of time, thus precluding an analysis of trends (see, for example, [5] and [2]). One earlier study used data from the medicare program, but at that time the medicare program had not existed for a long enough time to display trends [1].

Over the years, the medicare program has accumulated a large quantity of reliable data on the mortality of the aged. The problem of misstatement of age is greatly reduced in this case, because most of the data relate to individuals who have had to verify their dates of birth to become entitled to benefits under the program. (Proof of date of birth requires the submission of a public record of birth or a religious record of birth or baptism. Where no such document is available, the individual must submit another document or documents that may serve as the basis for a determination of his date of birth, provided that such evidence is corroborated by other evidence or by information in the records of the Social Security Administration.) The problem of underregistration of deaths is small, because the availability of a small lump-sum death payment on insured workers' accounts encourages survivors and funeral directors to report deaths. The problem of underenumeration of population is negligible, because the group under observation is defined by program records; thus, the data do not include deaths of unobserved persons. Further, the data are so extensive, covering nearly the entire aged population of the United States, that meaningful analyses can be done over relatively short periods of time (and, hence, trends through time can be accurately detected).

This paper will analyze the medicare data from 1968 to 1978 by single years of age from age 65½ to age 99½. Also, the medicare data will be compared with the data published by the National Center for Health Statistics (NCHS).

II. DATA

The observation periods for this study are the calendar years 1968–78. Each year an update of the medicare data is prepared, which contains preliminary data for events occurring in the second prior calendar year and final data for events occurring in the third prior calendar year. For example, the 1980 update contains final data for events occurring during 1977 and preliminary data for events occurring during 1978, both recorded through January 1, 1980. The number of events recorded more than two calendar years after the year of occurrence is believed to be small and not to have a significant effect on the analysis in this study.

The medicare data used in this analysis cover the residents of the fifty states and the District of Columbia who are entitled to benefits under either or both of the following programs: hospital insurance (which generally cov-

ers hospitalization costs); and supplementary medical insurance (which generally covers physicians' fees). For enrollment under hospital insurance, a person must (1) be entitled to social security monthly cash benefits; or (2) be entitled to railroad retirement benefits; or (3) be a citizen or an alien admitted for permanent residence who has resided in the United States for five or more years and has at least three quarters of coverage under social security for every year elapsed after 1966 and before the year of attainment of age 65 (those attaining age 65 before 1968 did not need any quarters of coverage); or, beginning July, 1973, (4) elect coverage under both hospital insurance and supplementary medical insurance by payment of premium. Excluded are those federal employees who meet only requirement 3 and who could have enrolled under the health insurance plans for government employees. For enrollment under supplementary medical insurance, a person must be a citizen or an alien admitted for permanent residence who has resided in the United States for five or more years and who elects coverage by payment of premium. Certain persons under age 65 also are enrolled under hospital insurance and supplementary medical insurance, but they are excluded from our data.

From the above enrollment requirements, it can be deduced that all residents of the United States aged 65 or over are included in the data except the following:

1. Federal employees who could have enrolled under the health insurance plans for government employees, who are not entitled to cash benefits under social security or railroad retirement, and who have elected not to enroll in the supplementary medical insurance program (estimated at about 200,000 persons on July 1, 1977.[2]
2. Aliens not entitled to social security or railroad retirement benefits who have not been admitted for permanent residence or who have been admitted for permanent residence but have resided in the United States for less than five years (estimated at about 70,000 persons on July 1, 1977).[2]
3. Citizens, or aliens admitted for permanent residence who have resided in the United States for five or more years, who are not social security or railroad retirement beneficiaries, who have fewer than three quarters of coverage under social security for every year elapsed after 1966 and before the year of attainment of age 65, and who have elected not to enroll in the supplementary medical insurance program (estimated at about 300,000 individuals on July 1, 1977).[2]

If the estimates of the number of people in these three groups are added to the number of people in the medicare data, an estimate of 23,860,000 is obtained for the United States resident population aged 65 and over as of

[2] Estimates obtained from the Office of Financial and Actuarial Analysis, Health Care Financing Administration.

July 1, 1977. This is about 1.6 percent more than the Bureau of the Census estimate of 23,494,000, but it is very close to the Bureau of the Census estimate of 23,879,000, which is adjusted for net census undercount [7].

Table 1 compares, by age group and sex, the population shown in the medicare data with the Bureau of the Census population estimates as of July 1, 1977, which were used by NCHS. The medicare population as of July 1, 1977, was estimated by linear interpolation from the January 1, 1977, and January 1, 1978, populations. The pattern in the ratio of medicare to census populations through age is virtually the same for both sexes, following a U-shaped curve that opens downward. This pattern from age 65 to age 75 is to be expected, because there was no insured status requirement for medicare for those aged 75 or over in 1977, while the insured status requirement for those aged 65–74 becomes less stringent with increasing age (and very few uninsured persons buy coverage voluntarily). The decline after age group 75–79 in the medicare population relative to the census population is harder to explain, although it may be caused by the tendency of aged persons to overstate their age in the census or because of the methods used to estimate the 1977 population from the 1970 census.

Table 1 also compares the number of deaths shown in the medicare data with the NCHS death registrations for calendar year 1977. The number of medicare deaths by age last birthday was estimated from the number of deaths by calendar age by assuming that half the deaths within each single age occur before the birthday. The pattern in the ratio of medicare to NCHS deaths is generally increasing with age, except for females at ages 85 and over. This pattern is to be expected because of the increasing percentage of the population covered by medicare as age increases.

III. CENTRAL DEATH RATES

Every year, the National Center for Health Statistics publishes in the volumes of "Vital Statistics of the United States" central death rates of the United States resident population by five-year age groups up to the age group 85 and over. These central death rates are a composite of the number of deaths as compiled by the Center from the death registration data and the population estimates prepared by the Bureau of the Census on the basis of census counts. The two basic sources of information are different in nature and are subject to different errors. When data from the two are combined, the calculated death rates are subject to the errors of both sources. This is not the case when both number of deaths and population are obtained from the same source, such as medicare. The resulting death rates could be subject to other errors, but the errors due to noncomparability of numerator and denominator are eliminated.

TABLE 1

MEDICARE AND NCHS POPULATIONS AS OF JULY 1, 1977; NUMBERS OF DEATHS IN CALENDAR YEAR 1977, BY AGE GROUP AND SEX; AND SELECTED RATIOS

AGE LAST BIRTHDAY	MEDICARE*			NCHS†			RATIO OF MEDICARE TO NCHS		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
	Population (in Thousands)								
65–69	7,907	3,524	4,382	8,447	3,739	4,708	0.936	0.943	0.931
70–74	6,175	2,592	3,582	6,137	2,597	3,540	1.006	0.998	1.012
75–79	4,341	1,668	2,674	4,068	1,589	2,479	1.067	1.050	1.078
80–84	2,878	1,007	1,871	2,763	989	1,774	1.042	1.018	1.055
85 and over	1,990	615	1,375	2,079	655	1,424	0.957	0.939	0.965
65 and over	23,290	9,407	13,884	23,494	9,569	13,925	0.991	0.983	0.997
	Number of Deaths								
65–69	200,938	125,798	75,140	209,496	129,873	79,623	0.959	0.969	0.944
70–74	230,543	136,003	94,540	236,099	138,157	97,942	0.976	0.984	0.965
75–79	243,426	128,407	115,019	247,048	129,552	117,496	0.985	0.991	0.979
80–84	247,555	113,088	134,466	243,550	112,387	131,163	1.016	1.006	1.025
85 and over	310,737	114,600	196,136	306,151	113,309	192,842	1.015	1.011	1.017
65 and over	1,233,200	617,898	615,302	1,242,344	623,278	619,066	0.993	0.991	0.994

*The July 1, 1977, medicare population by age and sex is estimated from the January 1, 1977, and January 1, 1978, populations by linear interpolation. The calendar-year number of deaths by sex tabulated by age last birthday is estimated from the numbers of deaths tabulated by calendar age by assuming that half the deaths within each calendar age occur before the birthday.

†The July 1, 1977, population by age and sex used by NCHS is estimated by the Bureau of the Census and is published in Current Population Reports, Ser. P-25, No. 721, *Estimates of the Population of the United States by Age, Sex, and Race: 1970 to 1977*. The calendar-year number of deaths by age and sex is obtained from vital statistics death registrations and is published in NCHS Monthly Vital Statistics Reports, Vol. XXVIII, No. 1, *Final Mortality Statistics, 1977*.

To compare the mortality shown in the medicare data with the mortality shown in the NCHS data, central death rates by sex from the medicare data were calculated for age groups 65–69, 70–74, 75–79, 80–84, and 85 and over, for each calendar year, 1968–78. Populations as of July 1 were estimated by linear interpolation from populations as of January 1. Numbers of deaths during the calendar year by age last birthday were estimated from numbers of deaths by calendar age by assuming that half the deaths within each calendar age occur before the birthday. Age-adjusted central death rates were calculated by the direct method, using the enumerated population of the United States on April 1, 1970, as the standard. Average annual declines in mortality were computed as the slope of the least-squares line through the logarithms of the central death rates.

Age-adjusted Death Rates

Table 2 contains values of age-adjusted central death rates by sex and calendar year, according to medicare data and as published by the National Center for Health Statistics. These rates are also depicted in Figure 1. The comparisons show that the two different sources of data yield age-adjusted death rates that are very close, although the medicare rates are slightly lower than the NCHS rates for most calendar years. The medicare male death rates average 0.1 percent higher than the NCHS rates, while the medicare female rates average 2.6 percent lower. These differences are consistent with the sex differential in the estimated net census undercount of the aged for 1970 of 0.9 percent for males and 2.4 percent for females [7]. For both data sources, the average annual decline in the age-adjusted death rates from 1968 to 1978 was 1.9 percent for both sexes combined. The average annual decline for males was 1.5 percent in the medicare data and 1.4 percent in the NCHS data, while the average annual decline for females was 2.3 percent in the medicare data and 2.5 percent in the NCHS data.

It should be noted from Figure 1 that the patterns in changes in mortality during the period 1968–78 are identical for the two sources of data and similar for the two sexes. There were relatively fast decreases in mortality from 1968 to 1970; these were followed by three years (1971–73) of almost no change before the fast decrements began again. Provisional data through 1979 show a continuation of the rapid improvement.

According to medicare data, the death rates at the older ages published by the NCHS may be overstated by about 1 or 2 percent, primarily because of net underenumeration of the population. However, the medicare data fully corroborate the mortality trends published by the NCHS.

Table 3 shows the average annual decline in the NCHS age-adjusted death

TABLE 2

MEDICARE AND NCHS AGE-ADJUSTED CENTRAL DEATH RATES FOR AGES 65 and OVER, BY SEX AND CALENDAR YEAR; AVERAGE ANNUAL DECLINES, BY SEX; AND SELECTED RATIOS: 1968–78*

CALENDAR YEAR	MEDICARE			NCHS			RATIO OF MEDICARE TO NCHS		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
	Age-adjusted Death Rate (per 100,000)								
1968	6,174.4	7,534.3	5,195.9	6,258.4	7,458.3	5,394.9	0.9866	1.0102	0.9631
1969	5,959.5	7,304.8	4,991.4	6,102.9	7,278.9	5,256.6	0.9765	1.0036	0.9495
1970	5,813.0	7,174.2	4,833.4	5,848.3	7,136.7	4,921.2	0.9940	1.0053	0.9822
1971	5,823.4	7,197.6	4,834.5	5,872.2	7,092.0	4,994.4	0.9917	1.0149	0.9680
1972	5,821.0	7,236.1	4,802.7	5,886.3	7,243.6	4,909.6	0.9889	0.9990	0.9782
1973	5,728.5	7,147.1	4,707.6	5,827.5	7,189.5	4,847.4	0.9830	0.9941	0.9712
1974	5,502.1	6,864.6	4,521.6	5,613.4	6,945.3	4,655.0	0.9802	0.9884	0.9713
1975	5,297.7	6,667.7	4,311.8	5,349.6	6,686.8	4,387.3	0.9903	0.9972	0.9828
1976	5,272.4	6,642.2	4,286.7	5,324.0	6,653.2	4,367.6	0.9903	0.9983	0.9815
1977	5,129.0	6,497.2	4,144.4	5,177.0	6,501.9	4,223.7	0.9907	0.9993	0.9812
1978†	5,114.7	6,471.6	4,138.3	5,146.9	6,458.4	4,203.2	0.9937	1.0020	0.9846
	Average Annual Decline (Percent)								
1968–78†	1.9	1.5	2.3	1.9	1.4	2.5	0.9672	1.0800	0.9070

*Age-adjusted central death rates were calculated by the direct method, using the enumerated population of the United States on April 1, 1970, as the standard.

†Figures for 1978 are preliminary.

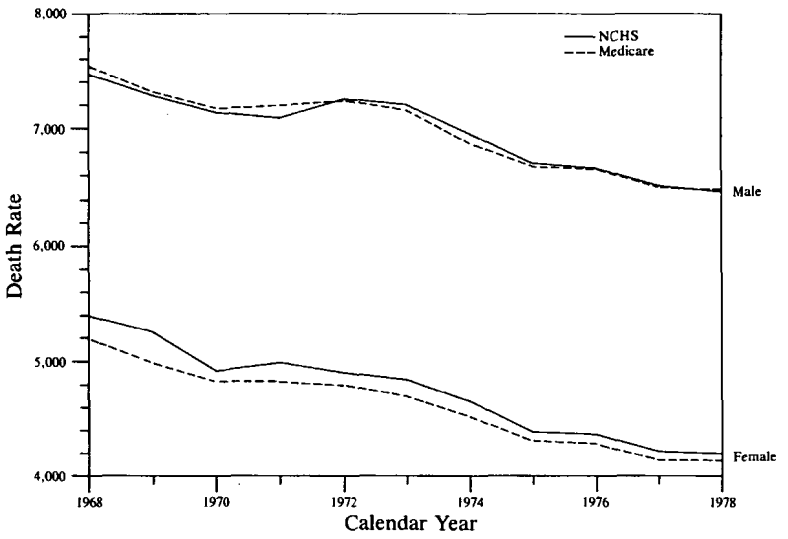

FIG. 1.—Age-adjusted central death rates (per 100,000) for ages 65 and over, by sex and source of data, calendar years 1968–78.

TABLE 3

AVERAGE ANNUAL DECLINES IN NCHS AGE-ADJUSTED CENTRAL DEATH RATES FOR AGES 65 AND OVER AND FOR ALL AGES DURING SELECTED PERIODS, BY SEX*

PERIOD†	MALE			FEMALE		
	Ages 65 and Over	All Ages	Ratio	Ages 65 and Over	All Ages	Ratio
1900–1936	0.16%	0.87%	0.18	0.30%	1.02%	0.29
1936–54	1.16	1.67	0.69	1.88	2.65	0.71
1954–68	−0.30	−0.14	.....	0.75	0.77	0.98
1968–77	1.55	1.83	0.84	2.38	2.35	1.01
1900–1977	0.47	0.99	0.48	1.00	1.52	0.66

*Age-adjusted central death rates were calculated by the direct method, using the enumerated population of the United States on April 1, 1970, as the standard, and using age-specific central death rates based on the most recent population estimates for each year.

†Periods were selected because of discernible changes in trend.

rates for the whole population and for the population aged 65 and over for selected periods in the twentieth century. This table helps to place the recent declines in the death rates of the aged in perspective. During the period 1900–1977, the average annual decline in the age-adjusted death rates for the whole population (all ages and both sexes) was 1.3 percent. The average annual decline for females was 1.5 percent, 50 percent more than the male rate of 1.0 percent. For the more recent period from 1968 to 1977, there has been an acceleration in the rate of improvement in the age-adjusted death rates for the whole population. The average annual decline has been 2.1 percent, with the rate again higher for females (2.4 percent) than for males (1.8 percent).

During the first half of this century, improvements in mortality resulted largely from control of infectious diseases, which affect primarily the young; as a result, the aged did not share to a very large extent in the mortality improvements of the population. Lately, however, the tendency has been for the aged to account for an increasing share of the improvements in mortality because recent improvements have resulted largely from increased control of degenerative diseases, which affect primarily the aged. For females, since 1954, the average annual decline in the age-adjusted death rates for ages 65 and over has been essentially the same as the rate for all ages.

Death Rates by Age Group

Table 4 shows medicare central death rates from 1968 to 1978 and the average annual decline by age group and sex. For males, the rate of mortality improvement during the period varied little by age. It was 1.6 percent for the age group 65–69, 1.4 percent for the age group 75–79, and 1.5 percent for all other age groups, as well as for all age groups combined. For females, there was more variation; from age 65 to age 85 the average annual rate of improvement increased with age from 1.7 to 2.6 percent, but then dropped to 2.1 percent for ages 85 and over. The rate for all age groups combined was 2.3 percent.

Table 5 shows NCHS central death rates from 1968 to 1978 and the average annual decline by age group and sex. A comparison of these rates with those in Table 4 indicates that, although the two data sources show almost identical rates of improvement for all ages 65 and over combined, the trends are quite different by age group. In general, the trends from one age group to the next vary much more in the NCHS data than in the medicare data. The NCHS rates of improvement are significantly higher than the medicare rates of improvement for ages 65–74, but are lower for ages 75–84. For ages 85 and over the NCHS rates of improvement are lower for males and higher

TABLE 4

MEDICARE CENTRAL DEATH RATES, BY AGE GROUP, SEX, AND CALENDAR YEAR, AND AVERAGE ANNUAL DECLINES, BY AGE GROUP AND SEX: 1968–78

CALENDAR YEAR	AGE LAST BIRTHDAY FOR MALES					AGE LAST BIRTHDAY FOR FEMALES				
	65–69	70–74	75–79	80–84	85 and Over	65–69	70–74	75–79	80–84	85 and Over
	Medicare Central Death Rate (per 100,000)									
1968	4,153.3	6,050.0	8,838.4	13,052.6	21,898.7	2,015.2	3,272.1	5,508.7	9,295.8	17,854.7
1969	4,027.7	5,888.3	8,567.9	12,743.6	20,967.7	1,935.3	3,176.1	5,284.5	8,934.0	17,056.4
1970	4,013.3	5,802.5	8,441.8	12,403.6	20,252.0	1,914.7	3,130.6	5,159.7	8,589.5	16,153.0
1971	3,986.3	5.803.8	8,451.9	12,497.8	20,612.7	1,903.9	3,077.8	5,129.7	8,582.3	16,474.0
1972	3.987.9	5,861.6	8,569.3	12,580.4	20,466.9	1,908.6	3,076.7	5,101.5	8,477.7	16,289.8
1973	3,929.1	5,744.7	8,431.0	12,460.3	20,528.1	1,848.8	2,966.4	4,992.8	8,312.6	16,238.9
1974	3,806.9	5,524.5	8,077.9	11,888.4	19,679.2	1,794.2	2,850.1	4,766.3	7,989.6	15,580.6
1975	3,699.0	5,393.3	7,879.4	11,540.6	18,887.3	1,737.9	2,748.3	4,553.6	7,597.2	14,655.5
1976	3,659.9	5,319.4	7,840.4	11,473.4	19,289.2	1,728.4	2,703.4	4,450.9	7,473.9	14,972.4
1977	3,569.4	5,246.2	7,699.4	11,231.4	18,624.0	1,714.6	2,639.0	4,302.1	7,187.7	14,269.6
1978*	3,552.8	5,213.1	7,627.7	11,218.2	18,700.3	1,713.3	2,635.7	4,258.2	7,143.4	14,385.4
	Medicare Average Annual Decline (Percent)									
1968–78*	1.6	1.5	1.4	1.5	1.5	1.7	2.3	2.6	2.6	2.1

*Figures for 1978 are preliminary.

TABLE 5

NCHS CENTRAL DEATH RATES, BY AGE GROUP, SEX, AND CALENDAR YEAR, AND AVERAGE ANNUAL DECLINES, BY AGE GROUP AND SEX: 1968–78

CALENDAR YEAR	AGE LAST BIRTHDAY FOR MALES					AGE LAST BIRTHDAY FOR FEMALES				
	65–69	70–74	75–79	80–84	85 and Over	65–69	70–74	75–79	80–84	85 and Over
	NCHS Central Death Rate (per 100,000)									
1968	4,258.3	6,453.1	8,653.8	12,073.9	20,388.3	2,210.8	3,487.8	5,486.9	9,092.2	19,167.8
1969	4,149.8	6,277.2	8,513.8	11,931.4	19,554.9	2,142.4	3,416.3	5,290.8	8,861.8	18,796.2
1970	4,117.9	5,893.4	8,676.8	12,386.8	17,821.5	2.042.4	3,244.2	5,380.1	8,772.3	15,518.0
1971	4,008.4	6,062.7	8,737.5	11,515.5	18,320.8	2,006.3	3,321.0	5,202.4	8,341.1	17,418.2
1972	3,995.7	5,977.0	8,836.7	12,335.6	19,595.8	1,976.8	3,241.1	5,348.1	8,466.3	16,202.5
1973	3,933.5	5,871.9	8,813.5	12,239.5	19,809.4	1,901.7	3,155.6	5,339.4	8,343.2	16,234.0
1974	3,796.2	5,720.9	8,509.2	11,864.3	18,875.7	1,823.3	3,073.7	5,109.8	8,085.0	15,387.6
1975	3,636.3	5,555.6	8,253.7	11,593.3	17,572.6	1,731.4	2,945.1	4,878.6	7,686.9	14,031.4
1976	3,586.9	5,433.7	8,263.3	11,521.1	17,983.9	1,712.8	2,856.4	4,850.6	7,632.5	14,312.1
1977	3,473.5	5,319.9	8,153.1	11,363.7	17,299.1	1,691.2	2,766.7	4,739.7	7,393.6	13,542.3
1978*	3,462.0	5,213.1	8,086.0	11,512.8	17,082.7	1,678.3	2,696.6	4,672.0	7,494.4	13,587.3
	NCHS Average Annual Decline (Percent)									
1968–78*	2.2	2.0	0.7	0.6	1.3	2.9	2.5	1.6	2.1	3.4

*Figures for 1978 are preliminary and are published in NCHS Monthly Vital Statistics Reports, Vol. XXVII, No. 13, *Provisional Statistics Annual Summary for the United States, 1978.*

for females. The trends in the central death rates by age group and source of data are depicted in Figures 2 and 3.

Since the medicare data generally are more accurate and complete than those used in deriving the NCHS death rates, most of the differences in the trends can be assumed to arise from a lower level of precision in the published NCHS rates, resulting generally from the use of postcensal population estimates. Three factors affect the level of precision of these population estimates: (1) the high level of variability by age in the accuracy of the estimated net census undercount; (2) discrepancies between the age reported on the death certificate and the age reported in the census by the same individual; and (3) the change in the basis of the estimated population from a projection of the 1960 census in 1969 to the 1970 census in 1970.

The Bureau of the Census makes estimates by age, sex, and race of the net undercount of the population for each decennial census, but it usually does not include the estimated net undercount in its publications of the United States population. The bureau, however, does use its estimated net undercount to make postcensal estimates of the population consistent with the previous census. This technique, which is used to estimate the population that would be counted if a census had taken place in a given year, is known as the inflation-deflation method [7]. Under this method, the last census count is "inflated" to take into account estimated net undercount, and is then projected forward on the basis of birth certificates, death certificates, and estimates of net migration. The resulting population is then "deflated" to take into account the estimated net undercount that would have occurred if the census had been taken at that time. This method dampens the distortion that exists in population trends by age when the net undercounts for adjacent age groups differ greatly. However, the amount of dampening depends on the accuracy of the estimated net census undercount by age. Part of the variation in the trends of the central death rates by age between the medicare rates and the NCHS published rates could result from variations in the accuracy of the estimated net census undercount by age.

The accuracy of the age distribution in postcensal population estimates depends upon consistency between the age reported on each death certificate and the age reported on the matching census record. Evidence of an important difference between ages reported on death certificates and in the census was found in a special study made in conjunction with the 1960 census [4]. The 1960 study found that 14 percent of the matching records were in different five-year age groups in the two record systems. The errors in the NCHS central death rates resulting from this inconsistency are difficult to trace because they not only distort the postcensal population es-

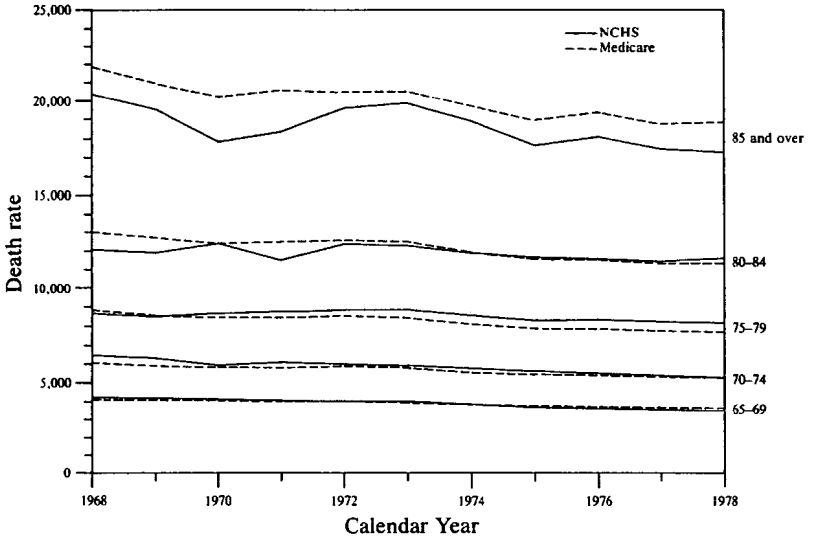

FIG. 2.—Male central death rates (per 100,000), by age group and source of data, calendar years 1968–78.

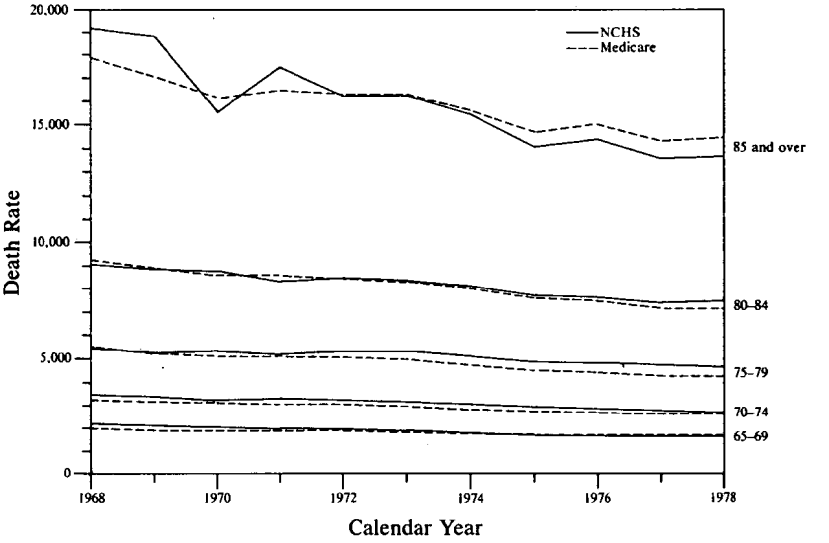

FIG. 3.—Female central death rates (per 100,000), by age group and source of data, calendar years 1968–78.

timates but also produce errors resulting from the noncomparability of numerator and denominator.

It is interesting to look at the ratio of the medicare death rates to the NCHS death rates for the years 1969 and 1970, as shown in Table 6. Much of the change in the ratios between these two years results from the change in the population estimates used by NCHS to compute the published death rates. The 1969 population estimate is based on the 1960 census projected by adding births and net migration and then subtracting deaths, whereas the 1970 population is based on the 1970 census. This change in the basis of the population estimates produces discontinuities in the trend of the published death rates. In some cases this discontinuity can explain much of the change from 1968 to 1978 in the ratio of the medicare death rates to the NCHS death rates. For males aged 70–74, for example, this ratio goes from 0.9375 in 1968 to 0.9846 in 1970 to 1.0000 in 1978. Almost 80 percent of the change from 1968 to 1978 occurred between 1969 and 1970.

The Bureau of the Census frequently revises its postcensal estimates of the population. Not until after the next census, when an interpolation method can be used, do the population estimates for intercensal years become final. The published NCHS death rates use the latest estimates of the population available at the time of publication. If the NCHS death rates were to be recalculated with intercensal population estimates after the 1980 census, the trends in the death rates probably would show less variation by age, thus exhibiting trends more similar to those shown by the medicare data. When the intercensal population estimates for the 1970s become available, NCHS will revise its death rates. Although these revised rates will not be published, they will be available upon request.

Death Rates by Sex

A comparison in the trends of the central death rates by sex is shown in Table 7. Because the medicare data appear to be more accurate by age and more consistent through time than the NCHS data, the ratios of female to male central death rates are shown only for the medicare data. The data show not only that the female death rates are lower than the male death rates but also that the relative gap is widening. The female rates have been declining at an average annual rate 50 percent faster than that for males; however, the absolute difference between female and male rates has remained fairly constant from 1968 to 1978.

Death Rates by Cause

Table 8 shows NCHS age-adjusted death rates by sex, cause of death, and calendar year (the medicare rates cannot be analyzed by cause of death).

TABLE 6

RATIO OF MEDICARE TO NCHS CENTRAL DEATH RATES, BY AGE GROUP, SEX, AND CALENDAR YEAR, AND RATIO OF MEDICARE TO NCHS AVERAGE ANNUAL DECLINES, BY AGE GROUP AND SEX: 1968–78

CALENDAR YEAR	AGE LAST BIRTHDAY FOR MALES					AGE LAST BIRTHDAY FOR FEMALES				
	65–69	70–74	75–79	80–84	85 and Over	65–69	70–74	75–79	80–84	85 and Over
	Ratio of Medicare to NCHS Central Death Rate									
1968	0.9753	0.9375	1.0213	1.0811	1.0741	0.9115	0.9382	1.0040	1.0224	0.9315
1969	0.9706	0.9380	1.0064	1.0681	1.0722	0.9034	0.9297	0.9988	1.0082	0.9074
1970	0.9746	0.9846	0.9729	1.0014	1.1364	0.9375	0.9650	0.9590	0.9792	1.0409
1971	0.9945	0.9573	0.9673	1.0853	1.1251	0.9489	0.9268	0.9860	1.0289	0.9458
1972	0.9980	0.9807	0.9697	1.0198	1.0445	0.9655	0.9493	0.9539	1.0013	1.0054
1973	0.9989	0.9783	0.9566	1.0180	1.0363	0.9722	0.9400	0.9351	0.9963	1.0003
1974	1.0028	0.9657	0.9493	1.0020	1.0426	0.9841	0.9272	0.9328	0.9882	1.0125
1975	1.0172	0.9708	0.9546	0.9955	1.0748	1.0038	0.9332	0.9334	0.9883	1.0445
1976	1.0203	0.9790	0.9488	0.9959	1.0726	1.0091	0.9464	0.9176	0.9792	1.0461
1977	1.0276	0.9862	0.9444	0.9884	1.0766	1.0139	0.9538	0.9077	0.9721	1.0537
1978*	1.0262	1.0000	0.9433	0.9744	1.0947	1.0209	0.9774	0.9114	0.9532	1.0587
	Ratio of Medicare to NCHS Average Annual Decline									
1968–78*	0.7237	0.7654	1.9485	2.5219	1.1050	0.5759	0.9155	1.6457	1.2510	0.6160

*Figures for 1978 are preliminary.

TABLE 7

RATIO OF FEMALE TO MALE MEDICARE CENTRAL DEATH RATES, BY AGE GROUP AND CALENDAR YEAR, AND RATIO OF FEMALE TO MALE MEDICARE AVERAGE ANNUAL DECLINES, BY AGE GROUP: 1968–78

CALENDAR YEAR	AGE LAST BIRTHDAY				
	65–69	70–74	75–79	80–84	85 and Over
	Ratio of Female to Male Medicare Central Death Rate				
1968	0.4852	0.5408	0.6233	0.7122	0.8153
1969	0.4805	0.5394	0.6168	0.7011	0.8135
1970	0.4771	0.5395	0.6112	0.6925	0.7976
1971	0.4776	0.5303	0.6069	0.6867	0.7992
1972	0.4786	0.5249	0.5953	0.6739	0.7959
1973	0.4705	0.5164	0.5922	0.6671	0.7911
1974	0.4713	0.5159	0.5900	0.6721	0.7917
1975	0.4698	0.5096	0.5779	0.6583	0.7917
1976	0.4723	0.5082	0.5677	0.6514	0.7759
1977	0.4804	0.5030	0.5588	0.6400	0.7662
1978*	0.4823	0.5056	0.5583	0.6368	0.7693
	Ratio of Female to Male Medicare Average Annual Decline				
1968–78*	1.0630	1.5273	1.7936	1.6888	1.4121

*Figures for 1978 are preliminary.

The main reason for recent declines in the death rates of the aged has been an increasing degree of control of diseases of the heart and circulatory system. On the other hand, the death rate from cancer has been rising. This data provides some support for the hypothesis that the recent improvement in mortality is due partly to the increased control of hypertension since the mid-1960s. The pattern of improvement by cause of death is very similar for males and females. Females show more improvement for diseases of the heart, the circulatory system, and the respiratory system. Females also show less deterioration for cancer, but males show more improvement for the group of all other causes.

IV. PROBABILITIES OF DEATH

The following analysis of probabilities of death by single years of age and sex is based on over one million deaths per year that, according to medicare data, occurred in the United States from 1968 through 1978. The exposure formula $E_x^z = \frac{1}{2}(P_x^z + P_{x+1}^{z+1} + \theta_x^z)$ was used, where P_x^z is the population at calendar age x on January 1 of year z, and θ_x^z is the number of deaths at calendar age x during calendar year z. The expression θ_x^z/E_x^z, then, is approximately equivalent to the mortality rate at exact age $x - \frac{1}{2}$, that is, the

TABLE 8

NCHS AGE-ADJUSTED DEATH RATES FOR AGES 65 AND OVER, BY SEX, CAUSE OF DEATH, AND CALENDAR YEAR, AND AVERAGE ANNUAL DECLINES, BY SEX AND CAUSE OF DEATH: 1968–77*

CALENDAR YEAR	CAUSE OF DEATH FOR MALES†					CAUSE OF DEATH FOR FEMALES†				
	I	II	III	IV	V	I	II	III	IV	V
	NCHS Age-adjusted Death Rate for Ages 65 and Over (per 100,000)									
1968	3,378.9	1,202.5	1,348.5	594.9	933.6	2,470.9	718.7	1,258.7	275.2	671.5
1969	3,306.4	1,206.1	1,296.4	557.3	912.8	2,412.6	718.8	1,212.6	251.5	661.0
1970	3,229.5	1,218.5	1,139.0	540.5	1,009.3	2,253.2	707.4	1,125.0	216.5	619.1
1971	3,208.1	1,248.4	1,235.7	527.0	872.7	2,297.2	722.7	1,134.5	217.2	622.7
1972	3,241.9	1,269.5	1,266.6	576.4	889.2	2,245.1	717.6	1,106.9	229.3	610.7
1973	3,210.0	1,277.8	1,239.1	587.6	875.1	2,192.4	713.2	1,099.6	235.5	606.8
1974	3,071.7	1,298.2	1,183.1	548.0	844.3	2,091.7	719.1	1,043.5	214.6	586.0
1975	2,921.7	1,307.6	1,080.9	559.7	816.9	1,953.2	720.0	860.0	214.2	639.9
1976	2,894.8	1,331.5	1,034.0	589.7	803.2	1,936.1	734.0	905.0	243.5	549.0
1977	2,829.8	1,347.0	984.8	541.2	799.1	1,871.9	740.2	854.5	209.7	547.4
	Average Annual Decline (Percent)									
1968–77	1.9	−1.3	2.9	0.1	2.1	3.0	−0.3	4.2	1.6	1.9

*Age-adjusted central death rates were calculated by the direct method, using the enumerated population of the United States on April 1, 1970, as the standard.

†Causes of death are (I) diseases of the heart (Eighth Revision Code Nos. 390–398, 402, 404, 410–429); (II) malignant neoplasms (140–209); (III) vascular diseases (400–401, 403, 430–458, 582–584); (IV) diseases of the respiratory system (460–519); (V) all other causes.

probability that a person aged exactly $x - ½$ will die before reaching age $x + ½$. These values of $q_{x-1/2}$ were graduated using a Whittaker-Henderson type B formula with a smoothing coefficient of 500,000.

Tables 9–19 show the medicare probabilities of death by age and sex, and selected ratios, for calendar years 1968–78. These tables compare the medicare probabilities of death for females with those for males. As expected, the female rates are considerably lower than the male rates. This differential in mortality is over 50 percent near age 65, but it becomes smaller with increasing age until it is only about 6 percent by age 100.

The tables also show the ratio of the probability of death for a given age to the probability of death at the preceding age. For males, these ratios remain fairly constant until close to age 90, fluctuating around 1.08. The pattern is similar for females, with the values fluctuating around 1.10. At about age 90, however, the observed mortality increases at progressively smaller rates.

The medicare data for calendar years 1969–71 for ages up to 102 were used in the preparation of the *U.S. Decennial Life Tables for 1969–71* for ages 85 and over [3]. At ages 85–94, a blending of the medicare experience with the experience based on census population and registered deaths was used in the United States Life Tables. At ages 95 and over, the medicare probabilities of death were used without adjustment until the ratio of q_x/q_{x-1} became less than 1.04. Thereafter, the probabilities of death were extrapolated using the formula

$$\frac{q_{x+1}}{q_x} - 1 = 0.9\left(\frac{q_x}{q_{x-1}} - 1\right).$$

This formula produced probabilities of death that increased at progressively smaller rates (consistent with the medicare experience for 1969–71 through age 102) until a ratio of 1.01 was reached between q_{108} and q_{109}. The more recent medicare experience shows probabilities of death that level off much more rapidly, becoming essentially flat near age 100. There are not sufficient reliable data at ages 100 and over to ascertain the path of the mortality curves for centenarians. It could remain flat, increase with age again, or turn down. Figure 4 neatly summarizes the pattern of probabilities of death by age and sex for calendar year 1977 (the latest year of final data).

Tables 20 and 21 summarize, for males and females, respectively, the medicare probabilities of death from 1968 to 1978, and show the average annual decline by single years of age.

TABLE 9

MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE AND SEX, AND SELECTED RATIOS: CALENDAR YEAR 1968

EXACT AGE	UNGRADUATED		GRADUATED				
	Male	Female	Male	Female	Ratio of Female to Male	Ratio to Preceding Age	
						Male	Female
.....	.03589	.01681	.03589	.01681	.46848	.....	.....
.....	.03889	.01881	.03904	.01889	.48371	1.0878	1.1232
.....	.04264	.02112	.04227	.02095	.49566	1.0825	1.1093
.....	.04531	.02286	.04555	.02301	.50510	1.0778	1.0983
.....	.04884	.02532	.04907	.02519	.51326	1.0773	1.0946
.....	.05288	.02745	.05287	.02759	.52182	1.0775	1.0955
.....	.05748	.03057	.05687	.03038	.53420	1.0755	1.1010
.....	.06066	.03323	.06102	.03363	.55109	1.0731	1.1070
.....	.06534	.03769	.06560	.03742	.57041	1.0750	1.1127
.....	.07065	.04150	.07072	.04161	.58842	1.0781	1.1121
.....	.07687	.04659	.07631	.04618	.60513	1.0791	1.1097
.....	.08182	.05076	.08227	.05116	.62188	1.0781	1.1079
.....	.08885	.05691	.08866	.05679	.64055	1.0777	1.1101
.....	.09544	.06262	.09552	.06315	.66111	1.0774	1.1119
.....	.10343	.07101	.10293	.07021	.68213	1.0776	1.1118
.....	.10974	.07738	.11099	.07781	.70101	1.0783	1.1081
.....	.12066	.08619	.11983	.08599	.71763	1.0796	1.1052
.....	.12962	.09471	.12938	.09485	.73310	1.0797	1.1030
.....	.13908	.10487	.13965	.10450	.74828	1.0794	1.1018
.....	.15073	.11459	.15072	.11506	.76338	1.0793	1.1010
.....	.16364	.12608	.16259	.12662	.77876	1.0787	1.1004
.....	.17501	.13951	.17524	.13907	.79361	1.0778	1.0984
.....	.18662	.15188	.18871	.15214	.80622	1.0769	1.0940
.....	.20356	.16725	.20295	.16559	.81594	1.0754	1.0884
.....	.21796	.18025	.21763	.17926	.82369	1.0723	1.0825
.....	.23051	.19016	.23235	.19322	.83160	1.0677	1.0779
.....	.25126	.20593	.24672	.20765	.84164	1.0618	1.0747
.....	.26446	.22333	.26039	.22245	.85429	1.0554	1.0713
.....	.26953	.24032	.27324	.23733	.86859	1.0493	1.0669
.....	.27913	.25464	.28535	.25202	.88321	1.0443	1.0619
.....	.29646	.26310	.29683	.26638	.89740	1.0402	1.0570
.....	.31333	.28085	.30774	.28038	.91111	1.0368	1.0526
.....	.30865	.29130	.31810	.29406	.92443	1.0337	1.0488
.....	.34367	.30825	.32792	.30742	.93749	1.0309	1.0454
.....	.33113	.32144	.33719	.32047	.95041	1.0283	1.0425

TABLE 10

MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE AND SEX, AND SELECTED RATIOS: CALENDAR YEAR 1969

EXACT AGE	UNGRADUATED		GRADUATED				
	Male	Female	Male	Female	Ratio of Female to Male	Ratio to Preceding Age	
						Male	Female
65.5	.03474	.01590	.03466	.01596	.46055	.....	.....
66.5	.03756	.01826	.03770	.01812	.48060	1.0877	1.135
67.5	.04083	.01999	.04099	.02017	.49200	1.0872	1.113
68.5	.04482	.02246	.04442	.02220	.49983	1.0837	1.101
69.5	.04770	.02405	.04787	.02431	.50793	1.0776	1.095
70.5	.05145	.02689	.05143	.02671	.51927	1.0745	1.098
71.5	.05522	.02929	.05524	.02948	.53361	1.0740	1.103
72.5	.05918	.03271	.05939	.03270	.55059	1.0752	1.109
73.5	.06421	.03634	.06395	.03633	.56810	1.0767	1.110
74.5	.06882	.04037	.06886	.04027	.58482	1.0769	1.108
75.5	.07388	.04461	.07418	.04451	.60005	1.0772	1.105
76.5	.08059	.04917	.07995	.04916	.61497	1.0777	1.104
77.5	.08583	.05417	.08617	.05444	.63186	1.0778	1.107
78.5	.09246	.06059	.09301	.06053	.65075	1.0795	1.111
79.5	.10099	.06719	.10055	.06740	.67028	1.0810	1.113
80.5	.10913	.07537	.10866	.07494	.68965	1.0807	1.111
81.5	.11631	.08274	.11731	.08301	.70760	1.0796	1.107
82.5	.12693	.09227	.12653	.09162	.72407	1.0786	1.103
83.5	.13653	.10012	.13626	.10085	.74014	1.0769	1.100
84.5	.14674	.11081	.14649	.11092	.75719	1.0751	1.099
85.5	.15696	.12191	.15731	.12185	.77459	1.0738	1.098
86.5	.16933	.13364	.16884	.13351	.79074	1.0733	1.095
87.5	.17950	.14581	.18118	.14574	.80439	1.0731	1.091
88.5	.19527	.15906	.19434	.15842	.81514	1.0727	1.087
89.5	.20711	.17135	.20815	.17147	.82379	1.0710	1.082
90.5	.22257	.18306	.22231	.18491	.83176	1.0680	1.078
91.5	.23641	.20087	.23645	.19870	.84034	1.0636	1.074
92.5	.25238	.21118	.25019	.21268	.85010	1.0581	1.070
93.5	.26833	.22636	.26318	.22669	.86135	1.0519	1.065
94.5	.26558	.23893	.27521	.24045	.87371	1.0457	1.060
95.5	.29086	.25822	.28619	.25367	.88639	1.0399	1.055
96.5	.28605	.26902	.29600	.26605	.89882	1.0343	1.048
97.5	.32716	.27274	.30456	.27740	.91082	1.0289	1.042
98.5	.30468	.29036	.31177	.28764	.92258	1.0237	1.036
99.5	.30722	.29040	.31763	.29674	.93423	1.0188	1.031

TABLE 11

MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE AND SEX, AND SELECTED RATIOS: CALENDAR YEAR 1970

EXACT AGE	UNGRADUATED		GRADUATED				
	Male	Female	Male	Female	Ratio of Female to Male	Ratio to Preceding Age	
						Male	Female
5	.03468	.01604	.03471	.01605	.46229	.....	.....
5	.03782	.01785	.03766	.01779	.47246	1.0849	1.1088
5	.04048	.01962	.04074	.01971	.48374	1.0819	1.1077
5	.04389	.02174	.04400	.02181	.49574	1.0800	1.1068
5	.04799	.02441	.04736	.02407	.50838	1.0762	1.1036
5	.05035	.02616	.05075	.02647	.52167	1.0716	1.0996
5	.05429	.02923	.05444	.02918	.53605	1.0727	1.1023
5	.05853	.03229	.05857	.03225	.55059	1.0760	1.1052
5	.06340	.03570	.06313	.03570	.56541	1.0779	1.1069
5	.06774	.03932	.06804	.03953	.58102	1.0777	1.1074
5	.07368	.04402	.07328	.04373	.59685	1.0770	1.1063
5	.07855	.04818	.07883	.04824	.61194	1.0757	1.1030
5	.08505	.05351	.08480	.05315	.62673	1.0758	1.1018
5	.09086	.05792	.09129	.05866	.64255	1.0765	1.1037
5	.09860	.06517	.09839	.06502	.66078	1.0778	1.1084
5	.10618	.07227	.10610	.07214	.67996	1.0784	1.1097
5	.11402	.08015	.11440	.07989	.69839	1.0782	1.1074
5	.12385	.08798	.12327	.08818	.71535	1.0775	1.1037
5	.13269	.09689	.13266	.09702	.73136	1.0762	1.1003
5	.14200	.10643	.14261	.10643	.74628	1.0751	1.0970
5	.15425	.11679	.15321	.11640	.75973	1.0743	1.0936
5	.16340	.12707	.16445	.12693	.77187	1.0734	1.0905
5	.17589	.13718	.17636	.13813	.78323	1.0724	1.0882
5	.18968	.15015	.18882	.15005	.79466	1.0707	1.0863
5	.20140	.16416	.20164	.16261	.80644	1.0679	1.0837
5	.21428	.17378	.21456	.17565	.81865	1.0641	1.0802
5	.23100	.18917	.22736	.18907	.83156	1.0596	1.0764
5	.23547	.20342	.23980	.20258	.84479	1.0547	1.0715
5	.24891	.21362	.25169	.21584	.85755	1.0496	1.0654
5	.26599	.23008	.26278	.22844	.86933	1.0440	1.0584
5	.27214	.24181	.27274	.23993	.87971	1.0379	1.0503
.....	.29486	.24942	.28130	.24992	.88845	1.0314	1.0416
.....	.28034	.25881	.28825	.25811	.89546	1.0247	1.0328
.....	.29712	.27320	.29351	.26433	.90060	1.0183	1.0241
.....	.28484	.25449	.29705	.26849	.90385	1.0121	1.0157

TABLE 12

MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE AND SEX, AND SELECTED RATIOS: CALENDAR YEAR 1971

EXACT AGE	UNGRADUATED		GRADUATED				
	Male	Female	Male	Female	Ratio of Female to Male	Ratio to Preceding Age	
						Male	Female
65.5	.03456	.01650	.03459	.01651	.47732	.....	.....
66.5	.03749	.01789	.03741	.01778	.47522	1.0815	1.076
67.5	.04040	.01924	.04042	.01944	.48090	1.0805	1.093
68.5	.04363	.02151	.04366	.02150	.49252	1.0803	1.106
69.5	.04699	.02387	.04717	.02384	.50548	1.0803	1.108
70.5	.05112	.02646	.05090	.02630	.51665	1.0791	1.102
71.5	.05456	.02883	.05476	.02883	.52651	1.0758	1.096
72.5	.05918	.03158	.05876	.03161	.53795	1.0731	1.096
73.5	.06272	.03457	.06297	.03485	.55347	1.0717	1.102
74.5	.06743	.03874	.06764	.03868	.57193	1.0741	1.109
75.5	.07274	.04328	.07288	.04300	.59004	1.0776	1.111
76.5	.07925	.04758	.07867	.04772	.60657	1.0795	1.109
77.5	.08441	.05271	.08491	.05289	.62297	1.0792	1.108
78.5	.09212	.05906	.09162	.05857	.63925	1.0791	1.107
79.5	.09832	.06428	.09883	.06478	.65551	1.0787	1.106
80.5	.10655	.07201	.10663	.07173	.67272	1.0789	1.107
81.5	.11614	.07951	.11503	.07947	.69091	1.0788	1.108
82.5	.12265	.08783	.12405	.08809	.71010	1.0784	1.108
83.5	.13405	.09725	.13384	.09758	.72907	1.0789	1.107
84.5	.14523	.10799	.14432	.10778	.74679	1.0783	1.104
85.5	.15567	.11921	.15539	.11840	.76193	1.0767	1.098
86.5	.16542	.12878	.16706	.12928	.77381	1.0751	1.091
87.5	.17901	.14088	.17933	.14048	.78337	1.0734	1.086
88.5	.19516	.15204	.19201	.15213	.79233	1.0707	1.082
89.5	.20277	.16280	.20488	.16439	.80238	1.0670	1.080
90.5	.21760	.17872	.21786	.17731	.81389	1.0633	1.078
91.5	.23383	.19213	.23081	.19076	.82648	1.0594	1.075
92.5	.23544	.19885	.24354	.20455	.83992	1.0552	1.072
93.5	.25479	.22151	.25580	.21845	.85398	1.0504	1.067
94.5	.27578	.23415	.26717	.23195	.86818	1.0444	1.061
95.5	.27572	.24133	.27717	.24458	.88243	1.0374	1.054
96.5	.29556	.25972	.28543	.25593	.89666	1.0298	1.046
97.5	.28708	.27106	.29172	.26567	.91069	1.0221	1.038
98.5	.29134	.27137	.29595	.27360	.92446	1.0145	1.029
99.5	.28742	.27074	.29809	.27965	.93815	1.0072	1.022

TABLE 13

MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE AND SEX, AND SELECTED RATIOS: CALENDAR YEAR 1972

EXACT AGE	UNGRADUATED		GRADUATED				
	Male	Female	Male	Female	Ratio of Female to Male	Ratio to Preceding Age	
						Male	Female
5	.03416	.01625	.03431	.01625	.47373	.....	.....
5	.03788	.01786	.03762	.01784	.47424	1.0965	1.0977
5	.04071	.01953	.04069	.01962	.48212	1.0816	1.0995
5	.04381	.02178	.04374	.02158	.49352	1.0748	1.1002
5	.04677	.02349	.04706	.02372	.50407	1.0760	1.0990
5	.05060	.02636	.05090	.02610	.51285	1.0816	1.1005
5	.05566	.02868	.05520	.02874	.52062	1.0845	1.1010
5	.05971	.03148	.05971	.03173	.53148	1.0816	1.1041
5	.06430	.03521	.06434	.03513	.54594	1.0777	1.1070
5	.06906	.03910	.06917	.03883	.56134	1.0749	1.1053
5	.07435	.04286	.07426	.04281	.57646	1.0737	1.1026
5	.07996	.04690	.07972	.04727	.59293	1.0735	1.1042
5	.08521	.05238	.08568	.05241	.61169	1.0747	1.1087
5	.09242	.05819	.09229	.05819	.63050	1.0772	1.1103
5	.09955	.06498	.09956	.06448	.64765	1.0787	1.1081
5	.10750	.07098	.10741	.07121	.66293	1.0789	1.1044
5	.11586	.07839	.11580	.07856	.67841	1.0781	1.1032
5	.12465	.08680	.12469	.08670	.69535	1.0768	1.1036
5	.13420	.09549	.13409	.09569	.71366	1.0754	1.1037
5	.14385	.10564	.14404	.10553	.73268	1.0742	1.1028
5	.15407	.11629	.15456	.11611	.75123	1.0731	1.1002
5	.16619	.12698	.16566	.12731	.76853	1.0718	1.0965
5	.17851	.13963	.17728	.13904	.78433	1.0701	1.0921
5	.18945	.15065	.18945	.15120	.79811	1.0687	1.0874
5	.20156	.16458	.20229	.16375	.80949	1.0678	1.0830
5	.21310	.17609	.21583	.17664	.81841	1.0669	1.0787
5	.22502	.18826	.22985	.18981	.82582	1.0649	1.0746
5	.25084	.20464	.24374	.20310	.83326	1.0604	1.0700
5	.25663	.21484	.25663	.21616	.84231	1.0529	1.0643
5	.27361	.22980	.26770	.22864	.85411	1.0431	1.0577
5	.27065	.24027	.27626	.24016	.86935	1.0320	1.0504
5	.29618	.25336	.28182	.25042	.88855	1.0202	1.0427
5	.27617	.25852	.28408	.25917	.91233	1.0080	1.0350
5	.27993	.26592	.28289	.26633	.94149	0.9958	1.0276
5	.26564	.26771	.27821	.27187	.97719	0.9835	1.0208

TABLE 14

MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE AND SEX, AND SELECTED RATIOS: CALENDAR YEAR 1973

EXACT AGE	UNGRADUATED		GRADUATED				
	Male	Female	Male	Female	Ratio of Female to Male	Ratio to Preceding Age	
						Male	Female
65.5	.03385	.01581	.03382	.01579	.46690	.....	.....
66.5	.03678	.01723	.03687	.01734	.47041	1.0901	1.0983
67.5	.04008	.01920	.04005	.01903	.47505	1.0862	1.0969
68.5	.04348	.02088	.04332	.02081	.48032	1.0817	1.0937
69.5	.04648	.02258	.04670	.02280	.48834	1.0779	1.0959
70.5	.05049	.02523	.05028	.02516	.50039	1.0768	1.1034
71.5	.05393	.02758	.05413	.02786	.51461	1.0765	1.1071
72.5	.05827	.03130	.05832	.03080	.52821	1.0774	1.1058
73.5	.06269	.03371	.06283	.03388	.53925	1.0774	1.0999
74.5	.06836	.03740	.06762	.03730	.55165	1.0762	1.1009
75.5	.07220	.04116	.07267	.04131	.56848	1.0747	1.1075
76.5	.07802	.04562	.07825	.04611	.58923	1.0768	1.1161
77.5	.08455	.05198	.08450	.05163	.61098	1.0799	1.1198
78.5	.09157	.05779	.09139	.05751	.62926	1.0815	1.1139
79.5	.09860	.06365	.09882	.06357	.64326	1.0813	1.1054
80.5	.10685	.06986	.10672	.06995	.65541	1.0799	1.1003
81.5	.11529	.07661	.11502	.07696	.66912	1.0778	1.1003
82.5	.12458	.08522	.12376	.08490	.68605	1.0759	1.1032
83.5	.13083	.09336	.13308	.09386	.70530	1.0753	1.1055
84.5	.14377	.10434	.14320	.10386	.72527	1.0760	1.1065
85.5	.15535	.11433	.15397	.11473	.74512	1.0753	1.1047
86.5	.16582	.12677	.16529	.12633	.76429	1.0735	1.1011
87.5	.17667	.13773	.17720	.13846	.78136	1.0721	1.0960
88.5	.18657	.15167	.18982	.15096	.79533	1.0712	1.0903
89.5	.20519	.16537	.20308	.16370	.80610	1.0699	1.0844
90.5	.21795	.17573	.21661	.17666	.81559	1.0666	1.0792
91.5	.22813	.18754	.23000	.19001	.82613	1.0618	1.0755
92.5	.24347	.20234	.24284	.20367	.83870	1.0558	1.0719
93.5	.25667	.21563	.25472	.21719	.85265	1.0489	1.0664
94.5	.26530	.23668	.26528	.22980	.86628	1.0414	1.0581
95.5	.27150	.24356	.27422	.24066	.87761	1.0337	1.0473
96.5	.28943	.24933	.28136	.24918	.88562	1.0260	1.0354
97.5	.27711	.25240	.28654	.25502	.89000	1.0184	1.0235
98.5	.29795	.25858	.28971	.25806	.89077	1.0111	1.0119
99.5	.27999	.25204	.29083	.25825	.88797	1.0039	1.0007

TABLE 15

MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE AND SEX, AND SELECTED RATIOS: CALENDAR YEAR 1974

EXACT AGE	UNGRADUATED		GRADUATED				
	Male	Female	Male	Female	Ratio of Female to Male	Ratio to Preceding Age	
						Male	Female
5	.03293	.01517	.03290	.01520	.46193	.....	.....
5	.03565	.01690	.03582	.01686	.47061	1.0885	1.1090
5	.03899	.01845	.03879	.01851	.47731	1.0830	1.0984
5	.04187	.02037	.04177	.02022	.48405	1.0769	1.0921
5	.04478	.02203	.04488	.02204	.49120	1.0743	1.0902
5	.04806	.02400	.04829	.02416	.50026	1.0761	1.0960
5	.05223	.02651	.05210	.02669	.51228	1.0790	1.1049
5	.05611	.02978	.05623	.02959	.52619	1.0792	1.1085
5	.06107	.03291	.06058	.03270	.53988	1.0773	1.1054
5	.06473	.03574	.06511	.03607	.55394	1.0748	1.1028
5	.06976	.04002	.06999	.03986	.56946	1.0749	1.1051
5	.07568	.04404	.07529	.04415	.58633	1.0758	1.1077
5	.08101	.04890	.08102	.04901	.60499	1.0760	1.1102
5	.08714	.05467	.08725	.05445	.62407	1.0769	1.1109
5	.09408	.06013	.09410	.06039	.64176	1.0785	1.1091
5	.10113	.06760	.10162	.06688	.65810	1.0800	1.1075
5	.11093	.07331	.10980	.07399	.67386	1.0805	1.1064
5	.11762	.08195	.11855	.08200	.69170	1.0796	1.1082
5	.12787	.09089	.12792	.09092	.71074	1.0791	1.1088
5	.13837	.10082	.13791	.10062	.72963	1.0781	1.1067
5	.14881	.11124	.14845	.11091	.74711	1.0764	1.1022
5	.15873	.12089	.15955	.12166	.76250	1.0748	1.0969
5	.17136	.13371	.17126	.13285	.77576	1.0734	1.0920
5	.18392	.14478	.18350	.14445	.78716	1.0715	1.0873
5	.19523	.15547	.19615	.15651	.79790	1.0689	1.0835
5	.20934	.16899	.20900	.16912	.80919	1.0655	1.0806
5	.22257	.18154	.22174	.18217	.82153	1.0610	1.0772
5	.23541	.19796	.23401	.19537	.83485	1.0554	1.0725
5	.23627	.20459	.24543	.20830	.84874	1.0488	1.0662
5	.25638	.21901	.25552	.22054	.86310	1.0411	1.0588
5	.28272	.24162	.26373	.23153	.87792	1.0321	1.0498
5	.27179	.23777	.26951	.24072	.89316	1.0219	1.0397
5	.26421	.24470	.27262	.24782	.90901	1.0115	1.0295
5	.26816	.25980	.27297	.25267	.92565	1.0013	1.0196
5	.26380	.24565	.27052	.25519	.94332	0.9910	1.0100

TABLE 16

MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE AND SEX, AND SELECTED RATIOS: CALENDAR YEAR 1975

EXACT AGE	UNGRADUATED		GRADUATED				
						Ratio to Preceding Age	
	Male	Female	Male	Female	Ratio of Female to Male	Male	Female
65.5	.03197	.01479	.03197	.01478	.46219	.....	.....
66.5	.03483	.01628	.03494	.01627	.46556	1.0929	1.1009
67.5	.03813	.01780	.03787	.01792	.47315	1.0837	1.1014
68.5	.04066	.01979	.04075	.01971	.48356	1.0762	1.0999
69.5	.04369	.02167	.04378	.02156	.49258	1.0742	1.0943
70.5	.04719	.02349	.04711	.02352	.49930	1.0760	1.0907
71.5	.05072	.02568	.05081	.02573	.50634	1.0787	1.0939
72.5	.05481	.02823	.05492	.02833	.51590	1.0808	1.1012
73.5	.05932	.03124	.05934	.03137	.52864	1.0805	1.1072
74.5	.06442	.03521	.06393	.03474	.54351	1.0773	1.1076
75.5	.06826	.03807	.06861	.03835	.55888	1.0733	1.1037
76.5	.07360	.04224	.07358	.04232	.57518	1.0724	1.1037
77.5	.07892	.04680	.07899	.04677	.59215	1.0735	1.1052
78.5	.08520	.05226	.08497	.05175	.60910	1.0757	1.1065
79.5	.09109	.05647	.09159	.05735	.62620	1.0779	1.1082
80.5	.09912	.06399	.09889	.06375	.64466	1.0797	1.1115
81.5	.10670	.07104	.10676	.07076	.66287	1.0796	1.1100
82.5	.11524	.07794	.11508	.07822	.67969	1.0780	1.1054
83.5	.12454	.08689	.12381	.08609	.69536	1.0758	1.1006
84.5	.13231	.09405	.13299	.09445	.71020	1.0742	1.0971
85.5	.14207	.10312	.14281	.10360	.72542	1.0738	1.0968
86.5	.15422	.11365	.15333	.11371	.74161	1.0737	1.0976
87.5	.16428	.12446	.16448	.12472	.75830	1.0727	1.0969
88.5	.17603	.13795	.17617	.13641	.77430	1.0711	1.0937
89.5	.18752	.14741	.18826	.14848	.78873	1.0686	1.0885
90.5	.20127	.16077	.20051	.16083	.80210	1.0651	1.0831
91.5	.21282	.17310	.21263	.17325	.81481	1.0604	1.0772
92.5	.22371	.18648	.22429	.18550	.82706	1.0549	1.0707
93.5	.23890	.19689	.23520	.19731	.83891	1.0486	1.0637
94.5	.23582	.20676	.24506	.20843	.85051	1.0419	1.0563
95.5	.26204	.21825	.25362	.21855	.86175	1.0349	1.0486
96.5	.25936	.22873	.26055	.22733	.87250	1.0274	1.0402
97.5	.27040	.23898	.26565	.23442	.88246	1.0195	1.0312
98.5	.27667	.24330	.26874	.23957	.89147	1.0116	1.0220
99.5	.25094	.23268	.26976	.24268	.89961	1.0038	1.0130

TABLE 17

MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE AND SEX, AND SELECTED RATIOS: CALENDAR YEAR 1976

EXACT AGE	UNGRADUATED		GRADUATED				
	Male	Female	Male	Female	Ratio of Female to Male	Ratio to Preceding Age	
						Male	Female
5	.03165	.01488	.03157	.01487	.47096	.....	.....
5	.03415	.01615	.03431	.01614	.47050	1.0866	1.0855
5	.03728	.01764	.03732	.01768	.47381	1.0878	1.0954
5	.04060	.01942	.04049	.01947	.48086	1.0850	1.1011
5	.04377	.02138	.04368	.02142	.49036	1.0789	1.1002
5	.04681	.02373	.04689	.02342	.49948	1.0735	1.0935
5	.05038	.02534	.05026	.02546	.50650	1.0717	1.0868
5	.05381	.02759	.05393	.02775	.51457	1.0731	1.0902
5	.05813	.03054	.05811	.03051	.52508	1.0774	1.0994
5	.06245	.03374	.06285	.03376	.53721	1.0816	1.1066
5	.06830	.03756	.06809	.03746	.55015	1.0833	1.1094
5	.07364	.04127	.07355	.04151	.56441	1.0803	1.1083
5	.07970	.04640	.07911	.04592	.58049	1.0755	1.1061
5	.08447	.05062	.08481	.05068	.59765	1.0720	1.1037
5	.09044	.05562	.09098	.05606	.61618	1.0728	1.1061
5	.09857	.06217	.09791	.06227	.63603	1.0761	1.1107
5	.10447	.06982	.10563	.06926	.65568	1.0789	1.1122
5	.11481	.07671	.11417	.07690	.67355	1.0809	1.1103
5	.12459	.08560	.12334	.08526	.69127	1.0803	1.1087
5	.13229	.09353	.13307	.09442	.70957	1.0789	1.1075
5	.14241	.10416	.14357	.10446	.72757	1.0789	1.1063
5	.15605	.11659	.15494	.11516	.74321	1.0792	1.1024
5	.16676	.12651	.16708	.12625	.75566	1.0783	1.0964
5	.17956	.13651	.17983	.13783	.76646	1.0764	1.0917
5	.19309	.15070	.19297	.15010	.77784	1.0731	1.0890
5	.20490	.16265	.20616	.16306	.79096	1.0683	1.0863
5	.22048	.17553	.21897	.17659	.80646	1.0621	1.0829
5	.23193	.19066	.23093	.19034	.82422	1.0546	1.0779
5	.24282	.20401	.24165	.20375	.84317	1.0464	1.0705
5	.24944	.21780	.25081	.21621	.86204	1.0379	1.0611
5	.25295	.22774	.25819	.22715	.87978	1.0294	1.0506
5	.26326	.23676	.26355	.23616	.89607	1.0208	1.0397
5	.27787	.24151	.26666	.24299	.91126	1.0118	1.0289
5	.28017	.25028	.26730	.24751	.92596	1.0024	1.0186
5	.24082	.24447	.26539	.24965	.94071	0.9928	1.0087

TABLE 18

MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE AND SEX, AND SELECTED RATIOS: CALENDAR YEAR 1977

EXACT AGE	UNGRADUATED		GRADUATED				
	Male	Female	Male	Female	Ratio of Female to Male	Ratio to Preceding Age	
						Male	Female
65.5	.03079	.01480	.03088	.01482	.48004	.....	.....
66.5	.03374	.01620	.03356	.01613	.48076	1.0867	1.0883
67.5	.03637	.01746	.03629	.01754	.48334	1.0815	1.0873
68.5	.03883	.01925	.03922	.01910	.48691	1.0807	1.0886
69.5	.04263	.02062	.04248	.02082	.49012	1.0831	1.0902
70.5	.04605	.02278	.04595	.02278	.49578	1.0819	1.0944
71.5	.04963	.02511	.04957	.02493	.50300	1.0787	1.0944
72.5	.05325	.02721	.05336	.02723	.51024	1.0765	1.0920
73.5	.05763	.02975	.05745	.02978	.51840	1.0765	1.0937
74.5	.06170	.03273	.06192	.03275	.52887	1.0779	1.0996
75.5	.06656	.03591	.06688	.03623	.54173	1.0801	1.1063
76.5	.07250	.04055	.07225	.04021	.55650	1.0803	1.1098
77.5	.07809	.04456	.07782	.04450	.57187	1.0772	1.1069
78.5	.08380	.04909	.08353	.04914	.58824	1.0734	1.1041
79.5	.08924	.05427	.08954	.05425	.60586	1.0719	1.1040
80.5	.09595	.05992	.09615	.06001	.62405	1.0738	1.1061
81.5	.10344	.06637	.10357	.06653	.64235	1.0771	1.1087
82.5	.11142	.07380	.11180	.07382	.66029	1.0795	1.1096
83.5	.12148	.08188	.12072	.08177	.67737	1.0798	1.1077
84.5	.13022	.09077	.13011	.09026	.69374	1.0778	1.1038
85.5	.13999	.09903	.13991	.09930	.70976	1.0753	1.1002
86.5	.15030	.10904	.15020	.10910	.72637	1.0736	1.0987
87.5	.16193	.11926	.16113	.11982	.74365	1.0727	1.0983
88.5	.16941	.13112	.17280	.13147	.76081	1.0725	1.0972
89.5	.18798	.14566	.18523	.14382	.77645	1.0719	1.0939
90.5	.19480	.15497	.19803	.15655	.79051	1.0691	1.0885
91.5	.21371	.17114	.21075	.16947	.80413	1.0642	1.0825
92.5	.22317	.18130	.22273	.18232	.81854	1.0569	1.0758
93.5	.23563	.19324	.23345	.19486	.83471	1.0481	1.0688
94.5	.24007	.20663	.24247	.20675	.85270	1.0386	1.0610
95.5	.25019	.21937	.24951	.21747	.87159	1.0290	1.0518
96.5	.25552	.22411	.25437	.22646	.89027	1.0195	1.0413
97.5	.25995	.24222	.25693	.23324	.90781	1.0101	1.0300
98.5	.24788	.23949	.25714	.23746	.92345	1.0008	1.0181
99.5	.25542	.22707	.25501	.23897	.93711	0.9917	1.0064

TABLE 19

MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE AND SEX, AND SELECTED RATIOS: CALENDAR YEAR 1978*

EXACT AGE	UNGRADUATED		GRADUATED				
	Male	Female	Male	Female	Ratio of Female to Male	Ratio to Preceding Age	
						Male	Female
5	.03073	.01487	.03083	.01484	.48152	.....	.....
5	.03379	.01600	.03362	.01609	.47866	1.0906	1.0842
5	.03625	.01763	.03631	.01751	.48234	1.0800	1.0883
5	.03928	.01906	.03904	.01906	.48825	1.0753	1.0885
5	.04160	.02069	.04202	.02078	.49464	1.0763	1.0904
5	.04546	.02277	.04547	.02273	.49995	1.0821	1.0937
5	.04939	.02488	.04930	.02489	.50481	1.0843	1.0948
5	.05359	.02732	.05332	.02724	.51097	1.0815	1.0947
5	.05746	.02980	.05743	.02983	.51938	1.0772	1.0949
5	.06140	.03265	.06177	.03273	.52998	1.0755	1.0974
5	.06649	.03611	.06649	.03604	.54210	1.0764	1.1011
5	.07171	.03971	.07160	.03978	.55557	1.0769	1.1036
5	.07754	.04405	.07706	.04397	.57063	1.0763	1.1055
5	.08215	.04859	.08291	.04865	.58675	1.0759	1.1063
5	.08954	.05391	.08929	.05385	.60307	1.0770	1.1070
5	.09585	.05952	.09620	.05964	.61997	1.0774	1.1076
5	.10428	.06648	.10360	.06609	.63798	1.0769	1.1082
5	.11172	.07257	.11144	.07324	.65727	1.0757	1.1082
5	.11877	.08140	.11986	.08118	.67726	1.0756	1.1083
5	.13012	.08990	.12909	.08977	.69540	1.0770	1.1058
5	.13796	.09968	.13914	.09893	.71103	1.0779	1.1021
5	.14984	.10800	.15002	.10876	.72494	1.0782	1.0993
5	.16287	.11941	.16156	.11952	.73983	1.0769	1.0990
5	.17450	.13090	.17350	.13133	.75692	1.0739	1.0988
5	.18603	.14419	18578	.14406	.77543	1.0708	1.0970
5	.19554	.15834	.19841	.15741	.79337	1.0680	1.0927
5	.20985	.17095	.21132	.17103	.80934	1.0651	1.0865
5	.22372	.18373	.22414	.18462	.82365	1.0607	1.0794
5	.23904	.19762	.23624	.19787	.83758	1.0540	1.0718
5	.24420	.21006	.24682	.21039	.85241	1.0448	1.0633
5	.25608	.22328	.25512	.22178	.86931	1.0336	1.0541
5	.27200	.23511	.26042	.23164	.88951	1.0208	1.0445
5	.26552	.23595	.26215	.23975	.91455	1.0067	1.0350
5	.26146	.24770	.26003	.24602	.94613	0.9919	1.0262
5	.22851	.24734	.25395	.25042	.98610	0.9766	1.0179

*Figures are preliminary.

TABLE 20

GRADUATED MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR FOR MALES, BY AGE AND CALENDAR YEAR, AND AVERAGE ANNUAL DECLINES BY AGE

EXACT AGE	CALENDAR YEAR											AVERAGE ANNUAL PERCENT DECLINE
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978*	
65.5	.03589	.03466	.03471	.03459	.03431	.03382	.03290	.03197	.03157	.03088	.03083	1.54
66.5	.03904	.03770	.03766	.03741	.03762	.03687	.03582	.03494	.03431	.03356	.03362	1.51
67.5	.04227	.04099	.04074	.04042	.04069	.04005	.03879	.03787	.03732	.03629	.03631	1.52
68.5	.04555	.04442	.04400	.04366	.04374	.04332	.04177	.04075	.04049	.03922	.03904	1.54
69.5	.04907	.04787	.04736	.04717	.04706	.04670	.04488	.04378	.04368	.04248	.04202	1.53
70.5	.05287	.05143	.05075	.05090	.05090	.05028	.04829	.04711	.04689	.04595	.04547	1.49
71.5	.05687	.05524	.05444	.05476	.05520	.05413	.05210	.05081	.05026	.04957	.04930	1.44
72.5	.06102	.05939	.05857	.05876	.05971	.05832	.05623	.05492	.05393	.05336	.05332	1.40
73.5	.06560	.06395	.06313	.06297	.06434	.06283	.06058	.05934	.05811	.05745	.05743	1.37
74.5	.07072	.06886	.06804	.06764	.06917	.06762	.06511	.06393	.06285	.06192	.06177	1.37
75.5	.07631	.07418	.07328	.07288	.07426	.07267	.06999	.06861	.06809	.06688	.06649	1.36
76.5	.08227	.07995	.07883	.07867	.07972	.07825	.07529	.07358	.07355	.07225	.07160	1.35
77.5	.08866	.08617	.08480	.08491	.08568	.08450	.08102	.07899	.07911	.07782	.07706	1.37
78.5	.09552	.09301	.09129	.09162	.09229	.09139	.08725	.08497	.08481	.08353	.08291	1.41
79.5	.10293	.10055	.09839	.09883	.09956	.09882	.09410	.09159	.09098	.08954	.08929	1.46

*Figures for 1978 are preliminary.

TABLE 20—*Continued*

Exact Age	Calendar Year											Average Annual Percent Decline
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978*	
80.5	.11099	.10866	.10610	.10663	.10741	.10672	.10162	.09889	.09791	.09615	.09620	1.49
81.5	.11983	.11731	.11440	.11503	.11580	.11502	.10980	.10676	.10563	.10357	.10360	1.50
82.5	.12938	.12653	.12327	.12405	.12469	.12376	.11855	.11508	.11417	.11180	.11144	1.51
83.5	.13965	.13626	.13266	.13384	.13409	.13308	.12792	.12381	.12334	.12072	.11986	1.51
84.5	.15072	.14649	.14261	.14432	.14404	.14320	.13791	.13299	.13307	.13011	.12909	1.50
85.5	.16259	.15731	.15321	.15539	.15456	.15397	.14845	.14281	.14357	.13991	.13914	1.49
86.5	.17524	.16884	.16445	.16706	.16566	.16529	.15955	.15333	.15494	.15020	.15002	1.47
87.5	.18871	.18118	.17636	.17933	.17728	.17720	.17126	.16448	.16708	.16113	.16156	1.46
88.5	.20295	.19434	.18882	.19201	.18945	.18982	.18350	.17617	.17983	.17280	.17350	1.45
89.5	.21763	.20815	.20164	.20488	.20229	.20308	.19615	.18826	.19297	.18523	.18578	1.43
90.5	.23235	.22231	.21456	.21786	.21583	.21661	.20900	.20051	.20616	.19803	.19841	1.42
91.5	.24672	.23645	.22736	.23081	.22985	.23000	.22174	.21263	.21897	.21075	.21132	1.40
92.5	.26039	.25019	.23980	.24354	.24374	.24284	.23401	.22429	.23093	.22273	.22414	1.38
93.5	.27324	.26318	.25169	.25580	.25663	.25472	.24543	.23520	.24165	.23345	.23624	1.39
94.5	.28535	.27521	.26278	.26717	.26770	.26528	.25552	.24506	.25081	.24247	.24682	1.44
95.5	.29683	.28619	.27274	.27717	.27626	.27422	.26373	.25362	.25819	.24951	.25512	1.53
96.5	.30774	.29600	.28130	.28543	.28182	.28136	.26951	.26055	.26355	.25437	.26042	1.68
97.5	.31810	.30456	.28825	.29172	.28408	.28654	.27262	.26565	.26666	.25693	.26215	1.90
98.5	.32792	.31177	.29351	.29595	.28289	.28971	.27297	.26874	.26730	.25714	.26003	2.19
99.5	.33719	.31763	.29705	.29809	.27821	.29083	.27052	.26976	.26539	.25501	.25395	2.57

*Figures for 1978 are preliminary.

TABLE 21

GRADUATED MEDICARE PROBABILITIES OF DEATH WITHIN ONE YEAR FOR FEMALES, BY AGE AND CALENDAR YEAR, AND AVERAGE ANNUAL DECLINES BY AGE

EXACT AGE	CALENDAR YEAR											AVERAGE ANNUAL PERCENT DECLINE
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978*	
65.5	.01681	.01596	.01605	.01651	.01625	.01579	.01520	.01478	.01487	.01482	.01484	1.30
66.5	.01889	.01812	.01779	.01778	.01784	.01734	.01686	.01627	.01614	.01613	.01609	1.62
67.5	.02095	.02017	.01971	.01944	.01962	.01903	.01851	.01792	.01768	.01754	.01751	1.80
68.5	.02301	.02220	.02181	.02150	.02158	.02081	.02022	.01971	.01947	.01910	.01906	1.91
69.5	.02519	.02431	.02407	.02384	.02372	.02280	.02204	.02156	.02142	.02082	.02078	1.99
70.5	.02759	.02671	.02647	.02630	.02610	.02516	.02416	.02352	.02342	.02278	.02273	2.04
71.5	.03038	.02948	.02918	.02883	.02874	.02786	.02669	.02573	.02546	.02493	.02489	2.14
72.5	.03363	.03270	.03225	.03161	.03173	.03080	.02959	.02833	.02775	.02723	.02724	2.27
73.5	.03742	.03633	.03570	.03485	.03513	.03388	.03270	.03137	.03051	.02978	.02983	2.41
74.5	.04161	.04027	.03953	.03868	.03883	.03730	.03607	.03474	.03376	.03275	.03273	2.50
75.5	.04618	.01451	.04373	.04300	.04281	.04131	.03986	.03835	.03746	.03623	.03604	2.54
76.5	.05116	.04916	.04824	.04772	.04727	.04611	.04415	.04232	.04151	.04021	.03978	2.53
77.5	.05679	.05444	.05315	.05289	.05241	.05163	.04901	.04677	.04592	.04450	.04397	2.55
78.5	.06315	.06053	.05866	.05857	.05819	.05751	.05445	.05175	.05068	.04914	.04865	2.59
79.5	.07021	.06740	.06502	.06478	.06448	.06357	.06039	.05735	.05606	.05425	.05385	2.64

*Figures for 1978 are preliminary.

TABLE 21—*Continued*

Exact Age	Calendar Year											Average Annual Percent Decline
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978*	
80.5	.07781	.07494	.07214	.07173	.07121	.06995	.06688	.06375	.06227	.06001	.05964	2.65
81.5	.08599	.08301	.07989	.07947	.07856	.07696	.07399	.07076	.06926	.06653	.06609	2.62
82.5	.09485	.09162	.08818	.08809	.08670	.08490	.08200	.07822	.07690	.07382	.07324	2.57
83.5	.10450	.10085	.09702	.09758	.09569	.09386	.09092	.08609	.08526	.08177	.08118	2.51
84.5	.11506	.11092	.10643	.10778	.10553	.10386	.10062	.09445	.09442	.09026	.08977	2.46
85.5	.12662	.12185	.11640	.11840	.11611	.11473	.11091	.10360	.10446	.09930	.09893	2.42
86.5	.13907	.13351	.12693	.12928	.12731	.12633	.12166	.11371	.11516	.10910	.10876	2.36
87.5	.15214	.14574	.13813	.14048	.13904	.13846	.13285	.12472	.12625	.11982	.11952	2.29
88.5	.16559	.15842	.15005	.15213	.15120	.15096	.14445	.13641	.13783	.13147	.13133	2.18
89.5	.17926	.17147	.16261	.16439	.16375	.16370	.15651	.14848	.15010	.14382	.14406	2.06
90.5	.19322	.18491	.17565	.17731	.17664	.17666	.16912	.16083	.16306	.15655	.15741	1.94
91.5	.20765	.19870	.18907	.19076	.18981	.19001	.18217	.17325	.17659	.16947	.17103	1.84
92.5	.22245	.21268	.20258	.20455	.20310	.20367	.19537	.18550	.19034	.18232	.18462	1.77
93.5	.23733	.22669	.21584	.21845	.21616	.21719	.20830	.19731	.20375	.19486	.19787	1.74
94.5	.25202	.24045	.22844	.23195	.22864	.22980	.22054	.20843	.21621	.20675	.21039	1.73
95.5	.26638	.25367	.23993	.24458	.24016	.24066	.23153	.21855	.22715	.21747	.22178	1.76
96.5	.28038	.26605	.24992	.25593	.25042	.24918	.24072	.22733	.23616	.22646	.23164	1.84
97.5	.29406	.27740	.25811	.26567	.25917	.25502	.24782	.23442	.24299	.23324	.23975	1.97
98.5	.30742	.28764	.26433	.27360	.26633	.25806	.25267	.23957	.24751	.23746	.24602	2.15
99.5	.32047	.29674	.26849	.27965	.27187	.25825	.25519	.24268	.24965	.23897	.25042	2.39

*Figures for 1978 are preliminary.

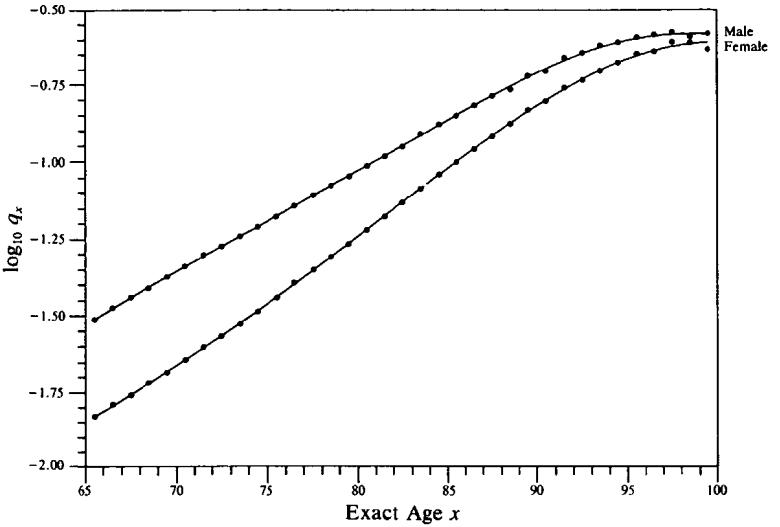

FIG. 4.—Common logarithm of 1977 medicare probabilities of death within one year, by sex, exact ages 65.5–99.5.

REFERENCES

1. BAYO, FRANCISCO. "Mortality of the Aged," *TSA*, XXIV (1972), 1.
2. BAYO, FRANCISCO, and SHIMAN, HOWARD. *Mortality of Charter Beneficiaries, 1970–77.* Actuarial Note No. 92. Baltimore, Md.: Department of Health, Education, and Welfare, 1977.
3. GREVILLE, T. N. E. "Methodology of the National and State Life Tables for the United States: 1969–71." In *U.S. Decennial Life Tables for 1969–71*, Vol. VII, No. 3. Rockville, Md.: National Center for Health Statistics, May, 1975.
4. HAMBRIGHT, THEA ZELMAN. *Comparability of Age on Death Certificate and Matching Census Record, United States, May–August, 1960.* Vital and Health Statistics, Ser. 2, No. 29. Rockville, Md.: National Center for Health Statistics, 1968.
5. MYERS, ROBERT J., and SHUDDE, LOUIS O. "Mortality Experience of Union Civil War Veterans," *TSA*, VII (1955), 63–68.
6. ROSENWAIKE, IRA. "A New Evaluation of United States Census Data on Extreme Aged," *Demography*, XVI, No. 2 (May, 1979), 279–88.
7. UNITED STATES DEPARTMENT OF COMMERCE, BUREAU OF THE CENSUS. *Estimates of the Population of the United States by Age, Sex, and Race: 1970 to 1977.* Current Population Reports, Ser. P-25, No. 721. Washington, D.C.: Government Printing Office, 1978.

DISCUSSION OF PRECEDING PAPER

DONALD M. KEITH:

Mr. Wilkin's paper gives Society members an unprecedented look at the upper end of the mortality curve for the United States population. The enviable volume of data available from his two sources provides us not only with a better idea of the shape of the curve itself, but also with some insight into mortality trends for the higher ages.

Perhaps the most startling observation is the pattern of mortality rates at advanced ages. In the construction of mortality tables, it usually has been assumed that, once the accident-related peak of the twenties is past, mortality rates rise with advancing age at a fairly constant rate until they reach 100 percent. Such an assumption is implicit in the Gompertz formula, and is often used at the highest ages, where data are sparse. It is now evident that this rate of increase begins to taper off around age 90 and that by age 100 the mortality rates are virtually constant. This was observed in 1972 in a paper by Francisco Bayo, "Mortality of the Aged" (*TSA*, XXIV, 1), also based on medicare data, and is confirmed by the much larger volume of data now accumulated. At what age and by what path do mortality rates eventually reach 100 percent? From what we now see, it seems that perhaps survivors simply dwindle to zero through the continued operation of a more or less constant force of mortality.

The data presented may also offer a clue to future long-range expectations for mortality improvement at the higher ages. The two currently popular theories are (1) that mortality improvement is following a pattern leading to a squaring of the survivorship curve within a fixed life span, and (2) that the life span is actually lengthening. Population tables show little change in the life span during the last half-century. Trends may be changing, however, and the mortality rates displayed in this paper at the extreme ages, which are nearly constant by age and are improving with time, combined with the ever increasing numbers reaching advanced age, would seem to hint at a gradual extension of the life span in the future. Mr. Wilkin notes that the data beyond age 100 are not sufficient to define the mortality curve reliably, but even the raw data for the eleven years of exposure combined would, I think, be of some interest and value to members.

Another important finding is the rapidity and pattern of mortality improvements between 1968 and 1978. The very fast improvement probably

can be attributed, at least in part, to the introduction of medicare in the United States in 1966. It is also clear that the rapid decline in deaths from heart and vascular diseases cannot continue indefinitely. Therefore, we may well expect the present pace of improvement to moderate before very long.

The medicare data in Table 4 of Mr. Wilkin's paper (which he feels are more reliable than the NCHS data in Table 5) indicate a pattern of improvement for males that is flat by age. Female mortality, on the other hand, shows increasing improvement rates to around age 80, after which improvement slows down. These patterns are both very similar to those exhibited by recent Canadian population data, although the Canadian improvement has been much slower. As the NCHS cause-of-death statistics show, mortality improvement has shifted from infectious diseases to degenerative diseases, and this shift has had considerable effect on the upper portion of the mortality curve. There is good reason to believe that these mortality improvements are shared to some extent by the segment of the population that has purchased annuities. This is a new trend in mortality improvement that has not yet been recognized in most of the projection scales used today.

We are indebted to Mr. Wilkin for his able presentation of such useful and interesting information. It is disappointing for many Canadian actuaries that similar data have not yet been drawn from comparable Canadian sources.

ROBERT J. MYERS:

Mr. Wilkin has presented an interesting and valuable analysis of the mortality of persons aged 65 and over, on the basis of the extensive medicare data. As he indicates, these data are, for a number of reasons, more accurate than general population data, as developed by the National Center for Health Statistics. As he also points out, however, the differences in the results are not too great and are explainable. Over the long run, it is likely that the results derived from medicare data will be even more accurate and useful.

The medicare data presented by Mr. Wilkin show probabilities of death that level off very rapidly at the oldest ages and become essentially flat near age 100. He points out that there are not sufficiently reliable data for centenarians to develop mortality rates for that category.

People are generally fascinated by the subject of centenarians. In a decade or two, the medicare data probably will give quite accurate information on this subject, because by then people will have been traced for a long period after having proven their ages reasonably well for social security adjudicative purposes.

I have some doubts about Mr. Wilkin's conclusion—or, rather, the results from his data—that probabilities of death level off and flatten out at about

age 100. This is, of course, in sharp contrast with the neat exponential nature of the results from Makeham's and Gompertz's laws, and with general reasoning. Moreover, in the studies made by the Office of the Actuary, in the Social Security Administration, as to the mortality of the so-called charter beneficiaries (to which Mr. Wilkin makes reference), there is some factual evidence to the contrary. In January, 1940, this group of some 32,000 persons had their ages closely verified as being neither too young nor too old, but rather, in a narrow range around age 65. This group, as it approached and exceeded age 100 in the mid-1970s and later, showed mortality significantly higher than that "expected" from medicare experience, with an apparently accelerating rate in the probabilities of death with increasing age.

I believe that it is very likely that the medicare data for the 1970s were considerably flawed at ages 90 and over, because the proof of age for this category was not too precise, the main criterion in many cases being that the person was at least age 65. To the extent that this is so, the mortality rates derived would be too low. As the material at the oldest ages becomes more reliable in the next decade or two, time will tell whether my belief is correct.

WILBUR M. BOLTON:

In publishing these data and this analysis, Mr. Wilkin has lived up to the motto of the Society by substituting facts for appearances. He has also earned the gratitude of members of committees responsible for the development of future mortality tables. I have one question and one qualified observation.

In Section IV, the author describes a method of projecting death rates at very high ages, after the ratio of q_x/q_{x-1} becomes less than 1.04. This method was used in preparation of the 1969–71 United States Decennial Life Tables. Was any similar adjustment applied to the graduated data in Tables 9–21?

If the answer to the question is negative, my observation is that the larger relative decline in female mortality in the 1968–78 decade seems to taper off in the high nineties. The table on page 48 was developed from the graduated ratios of female to male probabilities of death in Tables 9–18 of the paper. The secular trend correlation will have values close to 99 at ages where the ratio of female to male mortality is changing with a strong secular trend. Declining values of the secular trend correlation above age 95 suggest that random fluctuations from year to year tend to mask any trend at these ages. Finally, the progression of ratios above age 92 suggests that the ratio of female to male mortality should reach unity near age 105.

The author is to be thanked for publishing the data, which, hopefully, will be of value in the construction of population and other mortality tables in

Exact Age	Average Ratio, Female to Male 1968–77	Average Annual Decline in Ratio of Female to Male Mortality	Secular Trend Correlation
67.5	.48171	0.19%	57
72.5	.53168	0.50	96
77.5	.60943	0.73	97
82.5	.69693	0.76	97
87.5	.77763	0.64	92
92.5	.83657	0.36	94
93.5	.85020	0.32	84
94.5	.86432	0.28	67
95.5	.87839	0.23	50
96.5	.89212	0.18	30
97.5	.90543	0.15	13
98.5	.91839	0.12	4
99.5	.93126	0.10	1

the near future. I hope that the "average annual decline" shown in the table in this discussion is a real feature of the data and not an artifact of the method of graduation used in Tables 9–18 of the paper.

(AUTHOR'S REVIEW OF DISCUSSION)

JOHN C. WILKIN:

I thank Messrs. Keith, Myers, and Bolton for their thought-provoking comments. There is much interest in the mortality of the aged. Unfortunately, the topic is too broad to be covered in just one paper. Before starting on my paper, I had tentatively decided to divide my research into three broad areas. First would be the presentation of recent actual data on ages up to 100. I felt that the medicare data were particularly appropriate for this purpose because they were both reliable enough to be credible and voluminous enough to display trends. Second would be the development of information on centenarians. For this purpose, most of the large data sources would be ruled out because of unreliability. I am currently considering tests of reliability that can be applied to social security data on centenarians. Third would be an investigation into the shape of the mortality curve at the extreme ages. This investigation would rely on the data developed from the previous two, along with a consideration of the various "laws of mortality." Initially, of course, I did not know to what extent I would be able to develop good research in these areas or how much interest there would be in each of them, but now the discussants have encouraged me to proceed.

Concerning the recent trends in the mortality of the aged, Mr. Keith has mentioned that the rapid improvements experienced since 1968 are well above the average experienced during this century and are unlikely to continue indefinitely. As shown in Table 3 of my paper, improvements in mortality have fluctuated in the past and should be expected to do so in the future. The table shows a similar period of rapid improvement in mortality from 1936 to 1954, although in that period the aged did not share in the improvements to the same extent as in the period since 1968.

In our work in the Office of the Actuary in the Social Security Administration, we make population projections for the analysis of potential future financial commitments of the OASDI program. The most recent projections were based on the assumption that the mortality improvement of the aged would decelerate from the 1.9 percent annual rate representative of recent experience to an ultimate annual rate of about 0.4 percent, which is roughly one-half the average annual rate of improvement experienced from 1900 to 1978.[1]

As I have stated, my original intention was to present data just on the rate of recent improvements in the mortality of the aged. However, because of the interest that has been generated on the shape of the mortality curve at the very high ages, I now feel that a few additional comments are appropriate.

I agree with Mr. Keith's observation that there is little basis for the recently popular theory of "squaring the survivorship curve." Such a pattern would require a combination of improvements in mortality up to some particular age and a worsening in mortality at all higher ages. The medicare data show that recent mortality improvements are being observed at all ages, not just at younger ages. I believe that future improvements in mortality will depend upon such factors as the isolation and treatment of causes of disease, the presence of environmental pollutants, and the extent to which people assume responsibility for their own health. These factors will affect various causes of death to different degrees. To the extent that various causes of death affect different ages to different degrees, there will be variation in the rate of improvement by age.

One of the old, and perhaps most popular, theories of mortality is Gompertz's law. The Gompertz curve has been able to fit observed mortality between ages 30 and 90 remarkably well for many years. Because of the usual scantiness of observed data above age 90, and because of the generally small effect that mortality rates past age 90 have on actuarial evaluations,

[1] Joseph F. Faber and John C. Wilkin, *Social Security Area Population Projections*, Actuarial Study No. 85 (Baltimore, Md.: Department of Health and Human Services, July, 1981).

many actuaries have used the Gompertz curve to extrapolate mortality to the end of the life table. As Mr. Myers has pointed out, data on mortality of persons over age 90 has been accumulating and is likely to become more reliable with time. Mr. Myers has noted appropriately that the pattern of mortality displayed by the medicare data at ages near 100 deviates much further from the Gompertz curve than have other data, and that perhaps a closer look is warranted. The first step in comparing the mortality pattern exhibited by actual data with that expected from Gompertz's law is to determine just exactly what is implied by Gompertz's law. It is obvious that the ratio of the force of mortality between successive ages is constant (and equal to the Gompertz constant c). The pattern of the corresponding ratios of the probabilities of death (q_x) is not so obvious.

In order to determine just how quickly the medicare data is deviating from the Gompertz curve, I have prepared Table 1, below. This table shows the medicare data for calendar year 1977 graduated by two methods. The first method is the Whittaker-Henderson type B graduation that was displayed in Table 18 of my paper. The second method converts the expression for $1 - q_x$ in terms of the Gompertz parameters c and g into a straight line by the application of logarithms. The values of the Gompertz constants are then derived by the method of least squares applied to the data from age 65.5 to age 84.5. The resulting Gompertz curve is used to calculate the values of q_x for all ages 65.5–99.5. The Gompertz constant c used in Table 1 is 1.0809 for males and 1.1027 for females. From Table 1 it can be seen that the ratio of the probabilities of death are lower than c for all ages 65.5–99.5. Extrapolation of this Gompertz curve shows that the ratios of the probabilities of death approach c with decreasing age and approach 1.0 with increasing age.

For males, Table 1 shows that, as expected, the probabilities of death for ages 65.5–84.5 are about the same under either graduation. The values of $q_{89.5}$ are also very close, showing that the medicare data are following a Gompertz curve past age 84.5. However, above age 90 the Whittaker-Henderson graduation begins to deviate from the Gompertz curve at an increasing rate. The Whittaker-Henderson graduation value of $q_{94.5}$ is 7 percent below the Gompertz value, and the Whittaker-Henderson graduation value of $q_{99.5}$ is 29 percent below the Gompertz value. A similar pattern is displayed by the data for females, where the Whittaker-Henderson graduation value of $q_{99.5}$ is 27 percent below the Gompertz value.

There is a well-known tendency for persons at advanced ages to overstate their age. To the extent that this bias could be present in data, the reliability of the data must be questioned. This bias would result in the observed group of lives at the advanced ages having an average age that was lower than

TABLE 1

TOTAL MEDICARE ENROLLEE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE, SEX, AND METHOD OF GRADUATION, AND SELECTED RATIOS: CALENDAR YEAR 1977

EXACT AGE	WHITTAKER-HENDERSON GRADUATION				GOMPERTZ GRADUATION				RATIO OF WHITTAKER-HENDERSON TO GOMPERTZ	
	Male	Female	Ratio to Preceding Age		Male	Female	Ratio to Preceding Age		Male	Female
			Male	Female			Male	Female		
65.5	0.03088	0.01482	.....	.....	0.03119	0.01417	.....	.....	0.9900	1.0457
66.5	0.03356	0.01613	1.0868	1.0884	0.03367	0.01562	1.0796	1.1019	0.9966	1.0328
67.5	0.03629	0.01754	1.0813	1.0874	0.03635	0.01721	1.0795	1.1018	0.9984	1.0193
68.5	0.03922	0.01910	1.0807	1.0889	0.03923	0.01896	1.0793	1.1018	0.9997	1.0074
69.5	0.04248	0.02082	1.0831	1.0901	0.04234	0.02089	1.0792	1.1016	1.0033	0.9968
70.5	0.04595	0.02278	1.0817	1.0941	0.04569	0.02301	1.0791	1.1015	1.0057	0.9901
71.5	0.04957	0.02493	1.0788	1.0944	0.04930	0.02534	1.0789	1.1014	1.0056	0.9838
72.5	0.05336	0.02723	1.0765	1.0923	0.05318	0.02791	1.0788	1.1013	1.0034	0.9758
73.5	0.05745	0.02978	1.0766	1.0936	0.05736	0.03073	1.0786	1.1011	1.0016	0.9691
74.5	0.06192	0.03275	1.0778	1.0997	0.06185	0.03383	1.0784	1.1010	1.0011	0.9680
75.5	0.06688	0.03623	1.0801	1.1063	0.06669	0.03724	1.0782	1.1008	1.0029	0.9728
76.5	0.07225	0.04021	1.0803	1.1099	0.07189	0.04099	1.0780	1.1006	1.0050	0.9810
77.5	0.07782	0.04450	1.0771	1.1067	0.07748	0.04510	1.0777	1.1004	1.0044	0.9866
78.5	0.08353	0.04914	1.0734	1.1043	0.08348	0.04962	1.0775	1.1001	1.0006	0.9903
79.5	0.08954	0.05425	1.0720	1.1040	0.08992	0.05458	1.0772	1.0999	0.9957	0.9940

TABLE 1—*Continued*

Exact Age	Whittaker-Henderson Graduation				Gompertz Graduation				Ratio of Whittaker-Henderson to Gompertz	
	Male	Female	Ratio to Preceding Age		Male	Female	Ratio to Preceding Age		Male	Female
			Male	Female			Male	Female		
80.5	0.09615	0.06001	1.0738	1.1062	0.09684	0.06001	1.0769	1.0996	0.9929	1.0000
81.5	0.10357	0.06653	1.0772	1.1086	0.10426	0.06597	1.0766	1.0993	0.9934	1.0085
82.5	0.11180	0.07382	1.0795	1.1096	0.11220	0.07249	1.0762	1.0989	0.9964	1.0183
83.5	0.12072	0.08177	1.0798	1.1077	0.12072	0.07964	1.0759	1.0985	1.0000	1.0268
84.5	0.13011	0.09026	1.0778	1.1038	0.12982	0.08745	1.0755	1.0981	1.0022	1.0322
85.5	0.13991	0.09930	1.0753	1.1002	0.13957	0.09599	1.0750	1.0976	1.0025	1.0345
86.5	0.15020	0.10910	1.0735	1.0987	0.14997	0.10531	1.0746	1.0971	1.0015	1.0360
87.5	0.16113	0.11982	1.0728	1.0983	0.16108	0.11548	1.0741	1.0966	1.0003	1.0376
88.5	0.17280	0.13147	1.0724	1.0972	0.17292	0.12656	1.0735	1.0959	0.9993	1.0388
89.5	0.18523	0.14382	1.0719	1.0939	0.18554	0.13862	1.0729	1.0953	0.9984	1.0375
90.5	0.19803	0.15655	1.0691	1.0885	0.19895	0.15172	1.0723	1.0945	0.9954	1.0318
91.5	0.21075	0.16947	1.0642	1.0825	0.21321	0.16594	1.0717	1.0937	0.9885	1.0213
92.5	0.22273	0.18232	1.0568	1.0758	0.22834	0.18134	1.0709	1.0928	0.9754	1.0054
93.5	0.23345	0.19486	1.0481	1.0688	0.24436	0.19800	1.0702	1.0918	0.9554	0.9842
94.5	0.24247	0.20675	1.0386	1.0610	0.26131	0.21597	1.0693	1.0908	0.9279	0.9573
95.5	0.24951	0.21747	1.0290	1.0519	0.27920	0.23533	1.0685	1.0896	0.8937	0.9241
96.5	0.25437	0.22646	1.0195	1.0413	0.29805	0.25612	1.0675	1.0883	0.8535	0.8842
97.5	0.25693	0.23324	1.0101	1.0299	0.31787	0.27839	1.0665	1.0870	0.8083	0.8378
98.5	0.25714	0.23746	1.0008	1.0181	0.33867	0.30217	1.0654	1.0854	0.7593	0.7858
99.5	0.25501	0.23897	0.9917	1.0064	0.36044	0.32749	1.0643	1.0838	0.7075	0.7297

stated, and the observed mortality probably would be lower than the true value.

Mr. Myers points out that the proof of exact age for persons over age 90 in the 1970s was not precise in all cases. In particular, those persons over age 65 who were not insured under social security near the inception of the medicare program could qualify for medicare benefits merely by proving that they were over age 65. To test the fit of the Gompertz curve with more reliable data, the analysis shown in Table 1 of this review section is duplicated in Table 2, below, using insured lives only—that is, those persons who were also eligible to receive monthly cash benefits under either the social security program or the railroad retirement program, most of whom had shown proof of age near age 65. The number of deaths at ages 85 and over among the insured lives was 257,000, or 83 percent of the 311,000 deaths at ages 85 and over under the total medicare experience. The experience of the insured lives shows less of a tendency to flatten out after age 90 than the experience of all medicare lives. However, the pattern of mortality still shows an increasing deviation from the Gompertz curve after age 90, and by age 99.5 the actual probabilities of death are 17 percent and 15 percent below those of the Gompertz curve, for males and females respectively.

The use of the Gompertz curve to graduate mortality involves the implicit and often overlooked assumption that the group of lives being studied is sufficiently homogeneous to be represented by a single curve. It should be recognized also that if the mortality of each of a series of homogeneous subgroups of lives could be represented by a Gompertz curve, it does not immediately follow that all of them together could also be represented by a Gompertz curve. From general reasoning, one can conclude that the weighted average of a series of exponential curves, all of which are producing small probabilities of death, would also be very close to exponential. However, as the probabilities of death for the subgroup with the worst mortality began to rise, and its survivors decreased, its relative weighting in the overall curve would also decline. Thus, the healthier subgroups would become more preponderant, and the mortality of the aggregate group would tend to increase at a rate that is less than exponential (and could actually decline under unusual circumstances).

In order to test this hypothesis, I further limited the analysis to insured whites, thus achieving more homogeneity in the data, as shown in Table 3. There were 241,000 deaths at ages 85 and over in this experience. The resulting mortality rates above age 90 are slightly closer to those expected from the Gompertz extrapolation; nonetheless, the observed pattern still displays an increasing deviation from the Gompertz curve. At age 99.5, the actual probabilities of death are 14 percent below those of the Gompertz curve for both males and females.

TABLE 2

INSURED MEDICARE ENROLLEE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE, SEX, AND METHOD OF GRADUATION, AND SELECTED RATIOS: CALENDAR YEAR 1977

EXACT AGE	WHITTAKER-HENDERSON GRADUATION				GOMPERTZ GRADUATION				RATIO OF WHITTAKER-HENDERSON TO GOMPERTZ	
	Male	Female	Ratio to Preceding Age		Male	Female	Ratio to Preceding Age		Male	Female
			Male	Female			Male	Female		
65.5	0.03079	0.01466	.....	.....	0.03098	0.01421	.....	.....	0.9938	1.0316
66.5	0.03341	0.01598	1.0851	1.0900	0.03346	0.01566	1.0801	1.1021	0.9984	1.0203
67.5	0.03610	0.01736	1.0805	1.0864	0.03614	0.01726	1.0800	1.1020	0.9989	1.0059
68.5	0.03900	0.01883	1.0803	1.0847	0.03903	0.01902	1.0799	1.1019	0.9994	0.9902
69.5	0.04224	0.02040	1.0831	1.0834	0.04214	0.02095	1.0797	1.1018	1.0025	0.9736
70.5	0.04570	0.02222	1.0819	1.0892	0.04549	0.02308	1.0796	1.1017	1.0046	0.9626
71.5	0.04931	0.02455	1.0790	1.1049	0.04910	0.02543	1.0794	1.1015	1.0042	0.9655
72.5	0.05309	0.02771	1.0767	1.1287	0.05300	0.02800	1.0793	1.1014	1.0018	0.9895
73.5	0.05718	0.03174	1.0770	1.1454	0.05719	0.03084	1.0791	1.1013	0.9999	1.0292
74.5	0.06168	0.03575	1.0787	1.1263	0.06170	0.03396	1.0789	1.1011	0.9997	1.0528
75.5	0.06669	0.03829	1.0812	1.0710	0.06656	0.03739	1.0787	1.1009	1.0020	1.0242
76.5	0.07211	0.04076	1.0813	1.0645	0.07178	0.04115	1.0785	1.1007	1.0046	0.9905
77.5	0.07772	0.04408	1.0778	1.0815	0.07739	0.04529	1.0782	1.1005	1.0042	0.9733
78.5	0.08347	0.04838	1.0740	1.0975	0.08343	0.04983	1.0780	1.1003	1.0005	0.9710
79.5	0.08952	0.05353	1.0725	1.1064	0.08991	0.05481	1.0777	1.1000	0.9957	0.9766

TABLE 2—*Continued*

Exact Age	Whittaker-Henderson Graduation				Gompertz Graduation				Ratio of Whittaker-Henderson to Gompertz	
	Male	Female	Ratio to Preceding Age		Male	Female	Ratio to Preceding Age		Male	Female
			Male	Female			Male	Female		
80.5	0.09618	0.05942	1.0744	1.1100	0.09687	0.06027	1.0774	1.0997	0.9929	0.9858
81.5	0.10365	0.06602	1.0777	1.1111	0.10433	0.06626	1.0771	1.0994	0.9934	0.9963
82.5	0.11200	0.07334	1.0806	1.1109	0.11234	0.07283	1.0767	1.0990	0.9970	1.0070
83.5	0.12105	0.08129	1.0808	1.1084	0.12091	0.08001	1.0763	1.0986	1.0011	1.0160
84.5	0.13057	0.08984	1.0786	1.1052	0.13009	0.08787	1.0759	1.0982	1.0037	1.0224
85.5	0.14053	0.09901	1.0763	1.1021	0.13992	0.09646	1.0755	1.0977	1.0044	1.0265
86.5	0.15104	0.10899	1.0748	1.1008	0.15041	0.10584	1.0750	1.0972	1.0042	1.0298
87.5	0.16232	0.11993	1.0747	1.1004	0.16162	0.11607	1.0745	1.0967	1.0043	1.0333
88.5	0.17450	0.13192	1.0750	1.1000	0.17357	0.12721	1.0740	1.0960	1.0053	1.0370
89.5	0.18757	0.14482	1.0749	1.0978	0.18631	0.13934	1.0734	1.0954	1.0068	1.0393
90.5	0.20118	0.15837	1.0726	1.0936	0.19986	0.15253	1.0727	1.0946	1.0066	1.0383
91.5	0.21495	0.17248	1.0684	1.0891	0.21427	0.16683	1.0721	1.0938	1.0032	1.0339
92.5	0.22843	0.18698	1.0627	1.0841	0.22955	0.18233	1.0713	1.0929	0.9951	1.0255
93.5	0.24129	0.20176	1.0563	1.0790	0.24575	0.19909	1.0706	1.0919	0.9819	1.0134
94.5	0.25335	0.21663	1.0500	1.0737	0.26288	0.21717	1.0697	1.0908	0.9638	0.9975
95.5	0.26455	0.23126	1.0442	1.0675	0.28097	0.23664	1.0688	1.0897	0.9416	0.9773
96.5	0.27488	0.24529	1.0390	1.0607	0.30003	0.25755	1.0679	1.0884	0.9162	0.9524
97.5	0.28436	0.25841	1.0345	1.0535	0.32008	0.27995	1.0668	1.0870	0.8884	0.9231
98.5	0.29303	0.27038	1.0305	1.0463	0.34112	0.30387	1.0657	1.0854	0.8590	0.8898
99.5	0.30090	0.28114	1.0269	1.0398	0.36314	0.32933	1.0645	1.0838	0.8286	0.8537

TABLE 3

INSURED WHITE MEDICARE ENROLLEE PROBABILITIES OF DEATH WITHIN ONE YEAR, BY AGE, SEX, AND METHOD OF GRADUATION, AND SELECTED RATIOS: CALENDAR YEAR 1977

EXACT AGE	WHITTAKER-HENDERSON GRADUATION				GOMPERTZ GRADUATION				RATIO OF WHITTAKER-HENDERSON TO GOMPERTZ	
	Male	Female	Ratio to Preceding Age		Male	Female	Ratio to Preceding Age		Male	Female
			Male	Female			Male	Female		
65.5	0.03043	0.01427	.....	.....	0.03056	0.01352	.....	.....	0.9957	1.0556
66.5	0.03295	0.01548	1.0828	1.0848	0.03304	0.01493	1.0811	1.1042	0.9972	1.0371
67.5	0.03561	0.01682	1.0807	1.0866	0.03572	0.01648	1.0810	1.1042	0.9970	1.0205
68.5	0.03852	0.01829	1.0817	1.0874	0.03861	0.01820	1.0809	1.1041	0.9977	1.0051
69.5	0.04178	0.01993	1.0846	1.0897	0.04173	0.02009	1.0808	1.1040	1.0013	0.9921
70.5	0.04529	0.02184	1.0840	1.0958	0.04509	0.02218	1.0806	1.1039	1.0044	0.9849
71.5	0.04895	0.02398	1.0808	1.0980	0.04872	0.02448	1.0805	1.1037	1.0047	0.9798
72.5	0.05280	0.02629	1.0787	1.0963	0.05263	0.02701	1.0803	1.1036	1.0032	0.9733
73.5	0.05692	0.02886	1.0780	1.0978	0.05685	0.02981	1.0801	1.1034	1.0012	0.9683
74.5	0.06146	0.03183	1.0798	1.1029	0.06139	0.03288	1.0799	1.1033	1.0011	0.9680
75.5	0.06646	0.03528	1.0814	1.1084	0.06629	0.03627	1.0797	1.1031	1.0026	0.9726
76.5	0.07187	0.03924	1.0814	1.1122	0.07156	0.04001	1.0795	1.1029	1.0043	0.9808
77.5	0.07752	0.04354	1.0786	1.1096	0.07723	0.04411	1.0793	1.1027	1.0037	0.9870
78.5	0.08339	0.04820	1.0757	1.1070	0.08333	0.04863	1.0790	1.1024	1.0007	0.9911
79.5	0.08958	0.05333	1.0742	1.1064	0.08989	0.05360	1.0787	1.1022	0.9966	0.9949

TABLE 3—*Continued*

Exact Age	Whittaker-Henderson Graduation				Gompertz Graduation				Ratio of Whittaker-Henderson to Gompertz	
	Male	Female	Ratio to Preceding Age		Male	Female	Ratio to Preceding Age		Male	Female
			Male	Female			Male	Female		
80.5	0.09635	0.05910	1.0756	1.1082	0.09694	0.05906	1.0784	1.1019	0.9940	1.0006
81.5	0.10389	0.06564	1.0783	1.1107	0.10450	0.06506	1.0781	1.1015	0.9941	1.0089
82.5	0.11225	0.07299	1.0805	1.1120	0.11262	0.07164	1.0777	1.1012	0.9967	1.0188
83.5	0.12130	0.08106	1.0806	1.1106	0.12133	0.07886	1.0773	1.1008	0.9998	1.0279
84.5	0.13083	0.08977	1.0786	1.1075	0.13066	0.08677	1.0769	1.1003	1.0013	1.0345
85.5	0.14084	0.09915	1.0765	1.1045	0.14064	0.09544	1.0764	1.0999	1.0014	1.0389
86.5	0.15149	0.10934	1.0756	1.1028	0.15132	0.10492	1.0759	1.0993	1.0011	1.0421
87.5	0.16301	0.12051	1.0760	1.1022	0.16274	0.11528	1.0754	1.0987	1.0017	1.0454
88.5	0.17553	0.13274	1.0768	1.1015	0.17492	0.12659	1.0749	1.0981	1.0035	1.0486
89.5	0.18904	0.14586	1.0770	1.0988	0.18791	0.13891	1.0743	1.0974	1.0060	1.0500
90.5	0.20319	0.15964	1.0749	1.0945	0.20174	0.15234	1.0736	1.0966	1.0072	1.0480
91.5	0.21762	0.17394	1.0710	1.0896	0.21644	0.16692	1.0729	1.0958	1.0054	1.0420
92.5	0.23191	0.18865	1.0657	1.0846	0.23205	0.18275	1.0721	1.0948	0.9994	1.0323
93.5	0.24577	0.20369	1.0598	1.0797	0.24861	0.19989	1.0713	1.0938	0.9886	1.0190
94.5	0.25902	0.21886	1.0539	1.0745	0.26612	0.21841	1.0705	1.0927	0.9733	1.0021
95.5	0.27163	0.23387	1.0487	1.0686	0.28462	0.23838	1.0695	1.0914	0.9544	0.9811
96.5	0.28358	0.24836	1.0440	1.0620	0.30412	0.25985	1.0685	1.0901	0.9325	0.9558
97.5	0.29489	0.26199	1.0399	1.0549	0.32464	0.28288	1.0674	1.0886	0.9084	0.9262
98.5	0.30558	0.27455	1.0363	1.0479	0.34616	0.30749	1.0663	1.0870	0.8828	0.8929
99.5	0.31568	0.28597	1.0331	1.0416	0.36869	0.33371	1.0651	1.0853	0.8562	0.8569

A similar analysis of the data for insured nonwhites shows mixed results. At age 99.5, the actual probability of death is 14 percent below that of the Gompertz curve for females. Thus, both of the more homogeneous subgroups (white insured females and nonwhite insured females) are closer to a Gompertz curve than is the total group (total insured females). However, the actual probability of death at age 99.5 for the insured nonwhite male subgroup is 30 percent below the expected Gompertz value, which is a much larger deviation than the 17 percent deviation shown by the total group (total insured males).

Suspecting that these mixed results could be the result of less reliability in the data on nonwhite lives, I continued the analysis by reviewing the data on insured whites for both sexes combined. Each subgroup, males and females, should be of comparable reliability. Surprisingly, the actual probability of death at age 99.5 for total insured whites was only 7 percent below the expected Gompertz value, only one-half the deviation for each sex separately. In each case where I combined nonhomogeneous subgroups into a total, the resulting Gompertz constant c was between the values for the separate subgroups.

It appears that combining nonhomogeneous subgroups will often result in a total group that does not deviate from a Gompertz curve by more than both subgroups. Thus, the depressing effect on the increases in mortality of the total group, caused by the shifting of the relative sizes of the subgroups, seems to occur gradually over all ages, not abruptly at the very high ages. I believe that lack of homogeneity still should concern actuaries; I suspect, however, that it may become significant only if the group with the lower mortality is relatively small, has significantly lower mortality, and has a lower value of the Gompertz constant c.

Just as it is valuable to compare the trends in the mortality of the aged as shown by medicare data with those shown by NCHS data, it is also valuable to compare the shape of the mortality curve as shown by medicare data with that shown by NCHS data. This is a little more difficult, because NCHS publishes death rates only up to the age group 85 and over. Since 1951, however, NCHS has published the number of deaths in each year by single years of age for ages 85 and over. By using an "extinct cohort" method, with deaths available through 1978, we calculated probabilities of death by single years of age for the fifteen-year observation period 1953–67. This method estimates the probabilities of death for a calendar year y by the following formula:

$$q_x^y = D_x^y / P_x^y ,$$

where D_x^y is the number of deaths during calendar year y at age last birthday x and P_x^y is the cohort size, which is estimated as

$$\sum_{t=0}^{1978-y} D_{x+t}^{y+t} + \sum_{t=1979-y}^{\infty} D_{x+t}^{1978} .$$

The probabilities of death for each age for the entire fifteen-year period were obtained by adding all deaths during the observation period and then dividing by the sum of estimated cohort sizes for each year in the observation period. The second term in the above expression for cohort size is clearly a rough estimate of future deaths in the cohort after 1978, based on the deaths in 1978. This method is likely to underestimate the actual number of deaths, because, in general, at the higher ages, the number of persons attaining each age has been increasing each year. The rates produced by the extinct cohort method have an advantage over the rates normally produced by NCHS in that there is consistency between numerator and denominator.

The probabilities of death calculated for this analysis are based on about 2.7 million deaths between ages 85 and 99 that occurred in the period 1953–67. This large volume of data produces rates that do not fluctuate unduly and therefore are not affected much by graduation. Table 3 in my paper shows that the period 1953–67 was one of relatively little change in mortality. But even if mortality had decreased rapidly during the period, the use of the overall period rates for detecting the shape of the mortality curve would be justified if the decrease was fairly uniform by age.

Table 4, below, shows the NCHS probabilities of death using the extinct cohort method by sex for ages 85–99. Because no data exist before age 85, there is too little data to determine reliably a Gompertz curve below age 90 that could be extrapolated past age 90. The data show that after age 90 the ratios of successive probabilities of death decline rapidly, thus appearing to deviate from a Gompertz curve. If mortality rates follow a Gompertz curve, then the log of the colog of the probability of survival will follow a straight line. A plot of this function, based on the NCHS data shown in Table 4, is shown in Figure 1. From this graph it is obvious that after age 90 the mortality pattern exhibited by the NCHS data deviates progressively more from the Gompertz curve with increasing age. However, there is still the question of the reliability of the age reporting at these high ages. This is especially true for Vital Statistics, where the statement of age is obtained shortly after the death, not many years earlier as in the medicare data, where there is a higher chance of its being accurate.

TABLE 4

NCHS PROBABILITIES OF DEATH USING EXTINCT COHORT METHOD WITH DEATHS THROUGH 1978, BY AGE AND SEX, AND SELECTED RATIOS: CALENDAR YEARS 1953–1967

EXACT AGE	UNGRADUATED		GRADUATED				
	Male	Female	Male	Female	Ratio of Female to Male	Ratio to Preceding Age	
						Male	Female
85	0.15735	0.12692	0.15733	0.12694	0.80689	.....	.....
86	0.16936	0.13782	0.16977	0.13788	0.81213	1.0791	1.0861
87	0.18376	0.15006	0.18224	0.14938	0.81970	1.0734	1.0834
88	0.19234	0.16035	0.19466	0.16154	0.82989	1.0682	1.0814
89	0.20840	0.17392	0.20771	0.17485	0.84178	1.0671	1.0823
90	0.22408	0.19365	0.22103	0.18857	0.85315	1.0641	1.0785
91	0.23096	0.19697	0.23453	0.20188	0.86079	1.0611	1.0706
92	0.24838	0.21648	0.24899	0.21651	0.86956	1.0617	1.0725
93	0.26582	0.23348	0.26424	0.23243	0.87960	1.0613	1.0735
94	0.27984	0.24994	0.27944	0.24870	0.88998	1.0575	1.0700
95	0.29108	0.26381	0.29364	0.26439	0.90040	1.0508	1.0631
96	0.30757	0.27725	0.30586	0.27889	0.91182	1.0416	1.0548
97	0.31942	0.29331	0.31506	0.29157	0.92545	1.0301	1.0455
98	0.31958	0.30228	0.32048	0.30173	0.94149	1.0172	1.0349
99	0.31672	0.30266	0.32189	0.30886	0.95954	1.0044	1.0236

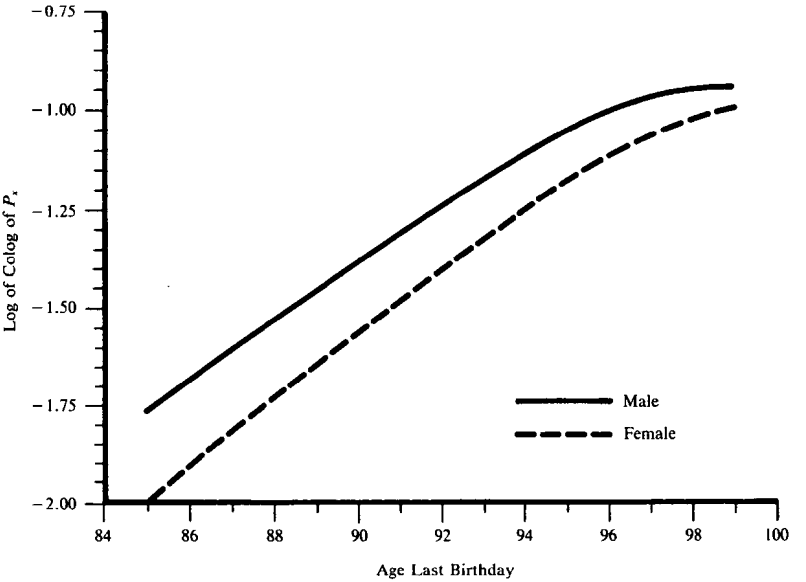

FIG. 1.—Log of colog of P_x based upon NCHS deaths for calendar years 1953–67 using extinct cohort method with deaths through 1978.

As Mr. Myers has stated, social security's charter beneficiaries provide a very reliable source of data for the aged. On the other hand, the small size of this group produces uncertainty, because of the chance of statistical fluctuations, and makes it impossible to examine trends. The latest analysis done in this area showed the number of surviving old-age charter beneficiaries by year of birth and sex at various dates. The charter beneficiaries are limited to dates of birth during the years 1872–74 and January, 1875. The number of survivors was shown as of February 1, 1940, December 1, 1964, January 1, 1970, and each January 1 from 1974 through 1977. Table 5 of this section shows the total number surviving at these dates. I have also added the number surviving on January 1, 1978 and 1979. There were 31,557 original old-age charter beneficiaries on February 1, 1940. As of January 1, 1979, there were only 4 living: one male born during 1873, who was 105, and two males and one female born during 1874, who were 104.

Separately for each year of birth and sex, I fitted a Gompertz curve to the number living on February 1, 1940, December 1, 1964, and January 1, 1970. The expected number living according to the Gompertz curve was then calculated for each January 1 from 1974 through 1979. The expected number living on these dates was also calculated on the basis of the total medicare experience for 1974. Because probabilities of death were not calculated above age 99.5 from medicare data, the probabilities of death at age 99.5 were used for all ages over 99.5. These expected numbers of living, along with the actual number, are also shown in Table 5. This table substantiates Mr. Myers's statement that the charter beneficiaries' mortality

TABLE 5

ACTUAL AND EXPECTED NUMBER OF SOCIAL SECURITY LIVING OLD-AGE CHARTER BENEFICIARIES AT SELECTED DATES

DATE	ACTUAL	EXPECTED BASED ON MEDICARE DATA		EXPECTED BASED ON GOMPERTZ'S LAW	
	Number	Number	Ratio of Actual to Expected	Number	Ratio of Actual to Expected
February 1, 1940	31,557	.....	.....	.....	.....
December 1, 1964	1,874	.....	.....	.....	.....
January 1, 1970	373	.....	.....	.....	.....
January 1, 1974	74	109	68%	61	121%
January 1, 1975	50	80	62	34	147
January 1, 1976	29	59	49	20	145
January 1, 1977	18	43	42	9	200
January 1, 1978	10	32	31	5	200
January 1, 1979	4	23	17	2	200

experience is significantly higher than that expected from medicare experience, and that the deviation increases with age. On January 1, 1979, the actual number of charter beneficiaries living around age 104 was only 17 percent of that "expected" based on the 1974 medicare data. It must be noted, however, that the "expected" number of living based on medicare data involved probabilities of death above age 99.5, and it was assumed that the mortality curve had flattened at age 99.5. On the other hand, the experience of charter beneficiaries also deviates from the Gompertz curve, and the deviation increases with age. On January 1, 1979, the actual number of living charter beneficiaries was 200 percent of that "expected" based on the Gompertz curve.

I conclude from this analysis that Gompertz's law does not accurately represent the observed overall pattern of mortality above age 90, and that the observed deviation from Gompertz's law could result from three separate causes: the fact that at the extreme old ages, mortality does not increase geometrically; the lack of reliability of the data; and, to a lesser extent, the lack of homogeneity of the group under study.

The answer to Mr. Bolton's question is that the graduated rates shown in all the tables are the result of a Whittaker-Henderson type B graduation with a smoothing coefficient of 500,000. The average exposure per age in 1977 was about 270,000 for males and about 400,000 for females. Therefore, I believe that the average annual declines are representative of the data. The comments regarding the method for projecting death rates relate solely to the construction of the *U.S. Decennial Life Tables for 1969–71*. The comments were made to emphasize that there is still much doubt about the actual pattern of mortality at the very high ages. Nevertheless, actuaries are often faced with the problem of ending a life table. This necessitates not only extrapolation from actual data, but also the substitution of personal preferences where the data are unreliable. Even though the actuary who prepares a life table is ultimately responsible for the final product, he can take comfort in knowing that his opinions are shared by others. The United States Life Table for 1969–71 ends at the age interval 109–10. The determination of the rates at the very high ages is a problem that had to be addressed. The procedure described was developed by Steven F. McKay in conjunction with Francisco R. Bayo and T. N. E. Greville. Just as these actuaries decided to modify or ignore the available data in ending the 1969–71 United States Life Tables, so may other actuaries who attempt to use the data that I have presented here.

Mr. Bolton's table showing the average annual decline of the ratio of female to male probabilities of death provides a very clever way of analyzing the relative trends of female and male mortality rates.