Predictors of Mortality in 2,249 Nonagenarians—The Danish 1905-Cohort Survey

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OBJECTIVES: To elucidate whether well-known predictions of mortality are reduced or even reversed, or whether mortality is a stochastic process in the oldest old.

DESIGN: A multidimensional survey of the Danish 1905 cohort conducted in 1998 with follow-up of vital status after 15 months.

SETTING: Denmark.

PARTICIPANTS: All Danes born in 1905, irrespective of physical and mental status were approached. Two thousand two hundred sixty-two persons of 3,600 participated in this survey.

MEASUREMENTS: Professional interviewers collected data concerning sociodemographic factors, smoking, alcohol consumption, body mass index, physical and cognitive performance, and health during a visit at the participant's residency. Cox regression models were used to evaluate predictors of mortality.

RESULTS: Five hundred seventy-nine (25.7%) of the 2,249 participants eligible for the analysis died during the 15 months follow-up. Multivariate analyses showed that marital status, education, smoking, obesity, consumption of alcohol, and number of self-reported diseases were not associated with mortality. Disability and cognitive impairment were significant risk factors in men and women. In addition poor self-rated health was associated with an increase in mortality in women.

CONCLUSION: In the oldest old, several known predictors of mortality, such as sociodemographic factors, smoking, and obesity, have lost their importance, but a high disability level, poor physical and cognitive performance, and self-rated health (women only), predict mortality, which shows that mortality in the oldest old is not a stochastic process. **J Am Geriatr Soc 51:1365–1373, 2003.**

Key words: predictors; mortality; nonagenarians; aged 80 and older; functional status

Most studies have shown that several sociodemographic factors, such as marital status, education,[1–7] smoking,[1,2,8,9] alcohol,[2,6,10–14] physical and cognitive abilities,[1,6,9,15–17] and self-rated health,[1,6,15,18,19] predict mortality in younger elderly, but some surveys have indicated that the relationship between certain risk factors and mortality is different in the oldest old.[3,16,20–23] It could also be suggested that survival in the oldest old is a stochastic process, which means that mortality is essentially independent of individual characteristics and primarily a function of chance events outside the individual's control. In this case, one would not expect to find any significant predictors of survival in the oldest old,[22] but predictors of mortality in nonagenarians are still uninvestigated, because only a limited number of surveys have been conducted, and sample sizes have generally been small.

The objective of this study was to examine the effect of well-known predictors of mortality on 2,249 fairly nonselected nonagenarians. The focus of this study was to elucidate whether known or suspected predictors of mortality in younger elderly are also important in the oldest old, whether these predictors lose their importance or their effect is reversed, or whether mortality in the oldest old seems to be a stochastic process.

METHODS

A detailed description of the survey and the study population has previously been published.[24] In brief, the main survey took place from August to October 1998 and was preceded by a feasibility study in the spring of 1998

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including 200 persons. All Danes born in 1905 and living in Denmark, a total of 3,600 persons, were approached irrespective of residence, health, and cognitive status. The cohort members were traced through the Danish Civil Registration System (DCRS), which keeps a record of all those living in Denmark since 1968. The register contains information on name, date of birth, residence, marriage, vital status, and children. Each person has a unique and permanent 10-digit personal identification number (called the CPR number), which is the key to individual information in all official registries covering the Danish population. The DCRS covers the total Danish population, because the CPR number is a prerequisite for obtaining any form of social benefit, health care, education, or salary from an employer. This valid, virtually complete, and permanently updated Danish registration system is a major strength of the 1905-Cohort Survey. The system ensures complete identification of the participants, provided they have not emigrated (a negligible problem in nonagenarians). The DCRS also keeps a record on date of death for deceased persons.[25,26]

Interviewers from the Danish National Institute of Social Research, who visited the participants at their residence, conducted the survey. After an invitation to participate in the survey was mailed, the interviewer contacted the nonagenarians to obtain consent to participate. A proxy-responder was encouraged to participate in the interview if the nonagenarian was unable to participate due to mental or physical handicaps. Pretesting of the participants was not feasible. The interviewer and the family made the decision as to whether to use a proxy upon initial contact to obtain consent to participate in the survey. The regional Scientific Ethical Committees of Denmark approved the survey. For analyses of predictors of mortality, vital status of the entire cohort was drawn from the DCRS 18 months after the start of the survey. All persons were followed for 15 months or until they died, whichever occurred first.

Two thousand two hundred sixty-two persons (62.8%) participated: 1,814 (80.2%) in person and 448 (19.8%) via a proxy-responder. Participants and nonparticipants were compared using the extensive registration of the Danish population that made it possible to evaluate differences between participants and nonparticipants thoroughly. No differences were found between participants and nonparticipants in marital status or housing type. Men and subjects living in rural areas were more likely to participate.[27] Analyzing hospitalization patterns did not indicate that participants were healthier than nonparticipants, because hospitalization patterns in the 26 years preceding the survey and in 1998 showed no difference between the two groups. Nevertheless, in a 6-month period after the start of the survey, nonparticipants had higher mortality, suggesting that terminal illness was one of the reasons for nonparticipation. A higher mortality rate in persons living in urban areas than in rural areas did not cause the higher nonresponse rate in the urban areas, because the mortality rate in urban areas was lower than in rural areas (10.8% vs 15.4%).

Furthermore, the Danish population of elderly is homogeneous with respect to ethnicity and social conditions. These circumstances, and the fact that no exclusion criteria were used, provide support for the participants being a reasonable representation of the oldest-old population. Details of these analyses have been published elsewhere.[24]

The survey consisted of an interview and testing of mental and physical functioning. In addition, participants were asked to give a cell sample (blood or cheek swab) from which deoxyribonucleic acid could be extracted.

Assessment of Predictor Variables

Sociodemographic Factors

Questions about marital status and years of schooling.

Lifestyle Factors

Participants were classified as smokers, former smokers, or never smokers. Alcohol consumption was recorded separately for different types of alcoholic beverages (beer, spirits, red and white wine). For these analyses, the numbers of drinks per week in the four categories were summed, yielding the following categories: no drinks, one to five drinks, six to 14 drinks, and more than 14 drinks.

Disability

Questions in this area covered the Katz Index of activities of daily living (ADL)—bathing, dressing, toileting, transfer, and feeding (continence was not included in accordance with the recommendations in the literature[28])—and were used to construct a three-level five-item ADL scale; "not disabled" was defined as independent in all items, "moderately disabled" as dependent in one or two items, and "severely disabled" as dependent in three or more items in accordance with the definitions given in Katz' paper.[29] These categories defined three sizable groups, which ranged from a group capable of doing the most basic activities independently to a group that was dependent in the majority of the five basic activities.[30] The five-item ADL scale correlated highly (Spearman, correlation coefficient (r) = 0.82) with a 26-item ADL scale composed of all information retrieved on ADLs.[30]

Measures of Physical Performance

Handgrip strength and ability to rise from a chair with or without the use of arms are included in the present analysis[24] because these tests were the strongest predictors of mortality of the tests included in the survey (handgrip strength, chair stand, timed walk, lifting a 2.7-kg box over the head, and flexibility[30]). Furthermore, handgrip strength has only a moderate correlation with the five-item ADL scale (Spearman $r = 0.39$), indicating that it may measure other aspects of functional limitations.[30] Handgrip strength was measured using a hand-held dynamometer (SMEDLYS' dynamometer, Scandidact, Kvistgaard, Denmark) for three performances with the stronger hand. The best performance of these three was used for the analysis. For the analysis of handgrip strength, the participants were divided into separate quartiles for men and women. The first quartile consisted of the best-performing participants. In the chair stand test, participants were divided into three groups (able to stand without use of arms, able to stand with use of arms, unable to stand). Persons unable to complete the tests were put into separate groups.

Health

Participants were presented with a list of 31 ailments and diseases and asked whether a physician had ever told them that they suffered from any of them. The number of present diseases was divided into three groups (0, 1–2, and ≥ 3). Major diseases such as cardiovascular disease (CVD), respiratory diseases, cancer, and diabetes mellitus were studied separately. Furthermore, subjective health was assessed using the question: "How do you consider your health in general?" with five response categories (excellent, good, acceptable, poor, and very poor).

Body Mass Index

Body mass index (hg/m^2) was calculated using self-reported data on height and weight. Approximately half of the persons did not answer the question themselves; an estimate was then made by the interviewer or reported by the proxy. Participants were divided into three groups (<22, 22–27, ≥ 28).[31]

Cognitive Function

Cognitive function was measured using the Mini-Mental State Examination (MMSE).[32] Cognitive impairment was graded as severe (0–17 points), mild (18–23 points), and not present (24–30 points).

Calculation of Follow-Up Time

Vital status for the total cohort, except for one person who had emigrated, was traced in February 2000. Individuals were followed up for 15 months or until they died, whichever occurred first. Participants in the pilot study (n = 200) were interviewed in the spring of 1998, 6 months earlier than participants in the main study. These participants were assigned August 1, 1998, as date of entry to avoid age-dependent effects on the mortality rate and to ensure that all participants were followed in the same 15 calendar months to avoid fluctuations in mortality during the seasons of the year. Twelve feasibility study participants had died before this date and were excluded. In all, 2,249 persons were included in the analysis.

Analytic Methods

Cox regression models using Stata version 6.0 (Stata Corp., College Station, TX) analyzed the effect of potential risk factors on mortality. The proportional hazards assumption was tested for each risk factor using Schoenfeld residuals. For relevant risk factors (all except marital status and smoking by nature nonlinear items) linearity was tested by comparing -2 log likelihood ratios with the risk factor in question obtained as categorical and continuous variables. Chi-square tests showed that all variables except education could be treated as linear.

Mortality rates and unadjusted hazard ratios (HRs) were computed for all variables using data on all possible subjects. Subsequently, unadjusted HRs for the same variables using only data on persons who had no missing values in any of the variables were calculated. This reduced the male sample from 579 to 463 and the female sample from 1,670 to 1,217, a reduction of 569 persons. Of these, 440 were interviewed by proxy and therefore did not go through the physical and cognitive tests. The remaining 129 had missing values in one or more variables. Finally, HRs with all variables in the Cox regression model were calculated.

RESULTS

Five hundred seventy-nine persons died (25.7%) during the 15 months of follow-up. As expected, the mortality was lower in women than in men (23.3% vs 32.8%, $P<.00001$). The basic statistics, including mortality rates, with regard to demographic and lifestyle characteristics are shown in Table 1. There was no significant difference between participants who survived and those who died with regard to marital status, education, or smoking habits ($P>.5$), but there was a significant association between higher mortality rate, lower consumption of alcohol ($P=.004$ (men), $P=.002$ (women)), and lower BMI ($P=.001$).

Table 2 shows the basic statistics, including mortality rates, with regard to physical and mental abilities and health characteristics. All factors, except number of diseases ($P=.69$ (men), $P=.10$ (women)) and specific major diseases showed a highly statistically significant ($P<.001$) elevated risk of dying with declining function for both sexes.

Table 3 (men) and Table 4 (women) show unadjusted HRs for all persons (column 1) and for persons with no missing data in any of the variables (column 2—restricted sample). The analysis based on the reduced sample did not change the HRs substantially.

Although the HRs did not change significantly with overall number of diseases, the analysis of major disease groups (CVD, respiratory diseases, cancer, and diabetes mellitus) showed associations with mortality for some subgroups. For CVD, the unadjusted HR was 1.4 (95% confidence interval (CI) = 1.0–1.9) for men and 1.3 (95% CI = 1.0–1.5) for women, whereas for diabetes mellitus, the association was significant for women (HR = 1.7 (95% CI = 1.2–2.3)). For cancer and respiratory diseases, the associations were statistically nonsignificant for both sexes.

Adjusted for all variables (column 3), the HRs for marital status, education, and smoking were still not significantly associated with mortality. In men, the effects of low BMI, disability, and cognitive impairment were reduced, but their effect remained statistically significant. Lower alcohol consumption, poor performance on the physical performance tests, poor self-rated health, and CVD were no longer significant predictors of mortality. In women, low BMI, disability, low handgrip strength, poor self-rated health, and CVD remained significant predictors of mortality, whereas former smoking became significant, and ability to rise from a chair, consumption of alcohol, and diabetes mellitus became nonsignificant.

DISCUSSION

In medical care and public health discussions, results from younger elderly are often extrapolated to the oldest old. Because the oldest old is the fastest growing segment of the population[33] and because characteristics of the oldest old may not follow the exponential trend found in surveys of younger elderly,[34–36] evidence should replace such extrapolation. This study showed that, after adjustment, factors often found to predict mortality in middle-aged and younger elderly, such as marital status, low education, smoking, and intake of alcohol, apparently lost their

Table 1. Baseline Demographic and Lifestyle Characteristics and Mortality During 15 Months of Follow-Up: The Danish 1905-Cohort Survey

Characteristic	Men		Women	
	No. at Baseline/ No. of Deaths (%)	Mortality Rate per 100 Person Years (95% CI)	No. at Baseline/ No. of Deaths (%)	Mortality Rate per 100 Person Years (95% CI)
Marital status				
Widow/widower	368/124 (33.7)	32.6 (27.4–38.9)	1359/308 (22.7)	20.4 (18.3–22.8)
Divorced	12/3 (25.0)	21.3 (6.9–66.2)	67/18 (26.9)	25.4 (16.0–40.3)
Married	170/55 (32.4)	30.5 (23.4–39.7)	55/15 (27.3)	26.4 (15.9–43.8)
Single	29/8 (27.6)	25.2 (12.6–50.4)	189/48 (25.4)	23.3 (17.6–30.9)
Education, years				
<7	136/45 (33.1)	32.5 (24.3–43.5)	372/91 (24.5)	22.7 (18.4–27.8)
7–8	325/107 (32.9)	31.3 (25.9–37.8)	993/223 (22.5)	20.2 (17.7–23.0)
9–10	67/21 (31.3)	29.1 (19.0–44.6)	213/53 (24.9)	22.5 (17.2–29.5)
≥ 11	39/12 (30.8)	29.2 (16.6–51.4)	45/9 (20.0)	17.5 (9.1–33.6)
Smoking				
Never smoker	112/37 (33.0)	31.8 (23.1–43.9)	1105/253 (22.9)	20.7 (18.3–23.4)
Former smoker	309/101 (32.7)	31.0 (25.5–37.7)	362/91 (25.1)	23.0 (18.8–28.3)
Smokers	142/44 (31.0)	29.3 (21.8–39.4)	170/36 (21.2)	19.2 (13.9–26.7)
Use of alcohol/week, drinks				
>14	62/13 (21.0)	18.2 (10.6–31.4)	53/11 (20.8)	18.8 (10.4–33.9)
6–14	243/71 (29.2)	27.5 (21.8–34.7)	391/76 (19.4)	17.0 (13.6–21.3)
1–5	126/44 (34.9)	33.1 (24.7–44.5)	467/92 (19.7)	17.4 (14.2–21.4)
0	133/53 (39.9)	40.3 (30.8–52.8)	725/201 (27.7)	26.0 (22.7–29.9)
Body Mass Index				
≥ 28	79/20 (25.3)	23.0 (14.8–35.6)	143/27 (18.9)	16.8 (11.5–24.4)
22–27	336/97 (28.9)	27.0 (22.1–32.9)	733/140 (19.1)	16.8 (14.2–19.8)
<22	152/67 (44.1)	44.7 (35.2–56.9)	733/199 (27.1)	25.4 (22.1–29.1)

CI = confidence interval.

importance, because they did not influence mortality. The number of self-reported diseases also did not predict mortality. Disability, cognitive impairment, and BMI less than 28, were significant risk factors in men and women. In addition, low handgrip strength and poor self-rated health were associated with an increase in mortality in women.

Marital status and education did not influence mortality significantly ($P>.6$) in the oldest old, in contrast to surveys of younger persons.[1–4,6,7,25,37] Level of education is often found to predict mortality in surveys of younger elderly.[1,3] Such an effect is difficult to detect in this survey because of the small number of persons with more than 7 to 8 years of schooling in the 1905 cohort, but in women, the HR was lower (although not significantly) in persons with more than 11 years of schooling.

Among lifestyle factors, smoking is consistently found to predict mortality,[1,2,9] but in the 1905-Cohort Survey, smoking had no significant effect on mortality; the HR was lowest in smokers, but 1,105 women were nonsmokers. In women, former smoking was marginally significant in predicting mortality in the adjusted analysis, which might be due to deaths from diseases that make the person quit smoking. This strongly suggests that persons surviving into their 90s have genetic and/or environmental characteristics that protect them against the obvious toxicity of cigarette smoking, but an interesting question, which can never be answered, is how long the smokers would have lived if they had never smoked. The U- or J-shaped relationship between alcohol consumption and mortality found in surveys of younger elderly[10,11,26,38] was not observed in this study, but there was a tendency toward lower mortality with increasing moderate alcohol intake. A part of the explanation of this phenomenon could be that abstainers were former drinkers who stopped drinking for health-related reasons.

A U-shaped relationship between BMI and the risk of all-cause mortality is often found in the middle-aged,[6,12,27,28,39,40] but some surveys have found that the relative risk associated with greater BMI seems to decline with age.[12,14,23] In the 1905-Cohort Survey, persons with the highest BMI (>28) had the lowest mortality, even after adjusting for potential confounders, a finding that parallel results from the French centenarian study.[23] Nevertheless, it should be noted that risk factors measured at old age do not necesssarily reflect lifetime exposure to these factors. Concerning BMI, not only the survival effect but also weight fluctuations during participants' lifetimes could explain the findings.

In the 1905 cohort, BMI was generally low, and these results may indicate that the linear relationship only represents the left leg of the U-shaped relation, because the obese persons may already have died. Persons may have low BMI due to (terminal) illnesses, which could explain the high

Table 2. Self-Reported Functional Capacity and Health of Nonagenarians at Baseline and Mortality During 15 Months of Follow-Up: The Danish 1905-Cohort Survey

	Men		Women	
Capacity/Health	No. at Baseline/ No. of Deaths (%)	Mortality Rate per 100 Person Years (95% CI)	No. at Baseline/ No. of Deaths (%)	Mortality Rate per 100 Person Years (95% CI)
Five-item ADL scale*				
Not disabled	290/55 (19.0)	16.6 (12.8–21.7)	676/67 (9.9)	8.3 (6.5–10.6)
Moderately disabled	181/64 (35.4)	33.8 (26.5–43.2)	626/163 (26.0)	23.9 (20.5–27.8)
Severely disabled	105/69 (65.7)	82.3 (65.0–104.2)	353/157 (44.5)	46.9 (40.1–54.9)
Hand grip, kg				
First quartile	110/19 (17.3)	14.9 (9.5–23.3)	299/26 (8.7)	7.2 (4.9–10.6)
Second quartile	119/22 (18.5)	16.2 (10.6–24.6)	298/36 (12.1)	10.3 (7.4–14.2)
Third quartile	115/31 (27.0)	25.1 (17.6–35.7)	263/47 (17.9)	15.6 (11.7–20.8)
Fourth quartile	120/50 (41.7)	41.2 (31.2–54.4)	325/91 (28.0)	25.8 (21.0–31.7)
Could not complete	29/16 (55.2)	59.4 (36.4–97.0)	131/43 (32.8)	30.7 (22.8–41.4)
Chair stand				
Stand without use of arms	287/59 (20.6)	18.1 (14.0–23.3)	622/70 (11.3)	9.5 (7.5–12.0)
Stand with use of arms	154/50 (32.5)	30.8 (23.3–40.6)	526/111 (21.1)	18.9 (15.7–22.7)
Could not complete	52/29 (55.8)	62.4 (43.4–89.8)	168/62 (36.9)	35.0 (27.3–44.9)
Mini-Mental State Examination categories				
23–30	225/47 (18.4)	16.1 (12.1–21.4)	566/64 (11.3)	9.6 (7.5–12.2)
18–22	150/49 (32.7)	30.7 (23.2–40.6)	425/79 (18.6)	16.3 (13.1–20.3)
0–17	86/40 (46.5)	48.7 (35.7–66.4)	312/98 (31.4)	29.3 (24.0–35.7)
Number of diseases				
0	136/39 (28.7)	26.6 (19.4–36.4)	317/68 (21.5)	19.2 (15.1–24.3)
1–2	268/94 (35.1)	33.9 (27.7–41.5)	733/160 (21.8)	19.7 (16.8–22.9)
>2	172/54 (31.4)	30.0 (23.0–39.2)	604/155 (25.7)	23.5 (20.1–27.6)
"How do you consider your health in general?"				
Excellent	80/13 (16.3)	14.4 (8.4–24.8)	212/19 (9.0)	7.5 (4.8–11.8)
Good	198/54 (27.3)	24.7 (18.9–32.2)	513/83 (16.2)	14.0 (11.3–17.3)
Acceptable	164 /48 (29.3)	27.3 (20.6–36.2)	435/90 (20.7)	18.1 (14.7–22.3)
Poor/very poor	51/23 (45.1)	45.1 (30.0–67.9)	153/51 (33.3)	32.3 (24.6–42.5)
Self-reported diseases				
Cancer				
No	515/172 (33.4)	32.0 (27.6–37.2)	1,462/336 (23.0)	20.8 (18.7–23.1)
Yes	63/17 (27.0)	25.0 (15.5–40.1)	193/50 (25.9)	23.8 (18.1–31.5)
Cardiovascular disease				
No	363/108 (29.8)	27.7 (22.9–33.5)	1,068/230 (21.5)	19.4 (17.0–22.1)
Yes	211/81 (38.4)	38.5 (30.9–47.8)	583/154 (26.4)	24.2 (20.7–28.4)
Respiratory disease				
No	502/160 (31.9)	30.4 (26.0–35.5)	1,441/329 (22.8)	20.7 (18.5–23.0)
Yes	75/29 (38.7)	37.2 (25.8–53.5)	217/56 (25.8)	23.5 (18.1–30.6)
Diabetes mellitus				
No	542/177 (32.7)	31.2 (26.9–36.2)	1,540/346 (22.5)	20.2 (18.2–22.5)
Yes	36/12 (33.3)	31.3 (17.8–55.1)	125/42 (33.6)	33.6 (24.9–45.5)

Note: Only nonproxy data was used, except for "number of diseases" and "self-reported diseases."
* "Not disabled" was defined as independent in all items, "moderately disabled" as dependent in one or two basic activities of daily living (ADL), and "severely disabled" as dependent in three or more items.
CI = confidence interval.

mortality in this group, but no relationship was found between number of self-reported diseases and level of BMI (data not shown). Because BMI is related to fat intake and level of cholesterol, a parallel to the results can be seen in the paradoxical finding of better survival of older persons with high levels of cholesterol.[20] The height and weight data used for the analysis were self-reported, and furthermore, for approximately half of the participants, a proxy reported the measures or the interviewers estimated them. Because there are no objective measures, one cannot directly evaluate whether the data on height and weight were reliable or not, but interaction analysis of the differences between sex and self-reported/proxy-reported data showed similar patterns. The only exception was a tendency to lower weight and

Table 3. Hazard Ratios (HR) and 95% Confidence Intervals (CI) for Men: The Danish 1905-Cohort Survey

Characteristic	Unadjusted: All Persons	Unadjusted: Restricted Sample* (n = 463)	Adjusted for All Variables† (n = 463)
		HR (95% CI)	
Marital status	n = 579		
Widow/widower	1	1	1
Divorced	0.65 (0.21–2.04)	0.72 (0.18–2.92)	0.74 (0.18–3.08)
Married	0.93 (0.68–1.28)	0.74 (0.49–1.12)	0.79 (0.51–1.20)
Single	0.77 (0.38–1.57)	0.99 (0.46–2.13)	0.67 (0.31–1.47)
Education, years	n = 567		
<7	1.04 (0.73–1.48)	1.14 (0.75–1.73)	1.05 (0.69–1.60)
7–8	1	1	1
9–10	0.93 (0.59–1.49)	0.93 (0.52–1.65)	1.00 (0.55–1.82)
>10	0.94 (0.51–1.69)	0.82 (0.38–1.79)	0.84 (0.38–1.85)
Smoking	n = 563		
Never smoker	1	1	1
Smoker	0.92 (0.59–1.42)	0.79 (0.46–1.34)	0.80 (0.46–1.39)
Former smoker	0.97 (0.67–1.42)	0.94 (0.61–1.47)	0.97 (0.62–1.54)
Use of alcohol	n = 564		
	1.26 (1.08–1.46)	1.24 (1.04–1.49)	1.06 (0.87–1.29)
BMI	n = 567		
	1.49 (1.18–1.89)	1.49 (1.11–2.01)	1.43 (1.06–1.91)
Number of diseases	n = 576		
	1.05 (0.86–1.28)	0.99 (0.78–1.26)	0.86 (0.66–1.13)
"How do you consider your health in general?"	n = 493		
	1.38 (1.14–1.67)	1.35 (1.10–1.65)	1.16 (0.94–1.45)
Five-item ADL scale	n = 576		
	2.29 (1.91–2.74)	2.09 (1.66–2.63)	1.62 (1.19–2.22)
Hand grip, kg	n = 493		
	1.48 (1.29–1.71)	1.47 (1.25–1.70)	1.13 (0.94–1.36)
Chair stand	n = 493		
	1.87 (1.50–2.34)	1.84 (1.44–2.36)	1.08 (0.79–1.49)
MMSE categories	n = 491		
	1.77 (1.44–2.18)	1.74 (1.40–2.17)	1.30 (1.00–1.68)
Self-reported diseases			
Cancer	n = 578		
	0.78 (0.47–1.28)	0.54 (0.26–1.10)	0.52 (0.25–1.10)
Cardiovascular disease	n = 574		
	1.40 (1.05–1.86)	1.13 (0.79–1.63)	1.34 (0.91–1.97)
Respiratory disease	n = 577		
	1.23 (0.83–1.82)	1.07 (0.64–1.79)	1.19 (0.68–2.08)
Diabetes mellitus	n = 578		
	1.01 (0.56–1.81)	1.15 (0.59–2.27)	1.03 (0.50–2.13)

Note: All variables except marital status, education, and smoking were treated as linear. The reference groups were: for use of alcohol: >14 drinks (4 categories), for body mass index (BMI): = 28 (3 categories), for number of diseases: 0 diseases (3 categories), for self-rated health: excellent (4 categories), for the five-item activities of daily living (ADL) scale: not disabled (3 categories), for handgrip: first quartile (5 categories), for chair stand: rise without use of arms (3 categories), and for Mini-Mental State Examination (MMSE) categories: 24–30 points (3 categories), in accordance with the categorization of the variables shown in Tables 1 and 2.

* The restricted sample consisted of persons who had no missing answers in any of the variables.

† All variables listed in the table were used for the adjusted analysis.

higher mortality in men who participated through a proxy, but this seems reasonable, because a lower proportion of men participated through a proxy (probably only the frailest). Furthermore, in this group, the men did not have better functional status than the women (which was the case in men participating in person), also indicating that men in this group were frail.

In surveys of younger elderly[16,17,29–33,41–45] and centenarians,[22,23] functional status and cognition have been shown to be associated with mortality, which parallels the results from the 1905-Cohort Study. Disability, handgrip strength, chair stand, and cognitive function were strong predictors in the univariate analyses, but after adjustment, the effect of chair stand disappeared, while

Table 4. Hazard Ratios (HR) and 95% Confidence Intervals (CI) for Women: The Danish 1905-Cohort Survey

Characteristic	Unadjusted: All Persons	Unadjusted: Restricted Sample (n = 1,217)	Adjusted for All Variables† (n = 1,217)
	HR (95% CI)		
Marital status	n = 1,670		
Widow/widower	1	1	1
Divorced	1.25 (0.77–2.01)	0.78 (0.35–1.76)	0.92 (0.40–2.09)
Married	1.30 (0.77–2.18)	1.21 (0.62–2.37)	1.28 (0.65–2.53)
Single	1.14 (0.84–1.55)	1.23 (0.84–1.79)	1.33 (0.90–1.96)
Education, years	n = 1,623		
<7	1.12 (0.88–1.43)	1.20 (0.88–1.64)	1.05 (0.77–1.44)
7–8	1	1	1
9–10	1.11 (0.88–1.50)	1.36 (0.95–1.94)	1.48 (1.01–2.15)
>10	0.86 (0.44–1.68)	0.35 (0.09–1.43)	0.45 (0.11–1.83)
Smoking	n = 1,637		
Never smoker	1	1	1
Smoker	0.93 (0.66–1.32)	0.86 (0.54–1.36)	1.03 (0.64–1.66)
Former smoker	1.11 (0.88–1.42)	1.30 (0.97–1.76)	1.37 (0.99–1.87)
Use of alcohol	n = 1,636		
	1.23 (1.09–1.39)	1.19 (1.02–1.38)	1.04 (0.89–1.23)
BMI	n = 1,609		
	1.36 (1.15–1.61)	1.37 (1.10–1.71)	1.26 (1.01–1.58)
Number of diseases	n = 1,654		
	1.13 (0.98–1.29)	1.19 (0.99–1.43)	0.98 (0.78–1.22)
"How do you consider your health in general?"	n = 1,313		
	1.55 (1.34–1.79)	1.60 (1.37–1.86)	1.17 (0.99–1.39)
Five-item ADL scale	n = 1,655		
	2.32 (2.03–2.64)	2.29 (1.91–2.74)	1.61 (1.27–2.03)
Hand grip (kg)	n = 1,316		
	1.48 (1.34–1.64)	1.48 (1.33–1.64)	1.14 (1.01–1.29)
Chair stand	n = 1,316		
	1.94 (1.64–2.30)	2.01 (1.68–2.42)	1.14 (0.90–1.46)
MMSE categories	n = 1,303		
	1.77 (1.51–2.07)	1.72 (1.46–2.02)	1.42 (1.18–1.70)
Self-reported diseases			
Cancer	n = 1,665		
	1.15 (0.85–1.55)	1.22 (0.83–1.79)	1.10 (0.74–1.64)
Cardiovascular disease	n = 1,651		
	1.25 (1.02–1.53)	1.62 (1.24–2.11)	1.70 (1.27–2.29)
Respiratory disease	n = 1,658		
	1.14 (0.86–1.51)	1.34 (0.95–1.88)	1.04 (0.72–1.48)
Diabetes mellitus	n = 1,665		
	1.67 (1.21–2.30)	1.47 (0.91–2.34)	1.37 (0.84–2.22)

Note: All variables except marital status, education, and smoking were treated as linear. The reference group were: for use of alcohol: >14 drinks (4 categories), for body mass index (BMI): = 28 (3 categories), for number of diseases: 0 diseases (3 categories), for self-rated health: excellent (4 categories), for the five-item activities of daily living (ADL) scale: not disabled (3 categories), for hand grip: first quartile (5 categories), for chair stand: rise without use of arms (3 categories), and for Mini-Mental State Examination (MMSE) categories: 24–30 points (3 categories), in accordance with the categorization of the variables shown in Tables 1 and 2.

* The restricted sample consisted of persons who had no missing answers in any of the variables used in the analysis.

† All variables listed in the table were used for the adjusted analysis.

handgrip strength was only significant in women. However, the HR was virtually the same in men (1.13 vs 1.14) but not significant (odds ratio (OR) = 0.94–1.36) because of the smaller sample size in the male group. Nevertheless, disability and functional limitations are not necessarily risk factors in themselves. They could also reflect current resources and adaptive capacity, and they probably also reflect disease burden and comorbidity. Disability in the oldest old is interplay between the age-related loss of muscle mass, lung function, sedentary lifestyle, and chronic degenerative conditions such as arthritis and arteriosclerosis. Some of these factors are potentially modifiable, and intervention may improve not only survival but also quality of life.

Self-reported number of diseases did not predict mortality in the 1905-Cohort Study, in contrast to the relationship between morbidity and mortality generally observed. However, this may be interpreted with caution, because the number of diseases was based on self-report and was not clinically confirmed, nor was severity of disease taken into account. Furthermore, the list consisted of 31 diseases, some of which could be expected to be more associated with mortality than others. Nevertheless, the analysis of some major disease groups, such as CVD, respiratory disease, cancer, and diabetes mellitus, revealed significant associations only with CVD and diabetes mellitus, and the latter only for women. Moreover, after adjusting for other covariates (Tables 3 and 4), only the risk associated with CVDs in women remained statistically significant. Health might more advantageously be reflected in the question on self-rated health, which was a good predictor of mortality, especially in women, although this question may also reflect aspects of well-being and disability.[42,46] It is also possible that mortality in nonagenarians is mainly due to a combination of age-related decline in the function of the organs and acute infections, but this is not reflected in the number of diseases. Additionally, the self-reported health data may not be detailed enough to elucidate the relationship between comorbidity, disability, and mortality.

Some methodological issues need to be addressed. As mentioned in the introduction, there are few data on mortality prediction in the oldest old, which impedes the comparison of these results with other surveys. The fact that results across surveys of younger elderly are inconsistent for some risk factors such as alcohol use and marital status impedes the discussion of differences between mortality patterns in younger elderly and the oldest old.[1–7]

The study population consisted of persons born in 1905 (92- or 93-year-olds) and results from a single birth cohort; therefore, the results may not be generalizable to all nonagenarians, but the longitudinal design of the survey, with follow-ups every second year will provide information on the age span until the participants become centenarians (200–300 of the participants are expected to become centenarians).

The data on health may not be as reliable and as detailed as possible. Optimally, a thorough clinical examination in a hospital setting should have been conducted, but this would have reduced the number of participants considerably because of the functional capacities of the nonagenarians.

The participation rate of 63% reflects that no exclusion criteria were used in the survey. (All Danes born in 1905 were approached irrespective of residence, mental and physical status.) Participants have previously been compared with the nonparticipants and found to be a fairly nonselected group of the 1905-Cohort Study.[24]

The multivariate analytical strategy using only persons who had no missing data may have introduced some bias. For example, all persons interviewed by proxy were excluded in the final model. Alternatively, persons who were able to answer all the questions might also have given the most reliable answers, and generally there was high agreement between results from the various analytical strategies.

Finally, the present data do not explain why the effect of some of the predictors changed with the respondents' age. Selection is the most likely explanation; the frailest persons had died, leaving only persons with a favorable genetic make-up or environmental exposure history.

In conclusion, factors predicting survival in the oldest old differ from findings in surveys of younger elderly, but the mortality pattern is not a stochastic phenomenon. The disability measure was an especially strong predictor. Because the underlying causes of disability and disability in itself are potentially modifiable, one might assume that the possibility of a further life expansion and improvement of quality of life exists. Interventions for improving survival in the oldest old should not focus on well-known risk factors such as quitting smoking, lowering alcohol intake, or reducing body weight. The focus should be on reducing risk factors causing high levels of disability, functional limitations, and cognitive decline, aims that in themselves are highly worthwhile.

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