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Trends in prevalence, treatment and control of hypertension in 38,825 adults over 36 years in Tromsø prospective study

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Abstract

Aims/Background: Serial blood pressure surveys in cohort studies can inform public health policies to control blood pressure for prevention of cardiovascular diseases. *Methods:* Mean levels of systolic blood pressure (SBP) were collected in six sequential surveys, involving 38,825 individuals aged 30–79 years (51% female), between 1979 and 2015 in the Tromsø Study in Norway. Mean levels of SBP, prevalence of hypertension and use of blood pressure-lowering treatment were estimated by age, sex and calendar year of survey. *Results:* Age-specific mean levels of SBP in each decade of age increased by 20–25 mmHg in men and 30–35 mmHg in women and the prevalence of hypertension increased from 25% to 75% among adults aged 30–79 years. Among successive cohorts of adults aged 40–49 years at the time of the six surveys between 1979 and 2015, the mean levels of SBP declined by about 10 mmHg and the prevalence of hypertension declined from 46% to 25% in men and from 30% to 14% in women. The proportion of individuals with hypertension who were treated increased sixfold (from 7% to 42%) between 1979 and 2015, and the proportion of adults with hypertension that were successfully controlled also increased sixfold from 10% to 60% between 1979 and 2015. ***Conclusions:*** **Although this study demonstrated a halving in the age-specific prevalence of hypertension in men and women and a sixfold increase in treatment and control of hypertension, the burden of hypertension remains high among older people in Norway.**

Keywords: *Hypertension, cardiovascular disease, epidemiology, systolic blood pressure, serial surveys, stroke, heart attack*

Introduction

Hypertension is a major modifiable risk factor for cardiovascular disease (CVD) that affects about 1.13 billion people worldwide and accounts for about 42% of deaths in Europe annually [1]. The World Health Organization has specified targets for countries to reduce the prevalence of hypertension by 25% by 2025 to prevent premature deaths due to hypertension-related diseases [1]. In Norway, the proportion of premature deaths (before the age of 70) from CVD declined from 50% to 20% between 1970 and 2015 [2]. While studies in Norway have already highlighted secular decreases in hypertension and other CVD risk factors during this time, detailed analyses summarising the treatment and control of high blood pressure have not been previously characterised [3-6]. Prospective studies, including serial surveys of CVD risk factors over several decades, are likely to be particularly informative for assessing changes in CVD risk factors within and between populations over time. Using data from the Tromsø Study, we assessed differences in age- and sex-specific mean levels of systolic blood pressure (SBP), prevalence of hypertension and use of antihypertensive treatment by calendar year in northern Norway over the last four decades.

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Methods

Study design and participants

The Tromsø Study is a prospective study of 45,473 individuals that assessed mean levels of CVD risk factors in seven sequential surveys between 1974 and 2016 (Table I) [7]. Individuals were recruited from birth cohorts and population registries, with response rates varying between 66% and 77% at successive surveys. Details of the recruitment criteria, study methods and population characteristics have been previously published [7]. Ethics approval for participation in the study was provided by the Regional Committee of Medical and Health Research Ethics and the Norwegian Data Protection Authority. All participants provided written informed consent.

Data collected

Data on past medical history (including prior CVD), lifestyle factors and use of blood pressure-lowering antihypertensive medication were collected by interviewer-administered questionnaires. All participants had measurements of height and weight recorded (which were used to estimate body mass index; BMI). Blood pressure (BP) was measured once in 1974 and twice in 1979 using a mercury sphygmomanometer (ERKAmeter; ERKA, Bad Tölz, Germany) after 1 min at rest in the seated position. From 1986–2016, BP was measured on three occasions using automatic devices at all other visits (from 1986–2002: Dinamap Vital Signs Monitor, Critikon Inc, Tampa, FL, and 2007–2008: Dinamap ProCare 300 monitor, GE Healthcare, Oslo, Norway).

Statistical analysis

Individuals with missing data, for example sex, or data outside the age range of 30–79 years or implausible BP measurements (SBP $\geqslant$ 220 mmHg or $\leqslant$ 80 mmHg; diastolic blood pressure (DBP) $\geqslant$ 120 mmHg or $\leqslant$ 40 mmHg) were excluded. Data collected during the first survey in 1974 were excluded from the present analyses since BP was only measured once and no information was collected on women [7]. In all other surveys used in the analyses, BP was recorded twice after 1 min between readings and the mean of both readings was used in the analyses. If only a single SBP and DBP measurement was recorded (n = 430) then this single value was used in the analyses. Individuals were classified as having hypertension if SBP was 140 mmHg or greater or DBP was 90 mmHg or greater, or they reported current use of antihypertensive medication. Use of antihypertensive medication involved self-reported use of any BP-lowering medication at each survey. Controlled hypertension was defined if individuals had SBP $<$ 140 mmHg and DBP $<$ 90 mmHg. Prior CVD was recorded if participants had reported a current or previous history of heart attack, angina pectoris or ischaemic heart disease at any of the surveys.

Mean levels of age, BMI, SBP and DBP and prevalence of prior CVD were determined at each survey (Supplementary Table I). Mean levels of SBP and DBP were estimated in 10-year age groups separately in men and women at each survey and standardised for the age and sex structure of participants in the 1994 survey (since this included the widest age range). The prevalence of hypertension, the proportion with hypertension who were on treatment, and the proportion of those treated who had their BP successfully controlled were estimated separately in men and women.

Linear mixed models were used to estimate the mean level of SBP by calendar year of survey and included interaction terms for age, sex and calendar year of survey. The present analyses focused on SBP as this is most strongly associated with risk of CVD [8-10]. To estimate differences in the prevalence of hypertension or use of treatment or control at successive surveys, generalised estimation equations (GEE) with age group and sex interaction terms, calendar year, and clustering on individuals were used.

Sensitivity and complete-case analyses were conducted to assess the reliability of estimates by adjusting for BMI and prior CVD diagnosis as model covariates (Supplementary Table II). All analyses were conducted using Stata version 14.2. Items were displayed using Excel 2013 and R version 3.5.1.

Results

After exclusions, a total of 38,825 unique participants were available for the present analysis of which 51% were women (Table I). Among these, 21% (n = 7963) had participated in at least three surveys and 3.7% (n = 1436) had participated in all six surveys (Supplementary Table I). The median age of participants varied by survey between 39 and 59 years in men and 37 and 58 years in women (Table II). The mean levels of BMI (kg/m^2) increased from 1979 to 2015 (25 (SD 3) to 28 (SD 4) kg/m^2) and were higher in men than in women in 2015 (23 (SD 3) kg/m^2 to 27 (SD 5) kg/m^2), respectively (Table II). A prior diagnosis of CVD was more common in men than women and increased in both men and women until 2001, after which it declined (Table II).

At each survey, the mean SBP for men and women increased with age by an approximate factor of 22 mmHg in men and 39 mmHg in women from the

Table I. Selected characteristics of study participants by age, sex, adiposity, prior CVD and calendar year of survey.

Survey year	1979 (n = 10,942)		1986 (n = 15,235)		1994 (n = 23,040)		2001 (n = 7789)		2007 (n = 12,373)		2015 (n = 20,279)	
	Men (n = 5944)	Women (n = 4998)	Men (n = 7902)	Women (n = 7333)	Men (n = 11,060)	Women (n = 11,980)	Men (n = 3364)	Women (n = 4425)	Men (n = 5820)	Women (n = 6553)	Men (n = 9664)	Women (n = 10635)
Age (years), n (%)												
30–39	3121 (53)	3141 (63)	3286 (42)	3517 (48)	3189 (29)	3591 (30)	279 (8)	420 (9)	210 (4)	295 (5)	-	-
40–49	1906 (32)	1857 (37)	2546 (32)	2571 (35)	3275 (30)	3370 (28)	605 (18)	756 (17)	1650 (28)	1899 (29)	3048 (32)	3371 (32)
50–59	917 (15)	-	1820 (22)	1245 (17)	2207 (20)	2197 (18)	363 (11)	716 (16)	1140 (20)	1287 (20)	2786 (29)	3239 (30)
60–69	-	-	3530 (4)	-	1474 (13)	1613 (13)	1242 (37)	1450 (33)	1986 (34)	2098 (32)	2497 (26)	2668 (25)
70–79	-	-	-	-	915 (8)	1209 (10)	875 (26)	1083 (24)	833 (14)	974 (15)	1313 (14)	1357 (13)
Blood pressure (mmHg) mean (SD)												
Systolic	133 (14)	125 (15)	133 (15)	124 (16)	133 (22)	137 (147)	139 (20)	137 (23)	137 (20)	132 (24)	132 (18)	126 (20)
Diastolic	85 (10)	81 (10)	80 (11)	76 (10)	81(11)	77 (12)	81 (11)	78 (12)	81 (10)	75 (10)	78 (10)	73 (10)
Mean BMI (SD)	25 (3)	23 (3)	25 (3)	24 (4)	26 (3)	25 (4)	27 (4)	26 (5)	27 (4)	27 (5)	28 (4)	27 (5)
Prior CVD, n(%)	111 (2)	17 (1)	291 (4)	54 (1)	878 (8)	555 (5)	506 (16)	317 (8)	632 (12)	309 (5)	870 (8)	324 (3)

SD: standard deviation; BMI: body mass index; CVD: cardiovascular disease including angina, heart attack and stroke. Estimates rounded to nearest whole number such that some subgroups do not equal 100.

- denotes the missing data

Table II. Age- and sex-standardised levels of systolic blood pressure and diastolic blood pressure by age group at survey.

Sex	SBP/DBP	Age (year)	Mean levels of BP by year of survey					
			1979	1986	1994	2001	2007	2015
Men	SBP	30–39	131	130	131	128	129	-
		40–49	134	132	133	137	135	126
		50–59	138	138	139	142	142	131
		60–69	-	142	148	149	147	136
		70–79	-	-	153	148	152	140
	DBP	30–39	84	77	75	72	76	80
		40–49	87	81	80	78	79	79
		50–59	89	85	84	84	82	79
		60–69	-	85	86	83	82	76
		70–79	-	-	85	82	79	70
Women	SBP	30–39	121	119	120	114	112	-
		40–49	129	125	126	120	118	116
		50–59	-	133	136	134	128	123
		60–69	-	-	149	142	141	133
		70–79	-	-	159	152	152	144
	DBP	30–39	79	73	71	69	70	-
		40–49	84	78	75	75	73	73
		50–59	-	81	80	79	75	74
		60–69	-	-	83	80	76	74
		70–79	-	-	84	81	76	74

SBP: systolic blood pressure (mmHg); DBP: diastolic blood pressure (mmHg); BP: blood pressure.

- denotes the missing data

Table III. Prevalence of hypertension, treatment among hypertensives, and hypertension control, by age group at survey.

		Sex and age at survey									
		Men					Women				
		30–39	40–49	50–59	60–69	70–79	30–39	40–49	50–59	60–69	70–79
Prevalence of hypertension, (%)	1979	36	46	48	-	-	14	30	-	-	-
	1986	23	31	47	60	-	8	19	37	-	-
	1994	24	32	49	67	78	-	19	39	61	80
	2001	20	27	43	62	74	7	16	33	56	76
	2007	22	30	47	65	76	8	18	36	59	78
	2015	-	25	40	59	71	-	14	31	53	73
Treatment among hypertensives, (%)	1979	2	5	8	-	-	3	7	-	-	-
	1986	3	7	12	19	-	4	10	13	-	-
	1994	4	8	14	23	28	5	12	16	21	58
	2001	8	15	25	37	44	10	22	27	35	44
	2007	12	22	34	48	56	15	31	37	46	55
	2015	-	31	46	60	67	-	42	48	58	66
Control of hypertension, (%)	1979	9	8	7	-	-	18	13	-	-	-
	1986	33	32	27	23	-	53	43	31	-	-
	1994	32	32	26	22	17	52	42	30	21	13
	2001	46	44	39	34	28	66	57	44	33	22
	2007	50	49	44	38	31	70	61	48	37	25
	2015	-	64	59	52	46	-	74	63	51	38

Hypertension is SBP/DBP $\geqslant$ 140/90 mm Hg, treatment is proportion initiated on antihypertensives among hypertensives and control is proportion among treated hypertensives achieving SBP/DBP $<$ 140/90 mmHg. The data were calculated from GEE models after adjustment for age and sex.

- denotes the missing data

youngest to oldest age groups (from age 30–39 years to age 70–79 years) (Figure 1). Among distinct cohorts of adults aged 40–49 years at the time of the six surveys, the mean levels of SBP declined by 8 mmHg among men and 13 mmHg among women between 1979 and 2015 (Table II). Likewise, the prevalence of hypertension among those aged 40–49 years at each survey almost halved between 1979 and 2015 in men (46% to 25%) and more than halved in women (30% to 14%) (Table III, Figure 2).

The proportion of individuals with hypertension who reported current use of antihypertensive treatment increased progressively with age in each decade, with the greatest increases occurring after 1986. From 1994 to 2001, the proportion of individuals with treated hypertension increased twofold for men

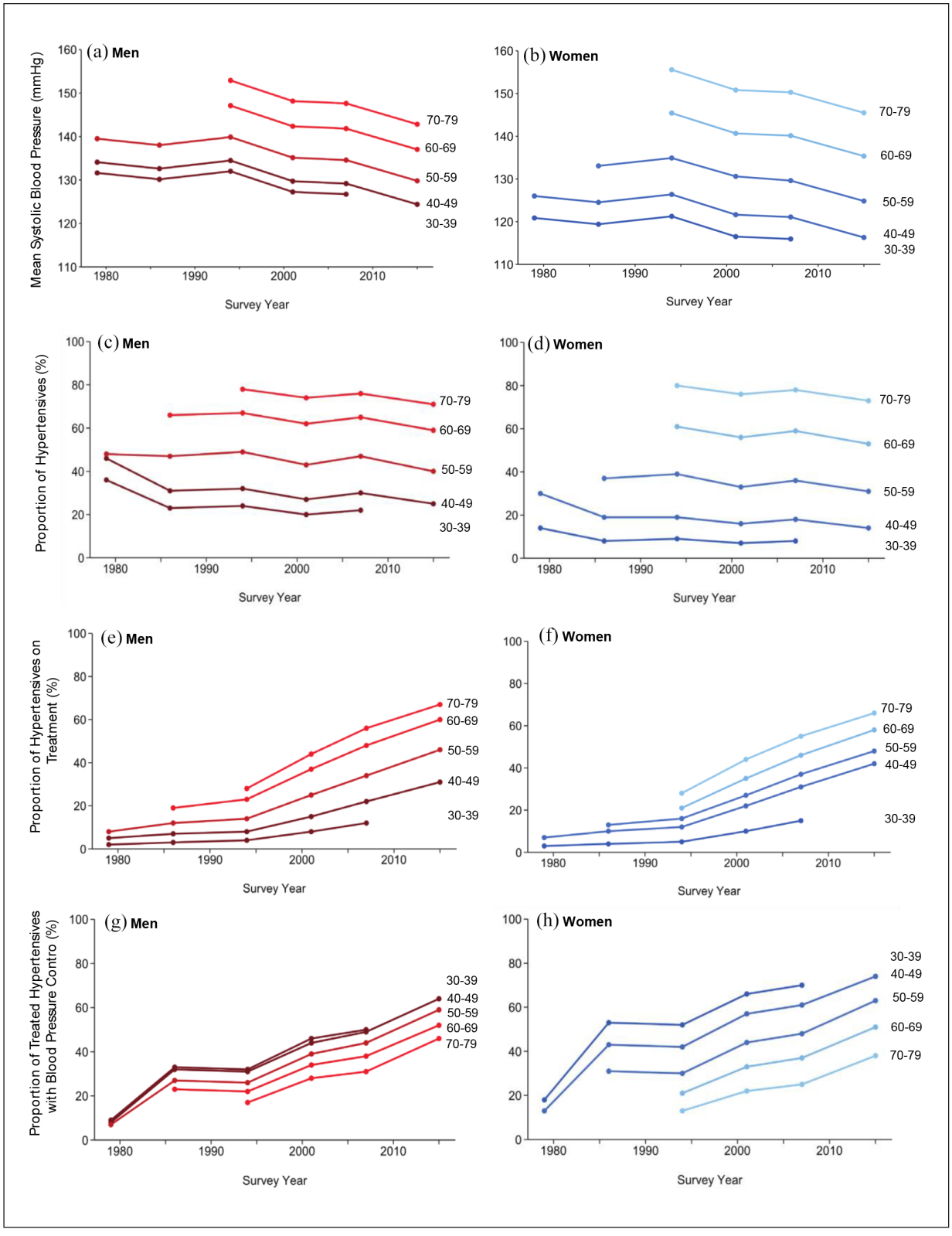

Figure 1. Mean systolic blood pressure (a, b), proportion of hypertensives (c, d), proportion of hypertensives on treatment (e, f), and proportion of treated hypertensives achieving blood pressure control (g, h) in men (left panels, red) and women (right panels, blue) by 10-year age categories. Continuous estimates are from a linear mixed model and categorical estimates are from a GEE. All estimates are adjusted for age and sex.

Hypertension is SBP/DBP $\geq$ 140/90 mm Hg, treatment is proportion initiated on antihypertensives among hypertensives and control is proportion among treated hypertensives achieving SBP/DBP $<$ 140/90 mmHg.

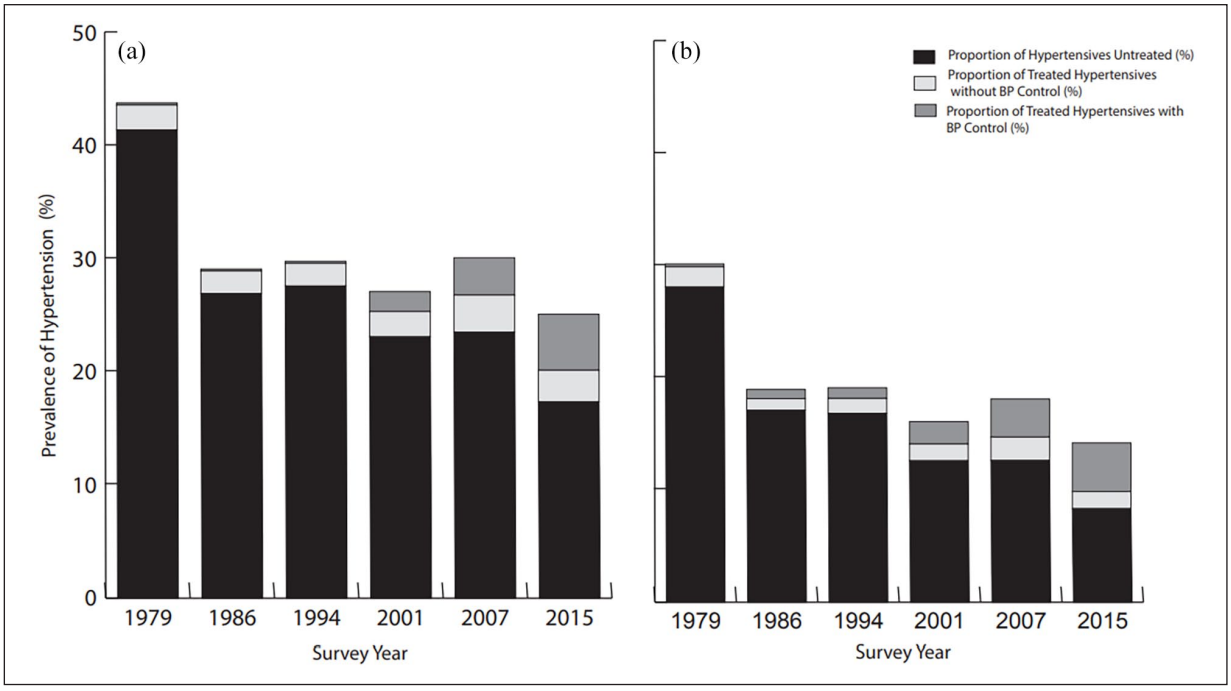

Figure 2. The prevalence of hypertension (full bar) among men (a) and women (b) aged 40–49 years throughout the survey years. The bottom black bar represents the proportion of hypertensives not on treatment, the middle bar represents the proportion of treated hypertensives without blood pressure control, and the top bar represents the proportion of treated hypertensives achieving blood pressure control. Estimates are derived from GEE models adjusted for age and sex.
Hypertension is SBP/DBP ⩾ 140/90 mm Hg, treatment is proportion initiated on antihypertensives among hypertensives and control is proportion among treated hypertensives achieving SBP.

aged 30–59 years. During this same period, the proportion of individuals with hypertension who were treated increased by 11% in men aged 50–59 years, 14% in men aged 60–69 years and 16% in men aged 70–79 years (Table III, Figure 2). From 1994 to 2001, the proportion of individuals with hypertension treated increased by 10% in women aged 40–49 years, 11% in women aged 50–59 years, 14% in women aged 60–69 years and 16% in women aged 70–79 years (Table III, Figure 2).

The proportion of adults with hypertension who were successfully controlled increased in all age groups between 1979 and 2015 and control rates were stable between 1986 and 1994 (Table III, Figure 2). Overall, the prevalence of hypertension and the proportion treated, but uncontrolled, decreased during each decade of follow-up. Among individuals aged 40–49 years, the prevalence of hypertension decreased from 1979 to 1994 and remained relatively stable before decreasing further until 2015 (Figure 2). The prevalence of hypertension declined in men from 46% in 1997 to 25% by 2015 and in women from 30% in 1979 to 14% by 2015.

The proportion of middle-aged treated hypertensives remained stable from 1979 to 1994, and subsequently increased until 2015 (Table III, Figure 2). The proportion of men with treated hypertension increased sixfold from 5% to 31% between 1979 and 2015. The proportion of women with treated hypertension also increased sixfold from 7% to 42% between 1979 and 2015. The proportion of adults with hypertension who were successfully controlled increased from 1979 to 1986, remained stable until 1994, and increased again until 2015 (Table III). Overall, between 1979 and 2015, there was a 56% increase in the proportion of adults with hypertension that were controlled in men and 61% increase in women aged 40–49 years (Figure 2).

Discussion

This study has demonstrated substantial reductions in mean SBP and the prevalence of hypertension and an increase in the use of BP-lowering treatment and control of hypertension over the last four decades in Norway. Between 1979 and 2015, the mean levels of SBP declined by 10 mmHg, the prevalence of hypertension was halved and the proportion of adults with hypertension who were treated increased sixfold among people aged 40 to 49 years. Moreover, the prevalence of control among those with hypertension who were successfully controlled also increased about sixfold in men and women between 1979 and 2015.

The magnitude of the reduction in mean levels of SBP observed in the present study were comparable with estimates from previous reports in Norway for people aged 40–60 years [5,6] and from pooled analyses of high-income countries (HICs) including the UK and USA, especially for older people [11,12]. In most countries, men had higher mean levels of SBP than women, which is consistent with the findings in the present study [11-13].

The approximate halving of the prevalence of hypertension is consistent with estimates in other HICs between the 1980s and the 2000s [12,13]. The findings of the present study are also consistent with trends reported in 12 HICs, which reported the greatest reduction in the prevalence of hypertension occurring between the 1990s and the mid-2000s [14]. However, in contrast with these countries, the prevalence of hypertension in Norway did not attenuate, but continued to decline from 2007 to 2015. [13] The prevalence of hypertension in Norway was lower than in Italy (77%) but was higher than Canada (61%) for men and women aged 70–79 after 2010 [14]. From 2005 to 2017, reductions in hypertension prevalence were comparable to those observed in the USA, but greater than those observed in Australia and in New Zealand among participants aged 50–59 years [9]. Nevertheless, a substantial burden of uncontrolled hypertension was still observed among men and women aged 60 years and older (>50%), which is higher than estimates for Denmark and Sweden [13-17].

The increasing proportions of treated hypertensives are consistent with those observed in middle-aged people in HICs [12]. Increases in the use of treatment were more extreme in Norway for middle-aged women compared with rates in the USA, UK and Japan [13,14]. The proportion of treated hypertensives was similar to individuals in the UK aged 50–69 years (45%–59%), but lower in individuals aged 40–49 and 70–79 years (36% and 73%, respectively) in 2016 [14]. Current estimates of hypertension treatment were at least 10% higher in 2015 than those calculated in a previous analysis of Tromsø data from 2007, however, these differences are inflated as the previous analysis calculated hypertensive treatment among the entire cohort and not as a proportion of hypertensives [4,6]. Consistent with the findings of the present study, the use of treatment was higher in women than in men in most HICs [13].

We have reported increasing proportions of BP control that are consistent with other HICs [13,14]. In the 1980s to early 1990s, the proportion of age- and sex-specific BP control was less than 25% in most countries, which is consistent with men aged 50–59 years in the present study [11-13]. Control rates in Norway were at least 10% higher for men and women than estimates in the UK and at least 15% higher than in Australians for those aged 40–79 years in 2015 [14]. Despite higher levels of treatment in South Korea and China, participants in the present study achieved >30% higher control rates than in Chinese and South Korean populations aged 40–49 years [13,14]. In contrast with most countries, the proportions of control in the present study decreased in the older age groups and were highest among middle-aged men and women (aged 40–60 years) [13,14]. The higher control rates in women than in men below 60 years are consistent with other HICs [14].

In addition to BP treatment, changes seen in hypertension treatment and control in this report may be attributed to greater primary prevention efforts and population modifications of hypertension risk factors. While these variables were available for the present analysis, previous studies have also characterised some of these trends. Research that was also based on the Tromsø cohort has demonstrated that smoking rates have declined substantially in Norway over the last half century [18-22]. Additionally, while the consumption of alcohol has remained steady during this time, it is currently among the lowest in Organisation for Economic Co-operation and Development countries [23]. In neighbouring Finland, where both behaviours are common, the prevalence of hypertension has remained high [13,23,24].

Changes in the proportion of hypertension treatment and control may in part reflect targeted increases in prescriptions of antihypertensives, higher intensity of treatment, and earlier initiation of treatment. Over the last few decades general European risk prediction scores were replaced with Norwegian-adapted models, firstly NORRISK1 and subsequently NORRISK2, which aimed to capture the risk of both fatal and non-fatal CVD events [25]. Recent analysis of the two risk scores in the Tromsø cohort has demonstrated that the proportion eligible for initiation is higher using NORRISK2, including an additional 3% on prevention and treatment for BP alone [26]. Improved control and treatment of hypertension may also reflect greater access to more effective antihypertensive medications. While antihypertensives are considered necessary medications and are reimbursed by Norwegian pharmacies, policies in the 1990s shifted reimbursements to exclusively cover specific antihypertensives (thiazides) as a first line of treatment [27]. This law concurrently encouraged multi-drug prescriptions, resulting in a sixfold increase in prescriptions for both angiotensin-converting-enzyme inhibitors and thiazides within 2 years of its ratification [27]. Further research investigating the relationships between prescription policies and intensity of treatment,

and lifestyle changes including smoking and alcohol consumption are needed to understand the determinants of the trends observed in this report.

The strengths of this study include its large sample size and the use of serial measurements of BP over almost four decades. This study documented age- and sex-specific trends over 40 years, which could guide public health policies on implementation of effective strategies for prevention and treatment of hypertension in age- and sex-specific subgroups in the Norwegian population. Although the cohort is regionally representative, the demographic characteristics of Tromsø are comparable to those living elsewhere in Norway, hence, the analyses from this cohort could be used to inform national policies [7]. Future research should explore additional covariates that affect BP beyond those examined in the present analysis, including seasonality and lifestyle behaviours [14]. The findings from the present analysis nonetheless provide strong support for further investigations of trends in mean levels of SBP, prevalence of hypertension, use of treatment and control.

Hypertension is a leading risk factor for CVD that contributes substantially to morbidity and mortality in Europe [1]. Previous studies have demonstrated substantial changes in CVD-related mortality in Norway over the last four decades; the present analysis of sequential survey data on BP over four decades has demonstrated marked and sustained reductions in SBP over this time period. Appreciation of the importance of public health strategies to improve detection, treatment and control of SBP is highly relevant to developing public health strategies to reduce the proportion of premature deaths from CVD, whose burden is increasing in many parts of the world [13]. The favourable trends in prevalence, treatment and control of BP observed in the Tromso cohort suggest that could be an exemplar for what could also be achieved elsewhere in Europe and beyond.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Supplemental material

Supplemental material for this article is available online.

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