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Large improvements in major cardiovascular risk factors in the population of northern Sweden: the MONICA study 1986–2009

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Abstract. Eriksson M, Holmgren L, Janlert U, Jansson J-H, Lundblad D, Stegmayr B, Söderberg S, Eliasson M (Department of Public Health and Clinical Medicine, Umeå University, Umeå; Research Department, Norrbotten County Council, Luleå; Department of Medicine, Skellefteå Hospital, Skellefteå; Department of Medicine, Sunderby Hospital, Luleå; and National Board of Health and Welfare, Stockholm, Sweden). Large improvements in major cardiovascular risk factors in the population of northern Sweden: the MONICA study 1986–2009. *J Intern Med* 2011; **269**: 219–231.

Objectives. The incidence of cardiovascular disease has declined rapidly in Sweden since the 1980s. We explored changes in major cardiovascular risk factors in northern Sweden between 1986 and 2009.

Design. Since 1986, six population surveys have been carried out in northern Sweden using procedures of the World Health Organization MONICA project. The population age range was 25–64 years in 1986 and 1990, and 25–74 years from 1994. Trends were analysed using generalized linear models.

Results. A total of 10 586 subjects were included in the surveys. Blood pressure decreased by 4.9/3.9 mmHg in women and 1.8/1.5 mmHg in men aged 25–64 years between 1986 and 2009. In men and women aged 65–74 years, the decrease was 12.6/6.1 mmHg between 1994 and 2009. From 1994, the use of blood pressure-lowering drugs increased, particularly among the older subgroup. The prevalence of smoking halved between 1986 and 2009; 11% of women and 9% of men were smokers in 2009. Cholesterol levels decreased by 0.9 mmol L^{-1} in the younger age group (25–64 years), and the use of lipid-lowering agents increased from 1994. Among subjects aged 25–64 years, one in five was obese in 2009, which was twice as many as in 1986, and body mass index (BMI) increased by 1.5 kg m^{-2}, corresponding to an increase in weight of 4 kg. There was no further increase in BMI from 2004. The prevalence of diabetes did not change between 1986 and 2009. The proportion that received a university education increased markedly in all age groups, especially in women, during the study period.

Conclusions. Significant improvements were observed in major cardiovascular risk factors in northern Sweden between 1986 and 2009.

Keywords: cardiovascular risk factors, cohort study, MONICA, trends.

Introduction

The incidence of mortality from cardiovascular disease (CVD) has decreased substantially in western societies since the World Health Organization (WHO) initiated the MONICA (multinational MONItoring of trends and determinants in CArdiovascular disease) project in the early 1980s. From the results of this project, it was concluded that decreases in the classical risk factors – smoking, cholesterol and blood pressure – explain a great part of the decline in coronary heart disease (CHD) [1]. In addition, changes in coronary care and secondary prevention contributed substantially to lower CHD mortality [2, 3]. Recent modelling of trends in Sweden and Finland showed that 55–60% of the reduction in CHD deaths was due to improved risk-factor patterns, particularly lower cholesterol levels [4, 5]. The importance of the classical

risk factors is further corroborated by results from the INTERHEART study [6].

The role of general obesity as a risk factor is unclear, and abdominal obesity may be a better predictor of myocardial infarction [6]. Obesity has been linked to increased cardiovascular mortality [7], but because of the close relation with other established risk factors, it has not been included in commonly used risk predictors, such as the Framingham risk score. Socioeconomic inequalities in CHD mortality [8] are partly due to higher risk-factor levels in subjects with a low socioeconomic position [9]. Increased mortality from ischaemic heart disease (IHD) has been reported among people with low income in Scotland [10], and a low level of education was the most consistent socioeconomic predictor in the INTERHEART study, with highest impact in high-income countries [11].

Modelling of the impact of risk factors is hampered by the lack of valid data from representative populations using strict and uniform methodology for assessing risk-factor levels over long time periods. Published studies suffer from short-time frames [12], comparisons between different populations or areas [5, 13, 14] and restriction of analyses by age groups and gender [15]; in addition, there is a lack of recent data [16–18]. The most comprehensive data come from the US NHANES study [19]. European data are scarce with the exception of a recent Finnish report [5].

In the Northern Sweden MONICA Study, we have repeated population surveys and maintained registries of myocardial infarction and stroke despite the termination of the WHO collaboration in 1995. Since 1985, mortality from IHD has decreased by 69% in men and 45% in women [20], and in nondiabetic subjects, the mortality from stroke has decreased by 4% per year [21]. Here, we present data on time trends in major cardiovascular risk factors from six population surveys over 23 years.

Methods

Survey participants

We used data from the northern Sweden component of the WHO MONICA study. Six population-based surveys were conducted between 1986 and 2009. Subjects were randomly selected from population registers, stratified for age (25–64 years in 1986 and 1990, 25–74 years in 1994, 1999, 2004 and 2009) and gender, in the two most northern counties of Sweden (target population 312 000). The survey samples were randomly selected independent of each other. Details of sampling and selection have been presented previously [22]. All surveys were performed during the same months (January–April).

Measurement procedures

Blood pressure was measured twice in the sitting position, after a 5-min rest, using the Hawksley random-zero sphygmomanometer, and the mean value was recorded. In 2009, the Omron M7 monitor was used to measure blood pressure in half the sample. Hence, only half the subjects (those with random-zero blood pressure measurements) are included in the analyses of blood pressure. Hypertension was defined as mean systolic blood pressure ≥140 mmHg and/or mean diastolic blood pressure ≥90 mmHg, and/or treatment with antihypertensive medication during the 2 weeks before the survey.

Subjects were weighed on a balance scale (calibrated daily) from 1986 to 1994, and on an electronic scale from 1999 [23].

Blood samples were drawn after at least a 4-h fast and analysed within 24 h without freezing. In 1986, 1990 and 1994, total cholesterol was determined using an enzymatic method (BM Monotest Cholesterol CHOD-PAP; Boehringer Mannheim GmbH, Mannheim, Germany); a dry chemistry method was used from 1999 (Vitros 950; Kodak Ektachem, Rochester, NY, USA) [24]. The measurement of total cholesterol is accredited by the Swedish EQUALIS national accreditation body, with a coefficient of variation of 3.6% at 3.9 mmol L^{-1} and 3.1% at 6.7 mmol L^{-1}. There are no uniform reference values for blood lipids in Sweden. Recommendations depend on sex, age and other risk factors. In the present study, total cholesterol levels above 7.0 mmol L^{-1} were defined as 'high'.

Subjects who answered yes to the question 'Do you have diabetes mellitus?' in the questionnaire are classified as having 'known diabetes' [25].

The highest attained educational level was classified as primary school (up to 9 years of school), secondary school (10–12 years of school) and university. Subjects who smoked at least one cigarette a day were classified as regular smokers; all others were considered nonsmokers [26]. Snus (i.e. moist oral snuff) consumption was defined as daily use of smokeless tobacco.

The study was approved by the Research Ethics Committee of Umeå University, and all subjects gave informed consent to participate.

Statistical methods

Estimated means and proportions were age standardized to the population in Norrbotten and Västerbotten counties in 2000, using 5-year age groups. Trends in risk factors were analysed using generalized linear models with identity link and normal distribution for continuous risk factors (linear regression) and log-link and binomial distribution for binary risk factors (log-linear regression). The initial model included the independent variables year of survey, sex, age group and year × sex. The interaction term, year × sex, was included to determine whether the trend differed between men and women. If significant, separate trend estimates are presented for men and women, otherwise the interaction term was removed from the model. The estimated model coefficient for year, B, approximates the mean annual change (continuous variables) and 100B the mean relative change (binary variables). Separate analyses were carried out for younger (25–64 years) and older (65–74 years) subjects. A value of $P < 0.05$ was considered statistically significant. Statistical analyses were carried out using sas 9.1 (SAS Institute Inc., Cary, NC, USA).

Results

A total of 10 586 subjects, 5374 women and 5212 men, were included in the six surveys; participation rates declined from 81.2% in 1986 to 69.2% in 2009 (Table 1). In order to obtain key supplementary information, attempts were made to contact all women and men who did not respond to the study invitation. Of the 771 nonparticipants in the 2009 survey, 485 answered a basic questionnaire. Compared to participants, nonparticipants were on average younger (46.7 vs. 50.8 years, $P < 0.001$) and more likely to smoke (17.5% vs. 11.0%, $P < 0.001$) or report diabetes (7.7% vs. 4.8%, $P = 0.013$). Nonparticipants were less likely to have a university education (23.9% vs. 29.9%, $P = 0.010$) or to be married/cohabiting (63.6% vs. 73.9%, $P < 0.001$). The use of antihypertensive medication or lipid-lowering drugs did not differ, and body mass index (BMI), based on self-reported height and weight, was similar in the two groups. Participants and nonparticipants are compared for each survey year in Table 2.

Blood pressure and hypertension

In 1986, systolic blood pressure was 125.4 and 129.8 mmHg in younger women and men, respectively, and the corresponding values decreased to 120.3 and 128.1 mmHg in 2009 (Table 3). The trend differed significantly between women and men ($P = 0.007$) (Table 4). Based on a regression model, the average decrease in systolic blood pressure was 0.21 mmHg year^{-1} (4.9 mmHg between 1986 and 2009) in women younger than 65 years but only 0.08 mmHg year^{-1} (1.8 mmHg between 1986 and 2009) in younger men. The mean annual change was higher in subjects ≥65 years [0.8 mmHg year^{-1}

Table 1 *Sample size and participation rate (%) of 250 men and 250 women in each age group*

Sex	Age	1986 $n = 1625$	1990 $n = 1583$	1994 $n = 1921$	1999 $n = 1823$	2004 $n = 1905$	2009 $n = 1729$
Women	25–34	187 (74.8%)	177 (70.8%)	173 (69.2%)	166 (66.4%)	180 (72.0%)	149 (59.6%)
	35–44	206 (82.4%)	206 (82.4%)	202 (80.8%)	177 (70.8%)	198 (79.2%)	177 (70.8%)
	45–54	211 (84.4%)	209 (83.6%)	209 (83.6%)	203 (81.2%)	199 (79.6%)	177 (70.8%)
	55–64	198 (79.2%)	215 (86.0%)	202 (80.8%)	196 (78.4%)	204 (81.6%)	188 (75.2%)
	65–74	–	–	194 (77.6%)	192 (76.8%)	194 (77.6%)	185 (74.0%)
Men	25–34	175 (70.0%)	167 (66.8%)	165 (66.0%)	157 (62.8%)	162 (64.8%)	126 (50.4%)
	35–44	212 (84.8%)	199 (79.6%)	180 (72.0%)	160 (64.0%)	172 (68.8%)	171 (68.4%)
	45–54	225 (90.0%)	203 (81.2%)	195 (78.0%)	170 (68.0%)	180 (72.0%)	169 (67.6%)
	55–64	211 (84.4%)	207 (82.8%)	208 (83.2%)	196 (78.4%)	213 (85.2%)	190 (76.0%)
	65–74	–	–	193 (77.2%)	206 (82.4%)	203 (81.2%)	197 (78.8%)
Total	25–64	1625 (81.2%)	1583 (79.2%)	1534 (76.7%)	1425 (71.2%)	1508 (75.4%)	1347 (67.4%)
	25–74	–	–	1921 (76.8%)	1823 (72.9%)	1905 (76.2%)	1729 (69.2%)

Table 2 *Comparisons of participants and nonparticipants (25–64 years old)*

	1986	1990	1994	1999	2004	2009
Informed of high blood pressure (%)						
Men						
Participants	18.3	16.5	18.0	18.6	20.3	25.0
Nonparticipants	18.2	11.5	11.2	13.7	25.0	30.0
Women						
Participants	23.5	21.4	21.5	22.0	24.9	25.9
Nonparticipants	22.2	12.1	16.5	15.2	24.6	28.5
Regular cigarette smokers (%)						
Men						
Participants	22.5	22.9	18.3	13.8	11.3	10.5
Nonparticipants	31.8	26.7	24.1	19.8	17.9	15.5
Women						
Participants	26.3	25.8	26.8	22.0	18.6	12.1
Nonparticipants	33.9	29.4	36.5	28.4	24.1	18.5
BMI[a] (mean, kg m^{-2})						
Men						
Participants	25.6	25.9	26.2	26.6	27.1	27.1
Nonparticipants	24.4	24.5	25.3	25.5	26.7	26.5
Women						
Participants	25.0	25.0	25.4	25.8	26.2	26.3
Nonparticipants	24.2	23.1	24.1	24.9	25.2	25.6
Education above primary school level (%)						
Men						
Participants	41.1	63.4	69.1	77.7	83.4	91.3
Nonparticipants	54.0	64.8	65.9	81.0	74.2	75.3
Women						
Participants	44.8	64.2	73.1	81.9	86.9	90.5
Nonparticipants	41.4	66.7	67.2	72.2	71.8	83.2
Married/cohabiting (%)						
Men						
Participants	80.3	81.7	79.3	71.7	76.1	71.6
Nonparticipants	63.0	56.7	66.7	60.3	62.0	61.8
Women						
Participants	83.2	80.9	78.0	78.0	80.7	76.2
Nonparticipants	62.0	68.1	69.2	73.4	61.0	65.3

BMI, body mass index; [a]Based on self-reporting of weight and height in nonparticipants.

(12.6 mmHg between 1994 and 2009)], and similar trends were observed in women and men (Table 4).

Diastolic blood pressure was lower in women than in men during the whole period (Table 3), and the time trend differed between the sexes in younger subjects (Table 4). In women <65 years, the estimated decrease was 0.2 mmHg year^{-1} (3.9 mmHg between 1986 and 2009). The corresponding decrease in men was 0.07 mmHg (1.5 mmHg between 1986 and 2009). In 65- to 74-year-old subjects, the decrease was 0.4 mmHg year^{-1} (6.1 mmHg between 1994 and 2009).

A diagnosis of hypertension, which includes subjects treated with blood pressure-lowering drugs,

Table 3 *Age-standardized mean or prevalence with 95% confidence intervals of cardiovascular risk factors in the northern Sweden MONICA cohorts 1986–2009*

Variable	Sex	Age (years)	1986	1990	1994	1999	2004	2009
Systolic BP (mmHg)	Women	25–64	125.4 (124.2–126.7)	125.2 (124.0–126.5)	122.7 (121.3–124.0)	125.2 (123.8–126.5)	120.7 (119.4–121.9)	120.3 (118.6–122.0)
		65–74			155.3 (152.2–158.5)	156.6 (153.2–160.0)	146.2 (143.2–149.3)	142.3 (138.1–146.6)
	Men	25–64	129.8 (128.7–130.9)	129.5 (128.3–130.7)	129.0 (127.8–130.2)	131.6 (130.3–132.9)	127.6 (126.4–128.7)	128.1 (126.4–129.8)
		65–74			145.7 (142.4–149.0)	149.7 (146.7–152.8)	141.6 (138.9–144.2)	136.9 (132.9–141.0)
Diastolic BP (mmHg)	Women	25–64	78.7 (78.0–79.5)	78.3 (77.5–79.1)	76.6 (75.9–77.4)	76.5 (75.7–77.3)	74.6 (73.9–75.3)	75.8 (74.7–76.8)
		65–74			83.9 (82.3–85.5)	83.0 (81.3–84.7)	78.6 (77.2–80.0)	78.2 (76.2–80.2)
	Men	25–64	81.8 (81.1–82.5)	82.4 (81.7–83.2)	82.2 (81.3–83.0)	81.7 (80.9–82.6)	80.0 (79.2–80.8)	81.5 (80.4–82.7)
		65–74			84.3 (82.6–86.0)	84.2 (82.6–85.8)	80.8 (79.3–82.4)	80.2 (78.2–82.1)
Hypertension (%)	Women	25–64	27.6 (24.5–30.7)	28.0 (24.9–31.1)	22.7 (19.8–25.7)	25.4 (22.3–28.6)	21.5 (18.6–24.4)	20.8 (16.6–25.0)
		65–74			82.5 (77.0–87.9)	80.0 (74.3–85.7)	74.2 (68.0–80.4)	77.2 (69.3–85.2)
	Men	25–64	36.9 (33.6–40.2)	32.9 (29.6–36.2)	33.9 (30.5–37.4)	35.6 (32.0–39.2)	30.4 (27.0–33.8)	39.0 (33.8–44.1)
		65–74			65.4 (58.6–72.2)	71.0 (64.8–77.3)	67.8 (61.3–74.2)	67.9 (58.7–77.1)
BP-lowering drug (%)	Women	25–64	9.1 (7.1–11.1)	8.7 (6.8–10.7)	5.7 (4.0–7.3)	7.6 (5.7–9.5)	8.4 (6.4–10.4)	8.8 (6.6–10.9)
		65–74			28.5 (22.0–35.0)	33.6 (26.8–40.4)	44.8 (37.7–51.9)	47.6 (40.2–55.0)
	Men	25–64	7.5 (5.7–9.4)	5.9 (4.3–7.6)	6.4 (4.6–8.2)	8.4 (6.3–10.5)	8.4 (6.4–10.5)	12.6 (10.0–15.1)
		65–74			26.7 (20.3–33.1)	26.4 (20.3–32.5)	36.6 (29.9–43.4)	43.1 (35.9–50.2)
Regular smoker (%)	Women	25–64	26.4 (23.3–29.4)	26.0 (23.0–29.1)	26.6 (23.5–29.7)	21.6 (18.6–24.6)	18.3 (15.6–21.0)	11.5 (9.1–13.9)
		65–74			12.5 (7.8–17.1)	9.9 (5.7–14.2)	10.8 (6.3–15.3)	11.2 (6.6–15.9)
	Men	25–64	22.8 (19.9–25.7)	22.6 (19.6–25.5)	18.2 (15.4–21.0)	13.5 (11.0–16.1)	10.4 (8.2–12.7)	10.1 (7.8–12.4)
		65–74			15.2 (10.0–20.3)	7.5 (3.9–11.2)	7.5 (3.8–11.2)	7.7 (3.9–11.5)
Cholesterol (mmol L^{-1})	Women	25–64	6.27 (6.18–6.36)	6.05 (5.96–6.14)	5.90 (5.81–5.99)	5.62 (5.53–5.71)	5.46 (5.38–5.54)	5.38 (5.30–5.47)
		65–74			7.10 (6.92–7.28)	6.51 (6.35–6.66)	6.28 (6.11–6.45)	6.05 (5.86–6.23)

Table 3 (*Continued*)

Variable	Sex	Age (years)	1986	1990	1994	1999	2004	2009
	Men	25–64	6.34 (6.25–6.43)	6.26 (6.18–6.35)	6.07 (5.98–6.16)	5.70 (5.61–5.78)	5.75 (5.66–5.84)	5.57 (5.48–5.65)
		65–74			6.35 (6.18–6.53)	6.17 (6.02–6.32)	5.74 (5.59–5.88)	5.48 (5.31–5.65)
Cholesterol > 7.0 (%)	Women	25–64	26.2 (23.2–29.3)	21.6 (18.7–24.4)	17.8 (15.1–20.4)	11.0 (8.7–13.3)	8.7 (6.7–10.7)	8.4 (6.3–10.5)
		65–74			46.3 (39.2–53.4)	30.5 (23.9–37.1)	23.2 (17.2–29.1)	20.2 (14.4–26.0)
	Men	25–64	28.6 (25.5–31.7)	25.8 (22.7–28.9)	21.5 (18.6–24.5)	11.9 (9.5–14.4)	14.8 (12.2–17.4)	10.5 (8.1–12.8)
		65–74			27.0 (20.6–33.3)	19.1 (13.7–24.5)	10.8 (6.5–15.1)	10.6 (6.3–15.0)
Lipid-lowering drug (%)	Women	25–64		0.3 (0.0–0.7)	0.4 (0.0–0.9)	1.9 (0.9–2.9)	3.6 (2.3–4.9)	3.0 (1.8–4.3)
		65–74			2.9 (0.5–5.3)	11.3 (6.8–15.9)	21.1 (15.3–27.0)	27.0 (20.5–33.5)
	Men	25–64		0.4 (0.0–0.8)	1.2 (0.4–2.0)	3.6 (2.2–5.0)	4.7 (3.1–6.2)	9.3 (7.1–11.5)
		65–74			3.7 (1.0–6.4)	9.6 (5.5–13.7)	28.5 (22.2–34.8)	36.0 (29.2–42.8)
BMI (kg m^{-2})	Women	25–64	24.8 (24.5–25.2)	24.9 (24.6–25.2)	25.2 (24.9–25.5)	25.7 (25.4–26.0)	26.1 (25.8–26.5)	26.2 (25.8–26.6)
		65–74			27.6 (26.9–28.3)	28.2 (27.6–28.9)	28.3 (27.6–29.0)	27.9 (27.1–28.6)
	Men	25–64	25.6 (25.3–25.8)	25.8 (25.6–26.1)	26.1 (25.8–26.4)	26.5 (26.2–26.7)	27.1 (26.8–27.3)	27.0 (26.7–27.3)
		65–74			26.4 (26.0–26.9)	26.9 (26.5–27.4)	27.6 (27.0–28.1)	26.9 (26.5–27.4)
Obese, BMI >30 (%)	Women	25–64	12.0 (9.7–14.2)	11.1 (8.9–13.3)	12.8 (10.5–15.2)	15.3 (12.7–17.9)	17.6 (14.9–20.3)	20.7 (17.7–23.8)
		65–74			28.2 (21.8–34.6)	29.9 (23.4–36.4)	33.3 (26.6–40.0)	30.6 (23.9–37.3)
	Men	25–64	10.1 (8.1–12.2)	11.0 (8.7–13.2)	12.8 (10.4–15.2)	14.1 (11.5–16.7)	19.2 (16.4–22.1)	20.2 (17.1–23.3)
		65–74			12.8 (8.0–17.5)	19.0 (13.6–24.4)	23.7 (17.7–29.6)	15.5 (10.4–20.6)
Diabetes, self-reported (%)	Women	25–64	1.7 (0.8–2.6)	2.0 (1.0–3.0)	1.8 (0.9–2.8)	1.9 (0.9–2.9)	2.1 (1.1–3.1)	2.4 (1.2–3.5)
		65–74			5.9 (2.6–9.3)	11.3 (6.8–15.8)	11.1 (6.6–15.6)	7.8 (3.9–11.7)
	Men	25–64	4.1 (2.8–5.5)	3.1 (1.9–4.3)	1.5 (0.7–2.4)	2.3 (1.2–3.5)	2.8 (1.6–4.0)	2.7 (1.5–4.0)
		65–74			11.7 (7.1–16.3)	6.8 (3.4–10.3)	12.8 (8.2–17.5)	15.3 (10.2–20.4)
Primary school only (%)	Women	25–64	53.3 (49.8–56.9)	34.2 (30.9–37.5)	25.2 (22.2–28.3)	16.6 (13.9–19.3)	13.0 (10.6–15.3)	8.6 (6.5–10.7)
		65–74			80.1 (74.4–85.8)	68.5 (61.8–75.1)	55.7 (48.6–62.8)	44.0 (36.7–51.3)
	Men	25–64	57.4 (53.9–60.8)	35.0 (31.6–38.4)	29.2 (25.9–32.5)	20.5 (17.5–23.5)	15.3 (12.7–18.0)	7.8 (5.7–9.9)
		65–74			68.6 (61.9–75.3)	61.7 (55.0–68.4)	59.4 (52.5–66.3)	44.9 (37.8–52.0)

Table 3 (*Continued*)

Variable	Sex	Age (years)	1986	1990	1994	1999	2004	2009
University education (%)	Women	25–64	12.8 (10.4–15.2)	21.3 (18.4–24.1)	25.2 (22.2–28.3)	28.9 (25.6–32.2)	34.3 (31.0–37.7)	43.0 (39.3–46.8)
		65–74			5.4 (2.2–8.6)	13.3 (8.4–18.1)	10.4 (6.1–14.7)	18.9 (13.1–24.6)
	Men	25–64	10.1 (8.0–12.2)	13.0 (10.6–15.3)	17.7 (14.9–20.4)	19.9 (16.9–22.9)	25.1 (22.0–28.3)	24.9 (21.6–28.3)
		65–74			3.9 (1.2–6.7)	12.0 (7.5–16.5)	10.5 (6.2–14.8)	18.8 (13.3–24.4)

BMI, body mass index.

became less prevalent in women and men <65 years (decreasing 0.4% per year) (Fig. 1, Table 3). In 2009, 20.8% and 39.0% of younger women and men, respectively, had a diagnosis of hypertension (Table 3). Hypertension did not decrease significantly; in 2009, 77.2% of women and 67.9% of men between 65 and 74 years of age had a diagnosis of hypertension.

Since 1994, there has been a rapid increase in the use of antihypertensive drugs, most evident in the 65- to 74-year-old age group (Table 3, Fig. 1). In the younger age group, only men increased their use of these agents (Table 4). In 2009, 8.8% of women and 12.6% of men <65 years used antihypertensive drugs, whereas 47.6% and 43.1%, respectively, were treated in the older group.

Tobacco use

The prevalence of smoking decreased in subjects younger than 65 years, particularly in men (Tables 3 and 4). Smoking was approximately twice as common in 1986 compared with 2009 when only 11.5% of women and 10.1% of men smoked. Smoking was initially replaced by snus both in women and men, but the total use of tobacco, including snus, started to decrease from 1999 in men and from 2004 in women (Fig. 2). Smoking was less prevalent among the older subgroup (65–74 years); in 2009, only 11.2% and 7.7% of elderly women and men, respectively, were regular smokers (Table 3).

Cholesterol levels and lipid-lowering drugs

Total serum cholesterol levels were high in 1986 (6.3 mmol L^{-1} in younger women and men) (Table 3). Since then, cholesterol levels have declined linearly and continuously with similar amplitude in both women and men, particularly in the older age group (Table 4). Until 2009, cholesterol levels declined by 0.9 mmol L^{-1} in subjects <65 years (estimated from regression model). Among older subjects, cholesterol was 1.0 mmol L^{-1} lower in 2009 than in 1994, reaching 5.5 mmol L^{-1} in men and 6.0 mmol L^{-1} in women. The proportion of subjects with cholesterol levels >7.0 mmol L^{-1} has decreased in women and men of all ages (Table 3). However, 20.2% of women aged 65–74 years had cholesterol levels >7.0 mmol L^{-1} in 2009.

The use of lipid-lowering agents has increased rapidly since 1994. In 2009, 3.0% and 9.3% of women and men aged 25–64 years, and 27% and 36% of women

Table 4 *Estimated mean annual change and corresponding 95% confidence interval (CI) in men and women 1986–2009*

Variable	Test if trend differs between men and women, $P_{sex \times year}$	Estimated mean annual change[a]		95% CI of annual change
25–64 years, 1986–2009				
Systolic BP (mmHg)	0.007	Women	−0.211	(−0.278, −0.145)
		Men	−0.078	(−0.143, −0.012)
Diastolic BP (mmHg)	0.001	Women	−0.171	(−0.212, −0.130)
		Men	−0.067	(−0.110, −0.023)
Hypertension (%)	0.088	Pooled	−0.4%	(−0.8, 0.0)
BP-lowering drug (%)	0.004	Women	0.3%	(−0.8, 1.5)
		Men	2.7%	(1.5, 3.8)
Regular smoker (%)	0.049	Women	−2.8%	(−3.5, −2.1)
		Men	−3.9%	(−4.8, −3.0)
Cholesterol (mmol L^{-1})	0.282	Pooled	−0.038	(−0.041, −0.035)
Lipid-lowering drug[b] (%)	0.164	Pooled	12.4%	(10.3, 14.6)
BMI (mmol L^{-1})	0.828	Pooled	0.067	(0.056, 0.078)
Obese, BMI >30 (%)	0.431	Pooled	2.9%	(2.2, 3.5)
Diabetes, self-reported (%)	0.143	Pooled	−0.3%	(−1.9, 1.3)
Primary school only (%)	0.292	Pooled	−7.2%	(−7.6, −6.8)
University education (%)	0.340	Pooled	4.0%	(3.5, 4.5)
65–74 years, 1994–2009				
Systolic BP (mmHg)	0.153	Pooled	−0.842	(−1.067, −0.618)
Diastolic BP (mmHg)	0.307	Pooled	−0.405	(−0.519, −0.291)
Hypertension (%)	0.269	Pooled	−0.4%	(−1.1, 0.1)
BP-lowering drug (%)	0.897	Pooled	3.5%	(2.3, 4.7)
Regular smoker (%)	0.146	Pooled	−2.4%	(−5.0, 0.3)
Cholesterol (mmol L^{-1})	0.502	Pooled	−0.064	(−0.075, −0.054)
Lipid-lowering drug (%)	0.444	Pooled	12.0%	(9.8, 14.3)
BMI (mmol L^{-1})	0.535	Pooled	0.029	(−0.009, 0.067)
Obese, BMI >30 (%)	0.705	Pooled	1.0%	(−0.5, 2.6)
Diabetes, self-reported (%)	0.569	Pooled	2.3%	(−0.4, 5.0)
Primary school only (%)	0.061	Pooled	−3.2%	(−3.9, −2.5)
University education (%)	0.615	Pooled	7.0%	(4.4, 9.6)

BMI, body mass index; [a]approximative absolute change for continuous variables (estimated by β_{year} from linear regression) and relative change (%) for proportions (estimated as $100\beta_{year}$ from log-linear regression); [b]1990–2009.

and men aged 65–74 years, respectively, used these drugs.

BMI and prevalence of obesity

Body mass index increased by 1.5 kg m^{-2} in women and men aged 25–64 years, which corresponds to a weight gain of approximately 4 kg (Table 4). In both women and men, BMI plateaued between 2004 and 2009.

In the 65- to 74-year-old group, BMI increased between 1994 and 2004, followed by a slight decrease, which was more prominent in men than in women (Table 3). In total, 21% of women and men aged 25–64 years were obese in 2009, which is twice

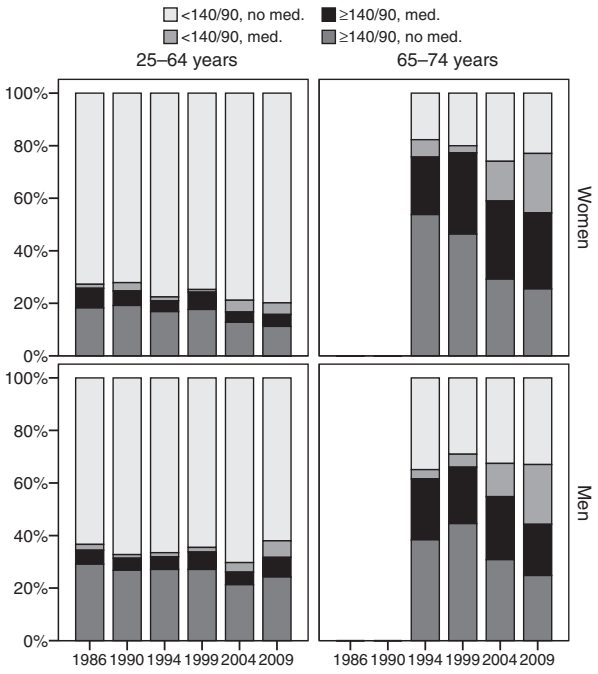

Fig. 1 *Blood pressure and antihypertensive medication in men and women in different age groups (25–64 and 65–74 years).*

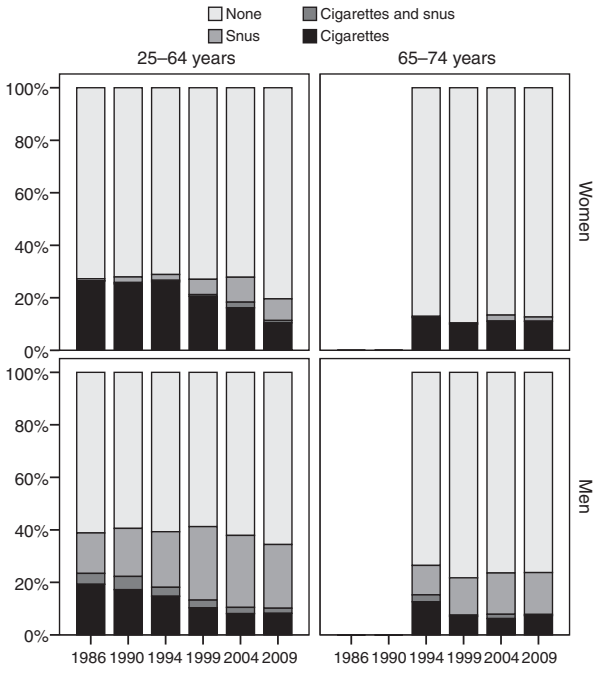

Fig. 2 *Prevalence of smoking (cigarettes and/or snus) in men and women in different age groups (25–64 and 65–74 years).*

as many as in 1986. The prevalence of obesity decreased in older women and men between 2004 and 2009; 16% of men and 31% of women in this subgroup were obese in 2009.

Self-reported diabetes

The prevalence of self-reported diabetes was higher in men than in women and varied between the surveys, although without any clear trend over time (Tables 3 and 4). In 2009, diabetes was reported by 2.4% and 2.7% of women and men under 65 years of age and by 7.8% and 15.3% of older women and men, respectively.

Education

The level of education changed dramatically. In 1986, 53.3% of women and 57.4% of men received only primary school level education; this rate rapidly declined to 8.6% and 7.8%, respectively, in the younger age group in 2009 (Table 3). The proportions with university education or similar increased from 12.8% of women and 10.1% of men aged 25–64 years in 1986 to 43.0% of women and 24.9% of men in the same age group in 2009.

Discussion

Key results

Between 1986 and 2009, the population of northern Sweden achieved important improvements in major cardiovascular risk factors, i.e. decreases in the prevalence of hypertension, smoking and hypercholesterolaemia and an increase in the level of education. Despite increasing obesity, the prevalence of diabetes and hypertension did not increase. Changing dietary patterns may explain the decrease in cholesterol levels in recent years [24, 27], and increasing use of more effective antihypertensive treatment has contributed to lower blood pressure, especially in subjects between 65 and 74 years of age. A markedly higher educational level may be a strong driving force behind the lower rate of smoking and may also contribute to improvement in other risk factors. In Västerbotten, one of the two counties in the Northern Sweden MONICA Study, a community-based, primary care intervention programme was launched in the mid-1980s with the aim of reducing morbidity and mortality from CVD and diabetes [28]. This intervention programme, involving all residents of Västerbotten of 40, 50 and 60 years old, is likely to have contributed to the positive changes in risk-factor pattern.

Strengths and limitations

Population questionnaires can provide reasonably valid estimates of known diabetes, but cholesterol and blood pressure have to be measured using uniform methodology over longer time periods. Most reported estimates of BMI in the population are based on self-reported weight and height, which are notoriously prone to bias, leading to underestimation of the true prevalence of obesity [29]. Self-reported smoking could also be misreported; however, a high correlation between reported smoking and biochemical markers of tobacco exposure was confirmed in the 1994 MONICA cohort [30].

We used the same strict methodology throughout the whole period. For example, blood pressure readings by random-zero methods avoid digit preference, total cholesterol was analysed in the same laboratory, older samples were re-run to adjust for newer methodologies, and anthropometry measurements were made by trained staff using similar equipment and protocols.

The major limitation is the declining participation rate, from 81% to 69% over the study period, most markedly among younger men and women. This could introduce a selection bias, and telephone interviews with the majority of nonparticipants in the first three surveys found that they were less likely to be obese or hypertensive, but more likely to smoke despite similar levels of educational, compared to participants [31]. In 2009, nonparticipants were younger with lower education and more often smokers and diabetics. We believe that our estimates reflect the true levels in the population for most of the period, but data from 2009 may be overoptimistic with regard to prevalence of smoking, diabetes and hypertension.

Interpretation

Blood pressure. A difference of 20 mmHg systolic or 10 mmHg diastolic blood pressure is associated with a 50% decrease in risk of death from stroke or myocardial infarction [32]. The significantly lower blood pressure over time in northern Sweden would translate into a reduction in CVD mortality by approximately 12% in women <65 years and 25% in 65- to 74-year-old women. In Finland, blood pressure levels declined among both men and women from 1972 to 2002, and thereafter levelled off [5], in line with our findings.

Pooling of subjects on treatment with those having high blood pressure summarizes risk-factor burden of hypertension in society. Data from the MONICA project showed decreasing prevalence of hypertension, more in women than in men, in most populations between the mid-1980s and mid-1990s [33]. In the USA, the prevalence of hypertension (≥140/90 mmHg or antihypertensive treatment) increased from 25% in 1988 to 29% in 2000 [34], but thereafter no further increase was noted in a recent update to 2008 [35].

It has been predicted that the increasing prevalence of obesity in western societies would increase blood pressure levels and the prevalence of hypertension. By contrast, studies originating in the early 1960s and continuing to around 2000 have found a remarkable decrease in the prevalence of hypertension among obese subjects, both in Sweden [15] and in the USA – the so-called healthy obese paradox [19] – and our data corroborate these findings.

Smoking. Smoking is a strong risk factor for CVD [6]. Diverging time trends in the prevalence of smoking between the mid-1980s and mid-1990s were found in the international MONICA project [16]. The prevalence of smoking in Finnish men declined between 1972 and 1982 but thereafter only marginally, and 30% were regular smokers in 2007 [13]. Among Finnish women, smoking increased until 2002 and 21% were regular smokers in 2007 [13]. US data resemble the results for Finland [19]. In Gothenburg, Sweden, the rate of smoking decreased by 62% in 50-year-old men from 1963; 22% were smokers in 2003[15].

In northern Sweden, the level of regular smoking halved in all groups, except older women in whom no decrease was noted; the rate of smoking reached 8–12% in 2009, which is exceptionally low compared to international levels. This was initially achieved by increasing use of snus, although recently all tobacco use has started to decrease. As CVD risk with snus use is probably very low [36], we believe that a reduction in smoking is an important explanation of the lower CVD mortality in northern Sweden.

Total cholesterol. Based on observational studies in 900 000 individuals, reduction of total cholesterol by 1 mmol L^{-1} is associated with 50% lower IHD mortality below the age of 50, and 33% lower IHD mortality in subjects aged 50–69 years [37].

In MONICA, the highest cholesterol levels were registered in Finland and northern Sweden [1]. In Finland

[5], the USA [38], Sweden [24, 39] and Australia [40], similar reductions in total cholesterol over the last 40 years have been described. The use of lipid-lowering drugs contributed little to the decline in levels until the last decade, and then especially among elderly people [24, 40].

A decrease in cholesterol of 1 mmol L^{-1} in the northern Swedish population confers large health benefits, and recent modelling supports the notion that this is the most important contributor to lower CHD mortality [4]. However, the finding of higher cholesterol levels in women over 65 years who also receive less treatment is of concern.

Obesity. The role of general obesity as a cardiovascular risk factor is debated [6]. A marked decline in CVD in parallel with increasing BMI noted in the MONICA populations [1] has added to this debate. Recently, concern has been raised that we are approaching such levels of obesity that the improvements in cardiovascular health will be compromised [39, 41].

The results of the MONICA project demonstrate increasing BMI and obesity in almost all of its populations, with the exception of central and eastern European subjects [18]. In middle-aged Swedish men, obesity more than doubled and BMI increased by 1.8 kg m^{-2} between 1963 and 2003 [15]. In the USA, obesity increased linearly from the early 1960s, but since 2000, there has been no significant further increase in women [42]. A similar trend of a recent attenuation in the rise in obesity is found in Finland [5]. Similarly, our data showed that since 2004, BMI has been stable in the younger group and decreased among the elderly. In spite of this, the prevalence of obesity continues to increases, which indicates shifts in the distribution of BMI and merits further analyses.

Diabetes. The proposed epidemic of diabetes has been disputed [43]. In Sweden, the incidence of type 2 diabetes was stable between 1990 and 1995 [44] and between 1972 and 2001 [45] and rose in the UK between 1996 and 2005 [46]. Increasing prevalence in the elderly may be due to both longer survival and better screening [47, 48]. We have extended the duration of our previous study [25] and, in spite of increasing obesity and in agreement with other Swedish studies [15, 45], still do not find any clear trend in self-reported diabetes up to the age of 74 years. The present study includes previously known diabetes, and the true diabetes prevalence is higher than reported. However, the same question to determine diabetes prevalence has been used throughout the study period, and misclassification is hence unlikely to affect the trend. Improvements in other risk factors such as a reduced prevalence of smoking and lower intake of saturated fat, and a possible delay between obesity and onset of diabetes, may explain the inconsistent pattern of increased obesity without an increase in diabetes prevalence.

Socioeconomic. Low level of education is the strongest socioeconomic predictor of IHD [49]. Increased educational inequalities in mortality were recently reported from Norway [8], probably mediated by a more marked risk-factor load [9, 24, 50].

We note two important trends. Having only primary school education is rapidly becoming very uncommon and women clearly outperform men in terms of achieving a university education. Part of the increased proportion of subjects with university education may be due to changes in the educational system. For example, from the mid-1970s, the education required to become a qualified nurse, physiotherapist or occupational therapist was at university level. The health effects of these educational trends have not been fully realized, and further gender inequalities may become apparent.

Concluding remarks

Great improvements in the major cardiovascular risk factors have been observed in the population of northern Sweden over 23 years, in spite of increasing obesity levels. This lends further support to the theory that primary prevention at a population level can have a large impact on the burden of CVD. Preventing any further increase in obesity and further improved treatments of hypertension and high blood lipids are challenges for the future.

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Conflict of interest statement

The authors have no conflict of interest to declare.

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