Original Article | Journal of INTERNAL MEDICINE

doi: 10.1111/j.1365-2796.2010.02331.x

Factors associated with reaching 90 years of age: a study of men born in 1913 in Gothenburg, Sweden

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Abstract. Wilhelmsen L, Svärdsudd K, Eriksson H, Rosengren A, Hansson P-O, Welin C, Odén A, Welin L (Sahlgrenska University Hospital/Östra, Sahlgrenska Academy, University of Gothenburg; Uppsala University, Uppsala; Chalmers University of Technology, Gothenburg; and Lidköping Hospital, Lidköping, Sweden). Factors associated with reaching 90 years of age: a study of men born in 1913 in Gothenburg, Sweden. *J Intern Med* 2010; doi: 10.1111/j.1365-2796.2010.02331.x.

Objectives. Increasing numbers of people reach old age. We wanted to identify variables of importance for reaching 90 years old and determine how the predictive ability of these variables might change over time.

Setting and subjects. All men in the city of Gothenburg born in 1913 on dates divisible by 3, which is on the 3rd, 6th, 9th etc., were included in the study. Thus, 973 men were invited, and 855 were examined in 1963 at age 50. Further examinations were made at age 54, 60 and 67. Anthropometric data, lifestyle and parental factors, blood pressure, lung function, X-ray of heart and lungs and maximum work performance were recorded. The area under the receiver operating characteristic curve was used to analyse the predictive capacity of a variable.

Results. A total of 111 men (13%) reached 90 years of age, men who reached 90 years were more likely at age 50 to be nonsmokers, consume less coffee, have higher socio-economic status and have low serum cholesterol levels than those who did not reach this age; however, at age 50 or 62, parents' survival was of no prognostic importance. Variables of greatest importance at higher ages were low blood pressure and measures related to good cardiorespiratory function. In multivariable analysis, including all examinations, being a nonsmoker, consuming small amounts of coffee, having high housing costs at age 50, good maximum working capacity and low serum cholesterol were related to a better chance of survival to age 90.

Conclusions. Low levels of cardiovascular risk factors, high socio-economic status and good functional capacity, irrespective of parents' survival, characterize men destined to reach the age of 90.

Keywords: coffee consumption, physical working capacity, risk factors, socio-economic status, survival of parents.

Introduction

Many articles have been published by us and others on risk factors for cardiovascular disease, certain cancers, osteoporotic fractures and overall mortality. The mean age at death is increasing, and there are indications that increasing numbers of people are reaching very old age. According to Swedish official statistics, the probability of a Swedish man of 50 years of age of reaching the age of 90 has increased from 12.0% amongst men born in 1913 to 22.9% amongst those born in 1943. It is unclear whether genetic/family factors or modifiable factors are of primary importance for long life. This issue has recently been addressed by both British and American studies [1–5].

In 1963, we initiated a prospective study of men born in the year 1913 (i.e. when they were all 50 years old). One in eight of these men reached the age of at least 90. Our primary aim was to identify variables of importance for becoming 90 years old and characterize their accuracy as predictors measured in middle age. A secondary aim was to elucidate how the predictive ability of any given variable may change over time, because the influence of strong predictors in the short term may be attenuated over a longer period. Thus, variables measured close to the age of 90 may have stronger predictive capacity than those observed earlier. We investigated the importance of variables measured in middle age and did not compare their predictive ability with variables measured closer to age 90 years, because we considered that this would be a biased comparison. We have also studied the probability of reaching 80 years; approximately half of the population reached this age. The difference in predictors for reaching 80 and 90 years is briefly discussed.

Methods

The study sample comprised all men in the city of Gothenburg born in 1913 on dates divisible by 3. Thus, 973 men were invited, and 855 (88%) were examined at Sahlgrenska University Hospital in 1963. Another 4% were examined at home, but fewer data are available for them, and they are not included in the present analysis.

Examinations were conducted at baseline and thereafter at 54, 60, 67, 75 and 80 years of age, as previously reported [6–8]. For the reasons discussed earlier, we decided at the start of the analyses not to use variables recorded at ages 75 and 80 years as they were too close to the age of 90. Follow-up regarding survival until age 90 was complete (100%) and also included men who emigrated for various periods of time.

The following main areas of potential interest were investigated at any one of the examinations: smoking habit, coffee consumption, alcohol-related problems, socio-economic status (e.g. cost of housing), dyspnoea on exertion, psychological stress, presence of diabetes mellitus, early death or myocardial infarction in parents, blood pressure, body mass index (BMI) and waist circumference, blood levels of lipids and glucose, plasma fibrinogen, lung function, maximum working capacity and heart volume (measured by X-ray).

Data on smoking, coffee consumption, physical activity, presence of dyspnoea, mental stress and cost of housing were collected through interviews with a physician. Data on some variables were collected via registers such as registration for alcohol-related problems with a temperance board (after obtaining a permit). Temperance boards were established in Sweden to register and follow-up individuals who were seen in legal or medical settings with problems of alcohol abuse. Other variables were recorded through personal interviews and recorded according to official scales, such as the social group of the man himself and his father and marital status. Parents' survival was assessed via questionnaire when the men were 50 and 62 years old and via comprehensive research through the parish offices. Height and weight, waist circumference, blood pressure and lung function (not at all examinations) were measured during the examination. X-rays of the heart and lungs were taken at some examinations.

Smoking habits were categorized as: (i) never smoker; (ii) former smoker of more than 1 month's duration (ex-smoker); (iii) smoker of 1–14 g tobacco per day; (iv) smoker of 15–24 g tobacco per day; (v) smoker ≥25 g tobacco per day. One cigarette was considered to contain 1 g tobacco, and a cigarillo and cigar to contain 2 and 5 g, respectively.

A questionnaire on physical activity at work and during leisure time was first introduced at the examination in 1967, when personal interviews were held with a physician (LWi) regarding activities from age 20 to 54, and these activities were later assessed by postal questionnaires at age 54. Activity at work was graded: (i) mainly sedentary; (ii) predominantly walking on the level and no heavy lifting; (iii) mainly walking, including climbing stairs, or walking uphill or lifting heavy objects; (iv) heavy physical labour. Leisure time activity was defined as: (i) mainly sedentary: (ii) moderate activity; (iii) regular exercise; and (iv) athletic training. Grades 3 and 4 were analysed together as a very small percentage was engaged in athletic training at any time [7].

A simple questionnaire on mental stress was also introduced for the 1967 examination. Stress was defined as feeling tense, irritable or filled with anxiety or having sleeping difficulties as a result of conditions at work or at home. There were six response options: (i) never experienced stress; (ii) one period of stress ever; (iii) some periods during the last 5 years; (iv) repeated periods during the last 5 years; (v) permanent stress during the last year; and (vi) permanent stress during the last 5 years. Items 5 and 6 have been shown to be associated with myocardial infarction during follow-up [9, 10]. Diabetes was recorded if the man had been diagnosed with diabetes by a physician, or blood glucose levels were ≥6.0 mmol L^{-1} at the screening examination. Dyspnoea was graded according to the classification of Rose & Blackburn [11]: (i) no dyspnoea; (ii) dyspnoea on walking uphill; (iii) dyspnoea on walking at ordinary speed on level ground; (iv) has to stop on level ground; (v) dyspnoea on dressing and undressing; and (vi) dyspnoea at rest.

All examinations, except the one in 1967, were performed in the morning after an overnight fast. Body weight was measured on a lever balance to the nearest 0.1 kg. Height was recorded barefoot to the nearest 1 cm, and BMI was calculated. Waist circumference was measured at the umbilicus; this measurement was first introduced at the 1967 examination when the men were 54 years old. Blood pressure was measured by the study physician (except in 1983, when measured by a study nurse). A standard cuff and a mercury manometer were used. Diastolic blood pressure (Korotkoff phase 5) was recorded.

Blood lipid measurements were performed according to available methods at the time and were analysed at the same hospital laboratory. Details have been reported previously [8].

The lung function test included forced expiratory volume in 1-s ($FEV_{1.0}$) corrected for body height and flow–volume curves expressed as expiratory flow at 25% of vital capacity (MEF25%) [12].

A maximum exercise test on a bicycle ergometer was performed at age 54, as previously reported [7]. In short, a thorough clinical examination including measurement of blood pressure and ECG was carried out before the test. There were preset criteria for interruption, limitation and nonperformance of the maximum exercise test. Reasons for not performing the test were symptoms or electrocardiographic signs of myocardial infarction and signs of congestive heart failure. The test was limited to submaximum exercise because of symptoms like dyspnoea or chest pain, systolic blood pressure ≥230 mmHg, atrial fibrillation, flutter or grade II or III heart block. Maximum exercise was achieved by 671 men.

Tables 1–4 show the variables that were selected for prospective analysis from the examinations at age 50, 54, 60 and 67, respectively. These tables also show areas under the receiver operating characteristic (ROC) curves, confidence limits, direction of any

Table 1 *Variables recorded at age 50 years included in the univariable analysis of factors of potential importance for survival until age 90 years. Area under the ROC curves with confidence intervals (95% CI), direction of association and* P*-values are given*

Variable	Area under the ROC curve	95% CI	Direction of association	*P*-value
Nonsmoker	0.604	0.548–0.660	+	0.0000***
Ex-smoker	0.517	0.459–0.575	+	0.3986
Smoke 1–14 g tobacco per day	0.537	0.480–0.594	–	0.1386
Smoke 15–24 g tobacco per day	0.570	0.513–0.627	–	0.0013**
Smoke ≥25 g tobacco per day	0.505	0.447–0.563	–	0.7125
Coffee, cups per day	0.594	0.536–0.652	–	0.0017**
Alcohol-related problems	0.524	0.466–0.582	–	0.4114
Years at school	0.592	0.536–0.648	+	0.0007***
Cost of housing	0.574	0.516–0.632	+	0.0076**
Marital status	0.504	0.446–0.562	–	0.8109
Systolic blood pressure	0.549	0.492–0.606	–	0.0974
Diastolic blood pressure	0.524	0.466–0.582	–	0.4188
Total serum cholesterol	0.597	0.541–0.653	–	0.0009***
Social group	0.582	0.525–0.639	–	0.0032**
Fathers' social group	0.581	0.523–0.639	–	0.0019**
Father died before 1963	0.515	0.457–0.573	–	0.5027
Mother died before 1963	0.552	0.495–0.609	–	0.0374*

+, the probability of becoming 90 years is increased; –, the probability of becoming 90 years is decreased in this and all tables.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$ in this and all tables. ROC, receiver operating characteristic.

Table 2 *Variables recorded at age 54 years included in univariable analysis of factors of potential importance for survival until age 90 years. Area under the ROC curves, confidence intervals (CI), direction of association and P-values are given*

Variable	Area under the ROC curve	95% CI	Direction of association	*P*-value
Dyspnoea, grade 2	0.539	0.480–0.598	–	0.1117
Dyspnoea, grade 3	0.515	0.456–0.574	–	0.0761
Dyspnoea, grade 4	0.502	0.443–0.561	–	0.5060
Dyspnoea, grade 5	0.502	0.443–0.561	–	0.5060
Never experienced psychological stress	0.542	0.483–0.601	+	0.1029
Psychological stress, sometimes	0.524	0.465–0.583	–	0.1396
Stress sometimes in last 5 years	0.514	0.455–0.573	–	0.3710
Repeated stress in last 5 years	0.506	0.447–0.565	–	0.7656
Continuous stress in last year	0.506	0.447–0.565	–	0.6824
Continuous stress in last 5 years	0.502	0.443–0.561	–	0.8820
Body mass index	0.504	0.445–0.563	–	0.8820
Waist circumference	0.528	0.469–0.587	–	0.3504
Systolic blood pressure	0.576	0.518–0.634	–	0.0113*
Diastolic blood pressure	0.572	0.514–0.630	–	0.0163*
Total serum cholesterol	0.549	0.484–0.614	–	0.1434
Plasma fibrinogen	0.623	0.566–0.680	–	0.0001***
$FEV_{1.0}$	0.581	0.523–0.639	+	0.0077**
MEF25%	0.544	0.485–0.603	+	0.1443
Could not manage maximum work load	0.557	0.498–0.616	–	0.0034**
Maximum working capacity	0.604	0.544–0.664	+	0.0010**

ROC, receiver operating characteristic; **P* < 0.05; ***P* < 0.01; ****P* < 0.001.

association as well as *P*-values for the association between variables and survival until age 90 years.

For the follow-up, the records in the computer file for the men in the study were run against the National Swedish Death Registry. Follow-up regarding survival until age 90 was complete including men who emigrated for various periods of time.

Statistical methods

As a measure of the predictive (or discriminative) capacity of a variable, we used the area under the ROC curve. The area under the curve for a variable is in this case equal to the probability of a randomly selected man amongst those surviving above 90 years having a higher (or lower) value for the current variable 'survival above age 90 years' compared with a randomly selected man who has died before that age. The probability is 0.5 for a continuous variable that has no predictive capacity, whereas it is 1.0 for a variable that has the complete ability to determine who will reach age 90 years. The area under the ROC curve does not determine all aspects of the predictive capacity, but we consider that it is the best measure in the present case.

Mann–Whitney's test was used to compare those men who reached age 90 years with those who did not. Multivariable logistic regression analysis was applied in a stepwise manner (the forward method) to find the best combination of variables. The procedure was applied for all variables registered at the age of 50 and also for the analysis including all variables. The area under the ROC curve can be considered as a way of quantifying the difference between those who survive above 90 years and those who do not with respect to the predictor. The value 0.5 corresponds to no difference at all, and the value 1 corresponds to such a large difference that there is no overlapping. Verbal characterizations of intermediate values are given [13]. Because of the variety of purposes and time

Table 3 *Variables recorded at age 60 years included in univariable analysis of factors of potential importance for survival until age 90 years. Area under the ROC curves, confidence intervals (CI), direction of association and P-values are given*

Variable	Area under the ROC curve	95% CI	Direction of association	*P*-value
Stopped smoking	0.510	0.410–0.610	–	0.8481
Physical activity at work	0.526	0.463–0.589	+	0.4005
Physical activity during leisure	0.563	0.501–0.625	+	0.0183*
Known diabetes mellitus	0.523	0.461–0.585	–	0.0303*
Alcohol-related problems, previously	0.531	0.469–0.593	–	0.0309*
Alcohol-related problems, currently	0.504	0.442–0566	–	0.5977
Teetotal	0.519	0.457–0.581	+	0.2568
Cohabiting	0.512	0.449–0.575	+	0.5238
Divorced	0.517	0.458–0.576	–	0.3075
Memory, self-perceived at age 50	0.516	0.453–0.579	+	0.1733
Memory self-perceived at age 60	0.506	0.443–0.569	+	0.5611
Self-perceived fitness at age 50	0.508	0.444–0.572	+	0.7939
Self-perceived fitness at age 54	0.522	0.458–0.586	+	0.4882
Myocardial infarction in father	0.508	0.444–0.572	–	0.7473
Myocardial infarction in mother	0.540	0.477–0.603	–	0.1449
Body mass index	0.517	0.455–0.579	–	0.5837
Waist circumference	0.540	0.478–0.602	–	0.2042
Systolic blood pressure	0.575	0.514–0.636	–	0.0172*
Diastolic blood pressure	0.560	0.499–0.621	–	0.0578
Total serum cholesterol	0.538	0.476–0.600	–	0.2286
Blood glucose	0.537	0.473–0.601	–	0.2637
$FEV_{1.0}$	0.623	0.539–0.707	+	0.0058**
MEF25%	0.601	0.516–0.686	+	0.0231*

ROC, receiver operating characteristic; *$P < 0.05$; **$P < 0.01$.

frames of predictions, general comparisons of their goodness are difficult to make.

A risk ratio (a quotient between probabilities) or an odds ratio provides little information about the predictive ability of a variable. If a zero–one variable attains the value 1 with a low probability, so the presence of that state is very rare, then the variable may be a weak predictor even if the odds ratio is extreme. The area under the ROC curve captures to a large extent both the risk ratio and the frequency aspect.

When we study the risk of an event over a period of time, we apply Cox proportional hazards model or a Poisson model [14]. The models produce a beta coefficient (β) for a variable. The gradient of risk per 1 standard deviation ($\exp(|\beta|\cdot\sigma)$, where σ is the standard deviation of the current variable) may be a relevant characterization of the predictive ability under some assumptions [15]. The variable should have a normal distribution and, when investigated by a nonproportional hazards model, β should not change with time. Both assumptions cause serious restrictions for the application in our study. If β is constant over time, then the area under the ROC curve will change with time. Therefore, comparisons between predictions in different time frames are difficult using the area under the ROC curve, but comparisons between variables independent of their distributions when the time frame is the same, are not affected by this problem.

To study the change in the predictive ability of a variable x measured at baseline, we have to evaluate β depending on the time t since the start of follow-up [β(t)]. In the simplest case, $\beta(t).x = (\beta_1 + \beta_2 \cdot t)\cdot x =$

Variable	Area under the ROC curve	95% CI	Direction of association	*P*-value
Stopped smoking	0.527	0.463–0.591	+	0.3637
Dyspnoea on walking uphill	0.582	0.519–0.645	–	0.0019**
Self-perceived financial situation at age 61	0.507	0.443–0.571	+	0.8279
Self-perceived financial situation at age 67	0.542	0.478–0.606	+	0.1789
Treatment for diabetes	0.532	0.468–0.596	–	0.0207*
Height	0.502	0.438–0.566	–	0.9460
Weight	0.503	0.439–0.567	–	0.9260
Waist circumference	0.539	0.475–0.603	–	0.2269
Systolic blood pressure	0.504	0.440–0.568	–	0.9000
Diastolic blood pressure	0.506	0.442–0.570	–	0.8583
Heart volume corrected for body surface area	0.538	0.474–0.602	–	0.2422

A plus-sign denotes that the probability of becoming 90 years is increased, and a minus-sign that the probability of becoming 90 years is decreased. ROC, receiver operating characteristic; *$P < 0.05$; **$P < 0.01$.

Table 4 *Variables recorded at age 67 years included in univariable analysis of factors of potential importance for survival until age 90 years. Area under the ROC curves, confidence intervals (CI), direction of association and P-values are given*

$\beta_1 \cdot x + \beta_2 \cdot t \cdot x$. That type of interaction is in conflict with the proportional hazards requirement of the Cox model [16]. In Fig. 4, we present the results of such an analysis performed by a special Poisson regression, in which the observation period of an individual is divided into small intervals.

Results

Age 90 years was reached by 111 men (13%). The probability of reaching the age of 90 for a man alive at age 60 was 84/691 (0.12; 95% confidence interval: 0.09–0.15). Figure 1 shows the distribution of age at death.

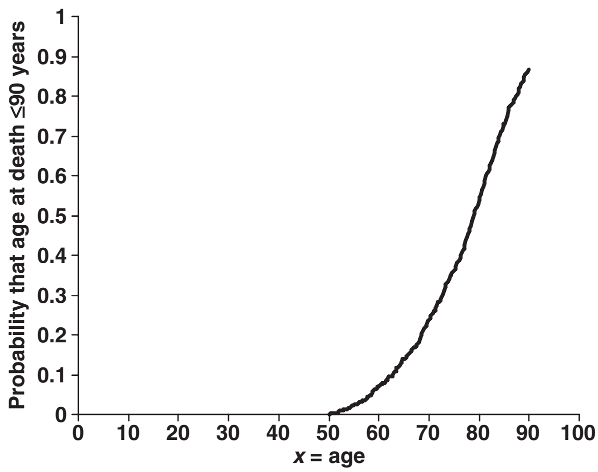

Fig. 1 *Distribution of age (years) at death.*

Variables recorded and their significance for survival until 90 years in univariable analyses are first reported for the examinations at age 50, 54, 60 and 67 years (Tables 1–4, respectively) followed by multivariable analysis of significant variables at these investigations.

Variables recorded at age 50 years

In the univariable analysis (Table 1), it was found that nonsmokers ($P < 0.00001$) and those who drank fewer cups of coffee ($P = 0.0015$) had a better chance of survival to age 90 years (Fig. 2). There was a better chance of reaching 90 years with a high level of education (more years at school; $P = 0.0318$) and higher cost for housing (0.045), but social group ($P = 0.0706$) and father's social group ($P = 0.067$) did not have a statistically significant impact. Death of the mother, but not father, before 1963 when the man was 50 years old was related to the chance of survival until 90 years. Registration for alcohol-related problems with a temperance board and marital status were not related to survival. Systolic and diastolic

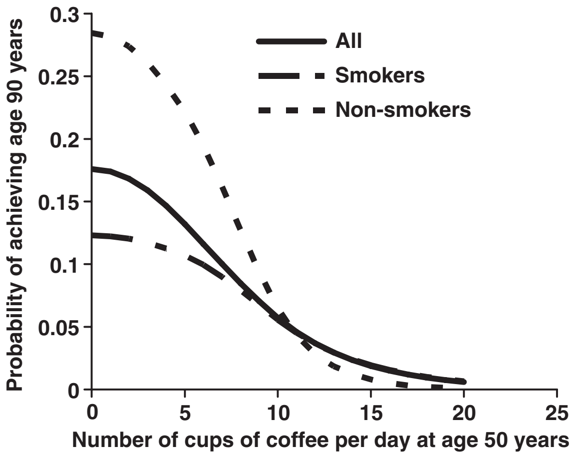

Fig. 2 *Probability of reaching age 90 years by coffee consumption and smoking habits at age 50 years.*

Fig. 3 *Probability of reaching age 90 years by serum cholesterol at age 50 years.*

blood pressures were not significant variables, and it is interesting that at age 50 years only 14 men (1.6%) were taking antihypertensive medication. Receiving antihypertensive treatment was not related to long-term survival either. The probability of survival declined with increasing levels of serum cholesterol at age 50 ($P = 0.012$) (Fig. 3).The relationship may have been influenced to a minor degree by antilipidaemic treatment, which was given to only 4% of men at age 80 years, and to even fewer at earlier ages when the positive effects of such treatment had not yet been shown.

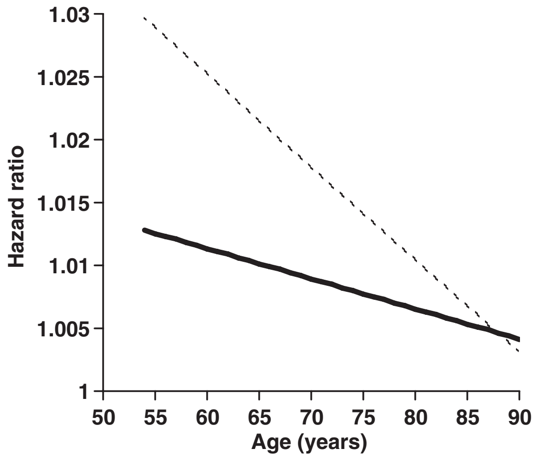

Fig. 4 *Hazard ratio per 1 mmHg difference in systolic (bold line) and diastolic (dotted line) blood pressure measured at age 54 years. The increased risk because of a rise in blood pressure by 1 mmHg was three times higher at age 54 years than at age 90 years, and the corresponding relationship for diastolic pressure was nine times higher.*

Table 5 *Variables significantly related to survival to age 90 years in multivariable regression analysis of data recorded at age 50 years*

Variable	β	SE	*P*-value	OR (95% CI)
Constant	−0.7540	0.7373		
Nonsmoker	0.9200	0.2290	0.0001***	2.51 (1.60–3.93)
Coffee, cups per day	−0.1144	0.0443	0.0098**	0.89 (0.82–0.97)
Cost of housing	0.3374	0.1030	0.0011**	1.40 (1.15–1.71)
Serum cholesterol	−0.0074	0.0027	0.0070**	0.99 (0.99–1.00)

–, the variable is negatively associated with survival. Area under the receiver operating characteristic curve for the above-mentioned combination of variables was 0.682 (95% CI: 0.628–0.737); $^{**}P < 0.01$; $^{***}P < 0.001$.

Variables recorded at age 54 years

According to the univariable analysis (Table 2), the following variables at this age were significantly related to better survival: lower systolic and diastolic blood pressure levels ($P = 0.013$ and 0.016, respectively); higher $FEV_{1.0}$ ($P = 0.0077$); lower plasma fibrinogen ($P = 0.0001$); and higher maximum work capacity ($P = 0.0010$). Men who could not manage a maximum work test had less chance of becoming 90 years. Physical activity at work or during leisure time, BMI, waist circumference, dyspnoea on exertion and mental stress were not significantly related to reaching 90 years.

Variables recorded at age 60 years

The following variables were significantly related to better survival from age 60 to 90 years (Table 3): physical activity during leisure time ($P = 0.0183$); absence of previous alcohol-related problems ($P = 0.031$); self-rated physical capacity at age 54 ($P = 0.030$); lower systolic blood pressure ($P = 0.017$); higher $FEV_{1.0}$ ($P = 0.0058$); and higher MEF25% ($P = 0.0231$). Diastolic blood pressure, blood glucose, waist circumference, BMI, cardiovascular disease in fathers or mothers or their age at death or serum cholesterol were not significantly related to outcome.

Variables recorded at age 67 years

The following variables were significantly related to better survival: absence of dyspnoea on walking uphill ($P = 0.0058$); better financial situation at age 61 ($P = 0.0231$); shorter stature ($P = 0.017$); and lower systolic blood pressure ($P = 0.031$). Body weight, waist circumference, treatment for diabetes mellitus, diastolic blood pressure and heart volume (measured by X-ray) were not significantly related to survival (Table 4).

Many variables that were important at age 50 lost their predictive capacity over time. As an example, Fig. 4 shows the estimated decline in predictive ability of systolic and diastolic blood pressure after measurement at 54 years. At this age, an increase in systolic blood pressure of 1 mmHg implied a 1.2% higher risk of death and a 20-mmHg increase raised the risk by $(\exp[20-\log[1.012]]-1) \times 100\% = 27\%$. At the age of 90, the 27% increased risk had declined to only a 9% rise in risk. The decline of the predictive capacity with time was higher for diastolic blood pressure. It is conceivable that the increasing prevalence of antihypertensive treatment may have influenced this decline, but at age 80 only 12% of men were receiving such treatment, and therefore, this would not have influenced the relationships to a large extent. Half of the deaths before the age of 90 occurred after age 79 years (Fig. 1), and by then a substantial part of the predictive ability of blood pressure had already been lost.

Multivariable analyses

All variables significantly related to becoming 90 years in univariable analyses with baseline at age 50 years were included in a stepwise multivariable analysis, and the final results are shown in Table 5. Being a nonsmoker, drinking less coffee, more expensive housing and low serum cholesterol were all significantly related to a better chance of reaching 90 years. However, early death of a mother, which was significant in univariable analysis, was no longer significant in multivariable analysis. As shown earlier, other variables that were also examined at ages 54 and 60 and were significant in univariable analyses were included in the stepwise multivariable analysis together with the variables included in the analysis shown in Table 5. The final analysis is shown in Table 6. A total of 737 men were included in this analysis, and at this point, maximum performance in the bicycle exercise test at age 54 was also significantly related to survival until age 90 years.

Causes of death

The causes of death amongst the men are shown in Table 7. As expected in this cohort of men, 39.4% died from cardiac causes, 9.5% from stroke and 24.9% from cancer, of which 5.3% cases were prostate cancer and 4.1% were lung cancer.

Prediction of survival to 90 compared with 80 years

Briefly, some social variables such as educational level, housing costs and fathers' social group were more important for survival after 90 years, whereas some physical variables such as physical activity during leisure time and at work and diabetes before age 60 were more important for reaching 80 years of age. Dyspnoea on walking uphill and relative heart volume were of great importance up to age 80, but were less important for reaching 90 years. It is beyond the scope of this study to evaluate these differences further.

Discussion

In the present study, we investigated the effect of a large number of variables measured in middle age on the chance of reaching the age of 90; however, comparatively few variables emerged as important for survival. It is not surprising that being a nonsmoker was the most important factor. Other predictors were financial strength (evidenced by the ability to afford expensive housing), being of general good health

Table 6 *Variables significantly related to survival to age 90 years in multivariable regression analysis of data recorded at any examinations*

Variable	β	SE	P-value	OR (95% CI)
Constant	−1.5653	0.8433		
Nonsmoker at age 50	1.0263	0.2368	0.0000***	2.79 (1.75–4.44)
Coffee, cups per day at age 50	−0.1273	0.0462	0.0058**	0.88 (0.80–0.96)
Cost of housing at age 50	0.2707	0.1097	0.0136*	1.31 (1.06–1.63)
Maximum working capacity at age 54	0.0006	0.0002	0.0008***	1.00 (1.00–1.00)
Serum cholesterol at age 50	−0.0080	0.0029	0.0063**	0.99 (0.99–1.00)

–, the variable is negatively associated with survival. Area under the receiver operating characteristic curve for the above combination of variables was 0.712 (95% CI: 0.658–0.776); *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 7 *Distribution of causes of death amongst study participants*

Cause of death	Percentage
Heart disease, excluding myocardial infarction	10.0
Myocardial infarction	29.4
Stroke	9.5
Cancer, total	24.9
Cancer of the prostate	5.3
Other causes of death	26.2

(indicated by a high physical working capacity) and having a low level of serum cholesterol. Unexpectedly, a high coffee consumption had a negative impact on survival. Contrary to common beliefs, we did not find in this population sample that father's survival to old age was of any prognostic importance.

Of these prognostic factors, smoking, coffee consumption and probably serum cholesterol would probably be of value for longer life in the future, but only randomized controlled clinical trials can determine whether such interventions can prolong survival. The cost of housing at age 50 years, which was associated with other factors related to socio-economic status later in life, might be difficult to influence. This may also be the case for physical working capacity, which to some extent is influenced by physical training but also by constitutional factors. In an earlier study of these men, it was found that maximum oxygen uptake was related to physical activity during work and at leisure, but the effect of physical activity on maximum oxygen uptake was not very strong [1]. Accordingly, constitutional factors seem to be important.

Our findings of the importance of socio-economic factors as well as that of not smoking are in agreement with findings amongst civil servants in London [2, 4]. The London study also analysed whether the socio-economic status was related to pathogen burden, defined as positive serostatus for *Chlamydia pneumoniae*, cytomegalovirus and herpes simplex virus and found that this index was higher in low socio-economic groups, compared with those with higher socio-economic status, but it did not appear to mediate the difference in cardiovascular risk. In this context, it is interesting that high plasma fibrinogen was negatively related to survival in univariable (but not multivariable) analyses of variables recorded at age 54 in the present study. We have previously found that plasma fibrinogen is related to myocardial infarction and stroke in a prospective study of these men [17] and that high fibrinogen is associated with low social class [18]. Yates *et al.* [5] found that smoking had a negative effect on survival until age 90 years and that blood pressure control, weight management and regular exercise had positive effects; however, the latter three variables were not found to be significant in multivariable analysis in the present study. However, we also found systolic blood pressure and physical activity to be significant only in univariable analysis at age 60 or 67 years, and the same applies to lung function tests.

It is noteworthy that smoking and high cholesterol levels were associated with poorer survival, reflecting the high proportion of cardiovascular deaths in our sample, and these factors have been found to be risk factors for the common causes of death (coronary heart disease and smoking for lung cancer) amongst these men as well as in many other studies. In the 38-year follow-up of the Whitehall study, the presence of cardiovascular risk factors (smoking, high blood pressure and high cholesterol concentration) measured on a single occasion in middle age predicted a threefold higher rate of vascular mortality, a twofold higher rate of nonvascular mortality and an almost 10-year shorter life expectancy compared with of the absence of these risk factors [19]. We have not previously observed an impact of maximum working capacity on survival, but this finding is very plausible and was recently corroborated in an elderly population in which it was found that mortality was lower in people who were better able to perform a 400-m walking test [20]. Coffee consumption was found to be a risk factor for heart disease in previous univariable, but not in multivariable, analyses [21]. In a more recent Finnish study of elderly people, it was found that higher coffee consumption was associated with better survival [22].

We have previously found that the more than 50% decline in the rate of myocardial infarction in Gothenburg over 30 years was comparable with the decline in risk factors, when risk factors were compared in successive cohorts of 50-year-old men with registered rates of myocardial infarction in the city [8]. Our results provide support for the public health policies aimed at achieving changes in major risk factors throughout the population to achieve improvements in life expectancy. However, given the recent trends of markedly decreasing levels of smoking in the population but, on the other hand, increasing obesity [8], other measures more directed towards preventing obesity and the development of diabetes mellitus will probably be needed in the future.

Strengths and limitations of the study

The present study has several strengths, including a prospective design, availability of a large number of potential predictors, an extended follow-up and a complete mortality follow-up. Additionally, the general population sample with an almost uniquely high attendance rate provides possibilities to generalize to the background population of men of similar age in the city and probably also to other men in general. However, there are also limitations, chiefly a comparatively limited study population, but also the fact that all were men of similar age and almost exclusively of Caucasian origin. Whilst this is, in some respects, a strength, reducing random variation in heterogeneous strata, it is also a limitation reducing the possibility to generalize the findings not only with respect to gender and age, but also to location and time period. Another limitation is that we were not able to assess the quality of life including the presence of Alzheimer's disease in the surviving men.

In summary, we found several modifiable lifestyle factors, such as smoking and diet-related serum cholesterol levels, as well as socio-economic status and physical working capacity to be significantly associated with survival until age 90. However, we did not find that parental survival was of significant importance for survival amongst these men, and therefore, lifestyle factors seem to be more important than familial/genetic factors.

Contributors

Lars Wilhelmsen (LWi) was responsible for the design of the study, Anders Odén performed the statistical analyses and all authors took part in the investigations, data interpretation and drafting the report.

Conflict of interest statement

None of the authors has any conflicts of interest to report.

Acknowledgements

Support was received from the Swedish Heart-Lung Foundation, the Health and Medical Care Committee of the Västra Götaland Region and the ALF agreement at the Sahlgrenska University Hospital.

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