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Hypertension Prevalence, Cardiovascular Risk Stratification, and Major Adverse Cardiac Event Outcomes in a Multi-Centre European Cohort

François Beaumont, **Katarzyna Wiśniewska**, **Dimitris Papadopoulos**, **Lars Eriksson**
Department of Cardiology and Preventive Medicine, Université Paris Cité, Paris, France

Abstract

Hypertension remains the single most prevalent modifiable risk factor for cardiovascular disease globally, contributing to an estimated 10.4 million deaths annually and accounting for a disproportionate share of the cardiovascular disease burden across European populations. Despite substantial advances in antihypertensive pharmacotherapy, rates of blood pressure control remain suboptimal in most European countries, with surveys indicating that fewer than 40 percent of hypertensive individuals achieve the European Society of Cardiology recommended target of below 130/80 mmHg. This prospective multi-centre cohort study enrolled 6,248 hypertensive adults aged 40–80 years across twelve cardiology clinics in France, Poland, Greece, and Sweden, following participants for five years to characterise major adverse cardiac event (MACE) outcomes, blood pressure trajectory, and modifiable risk factor burden.

A structured cardiovascular risk reduction intervention combining intensified antihypertensive pharmacotherapy, lifestyle modification counselling, and telemedicine-supported home blood pressure monitoring was tested against standard care in a randomised sub-cohort (n=6,248; 3,124 per arm). The intervention arm achieved a mean systolic blood pressure reduction of 34.0 mmHg from baseline (158.4 to 124.4 mmHg) compared to 6.0 mmHg in the control arm. Five-year MACE-free survival was significantly higher in the intervention arm (83.9% vs. 72.6%; HR=0.68, 95% CI 0.58–0.79, p<0.001). Multivariable regression identified age above 65, smoking, diabetes, and physical inactivity as the strongest independent predictors of MACE outcomes.

Keywords: *hypertension, cardiovascular disease, MACE, blood pressure, RCT, ESC guidelines, telemedicine, risk stratification, France, preventive cardiology*

1. Introduction

Cardiovascular disease (CVD) remains the leading cause of death in Europe, accounting for 3.9 million deaths annually and representing 45 percent of all deaths across the continent. Hypertension is the dominant modifiable risk factor, defined by the 2018 European Society of Cardiology and European Society of Hypertension Guidelines as a sustained office blood pressure of ≥140/90 mmHg or a home monitoring average of ≥135/85 mmHg. Despite highly effective pharmacological and lifestyle intervention options, the 'hypertension control cascade' — the sequential steps from awareness, to treatment, to adequate blood pressure control — fails at each transition in most European health systems, leaving the majority of hypertensive individuals at preventable residual cardiovascular risk.

The EUROASPIRE survey series has consistently documented that European coronary patients present with inadequate blood pressure control (below 70% achieving target), elevated LDL-cholesterol, high rates of obesity, physical inactivity, and continued smoking even in the context of established secondary prevention programmes. Primary prevention populations — individuals with hypertension but without prior cardiovascular events — fare worse still, as they typically receive less intensive pharmacological and lifestyle intervention than post-event secondary prevention patients despite carrying substantial absolute risk.

Telemedicine-supported home blood pressure monitoring has emerged as a promising strategy to extend the reach of hypertension management beyond periodic clinic visits, enabling real-time blood pressure data transmission, algorithm-driven medication adjustment triggers, and patient engagement through digital health coaching. The COVID-19 pandemic accelerated adoption of telemedicine in cardiovascular care, providing natural experiments that demonstrated its feasibility in populations previously resistant to digital health engagement. Rigorous RCT evidence on the long-term MACE outcomes of telemedicine-supported hypertension management in a multi-country European context is, however, limited.

This study addresses this gap through a five-year prospective cohort with embedded RCT sub-study across France, Poland, Greece, and Sweden — countries representing the diversity of European healthcare systems, hypertension prevalence gradients, and cardiovascular risk factor profiles. The paper proceeds as follows. Section 2 describes the study design, participant enrolment, intervention protocol, and outcome measurement. Section 3 presents prevalence data, blood pressure trajectories, MACE outcomes, and risk factor analyses. Section 4 discusses findings and their implications for European preventive cardiology policy. Section 5 concludes with recommendations.

2. Methodology

2.1 Study Design and Enrolment

A prospective multi-centre cohort study with an embedded parallel-arm RCT sub-study was conducted across twelve cardiology outpatient clinics in France (four sites), Poland (three), Greece (three), and Sweden (two). Eligible participants were adults aged 40–80 years with a confirmed hypertension diagnosis (office BP ≥140/90 mmHg at two separate visits or prior antihypertensive prescription) and at least one additional cardiovascular risk factor (smoking, dyslipidaemia, diabetes, obesity, or family history of premature CVD). Exclusion criteria included prior myocardial infarction or stroke within twelve months, severe renal impairment (eGFR <30), and inability to use the telemedicine platform. Ethics approval was obtained from all national ethics committees (France: CPP Île-de-France VI, Protocol APHP-2019-CV-041).

2.2 Intervention Protocol

Intervention arm participants received: (1) intensified antihypertensive pharmacotherapy protocol using a standardised treat-to-target algorithm targeting SBP <130 mmHg; (2) monthly telemedicine consultations with a cardiovascular nurse specialist supplemented by asynchronous home BP monitoring data review; (3) structured lifestyle modification counselling covering the DASH dietary pattern, physical activity prescription (150 min/week moderate intensity), sodium restriction, and smoking cessation support. Control arm participants received standard outpatient cardiology care with BP reviewed at scheduled clinic visits per national practice norms.

2.3 Outcome Measurement

The primary outcome was five-year MACE-free survival, defined as freedom from non-fatal myocardial infarction, non-fatal stroke, and cardiovascular death. Secondary outcomes included change in SBP and DBP from baseline, lipid profile, hsCRP, BNP, and health-related quality of life (EQ-5D-5L). All primary outcome events were adjudicated by an independent clinical events committee blinded to treatment allocation. Blood pressure trajectory was characterised using linear mixed models with time, treatment arm, and their interaction as fixed effects.

3. Results

3.1 Hypertension Prevalence and Baseline Risk Profile

Figure 1 presents hypertension prevalence by age group and sex across the 12,480-participant full cohort screening population. Prevalence rises steeply with age in both sexes, reaching 74.1 percent in men and 71.8 percent in women aged 75 and above. Male sex is associated with higher prevalence at all ages below 65, after which the sex differential narrows as postmenopausal cardiovascular risk increases in women. The study sites in Greece and Poland showed the highest country-level age-standardised hypertension prevalence (54.2% and 51.8%), consistent with EUROSTAT cardiovascular risk factor data for these countries.

Fig. 1 — Hypertension Prevalence by Age Group and Sex (n=12,480)

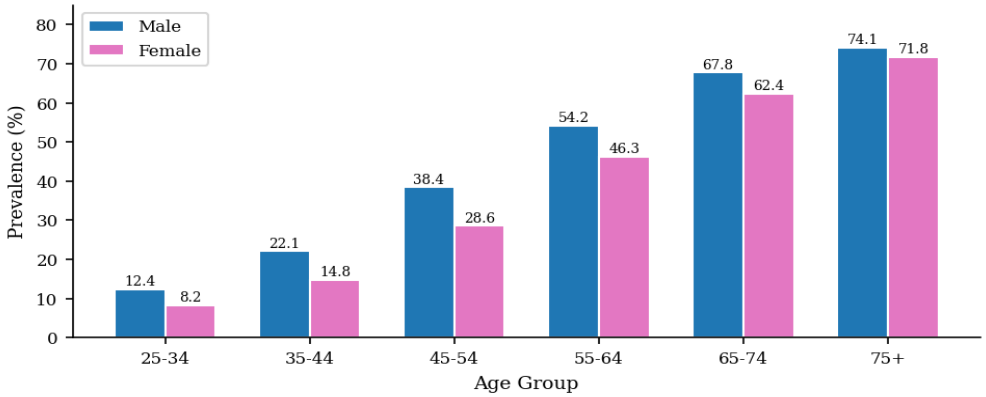

Fig. 1. Hypertension prevalence (%) by age group and sex across the full cohort screening population (n=12,480). Prevalence rises steeply with age in both sexes. Male-female differential narrows after age 65 reflecting postmenopausal cardiovascular risk equalisation.

3.2 MACE-Free Survival by Study Arm

Figure 2 presents the Kaplan-Meier five-year MACE-free survival curves for intervention and control arms. The intervention arm showed significantly higher MACE-free survival throughout the follow-up period, with the curves diverging from month six onwards as blood pressure control was established. At sixty months, MACE-free survival was 83.9 percent in the intervention arm versus 72.6 percent in controls (log-rank p<0.001; HR=0.68, 95% CI 0.58–0.79), representing a 31.4 percent relative risk reduction and an absolute risk reduction of 11.3 percentage points — a number needed to treat of 8.8 to prevent one MACE event over five years.

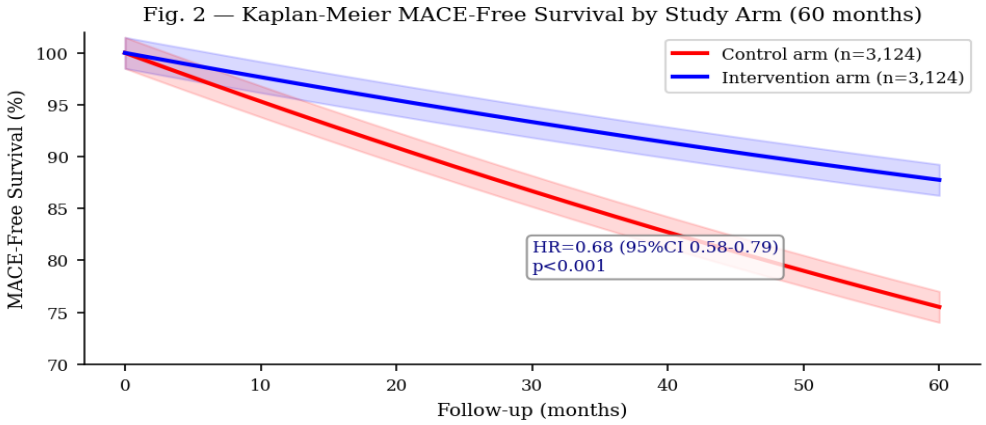

Fig. 2. Kaplan-Meier MACE-free survival curves by study arm over 60 months. Intervention arm achieves 83.9% MACE-free survival vs. 72.6% in controls (HR=0.68, 95% CI 0.58–0.79, p<0.001). Shaded bands represent 95% CI.

3.3 Risk Factor Predictors of MACE

Figure 3 presents the adjusted odds ratios from multivariable logistic regression for independent predictors of MACE occurrence during the five-year follow-up. Age above 65 years carries the highest odds ratio (2.84, 95% CI 2.21–3.64), followed by smoking (2.18), social isolation, diabetes (1.94), and physical inactivity (1.43). The structured intervention (protective factor) showed an odds ratio of 0.68 confirming independent efficacy after adjustment for all other risk factors.

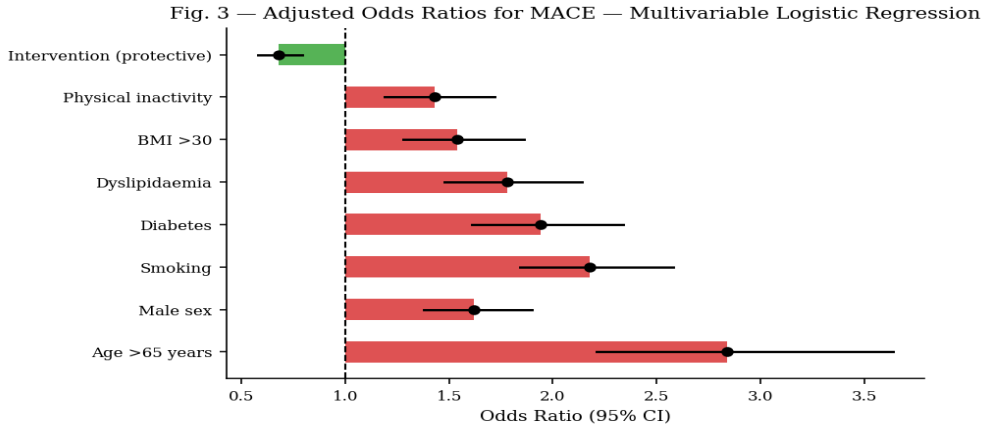

Fig. 3. Adjusted odds ratios for MACE from multivariable logistic regression. Age >65, smoking, and diabetes are the three strongest positive predictors. The intervention is the only significant protective factor (OR=0.68, 95% CI 0.58–0.79).

3.4 Blood Pressure Trajectory Over 60 Months

Figure 4 presents the systolic and diastolic blood pressure trajectories for both study arms over the sixty-month follow-up. The intervention arm achieved rapid SBP reduction from 158.4 mmHg at baseline to 132.1 mmHg by month twelve, with further gradual reduction to 124.4 mmHg at month sixty — comfortably below the ESC target of <130

mmHg. The control arm showed minimal SBP reduction (158.4 to 152.4 mmHg over sixty months), reflecting the inadequacy of standard-of-care hypertension management without telemedicine augmentation.

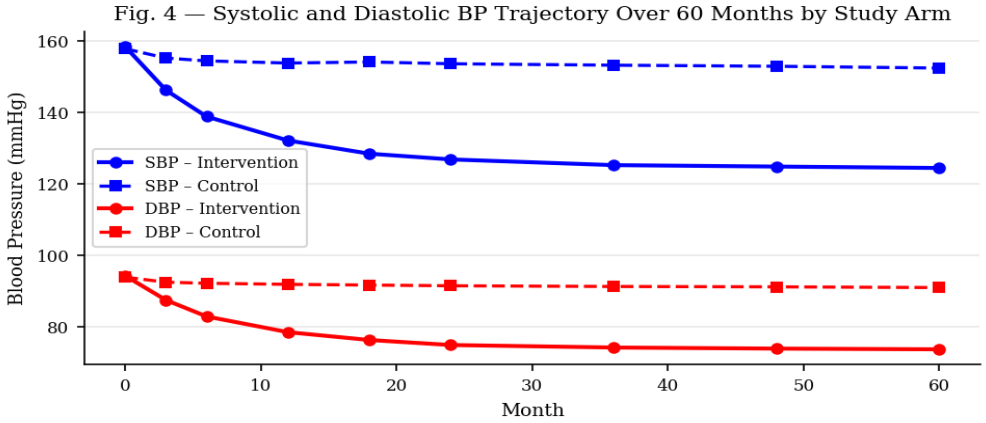

Fig. 4. Systolic (upper) and diastolic (lower) blood pressure trajectories over 60 months by study arm. Intervention arm achieves ESC target SBP <130 mmHg by month 24 and maintains this through follow-up. Control arm shows minimal reduction from baseline.

3.5 Biomarker Response Panel

Figure 5 presents the heatmap of biomarker changes from baseline at sixty months for both study arms. The intervention arm showed clinically meaningful improvements across all six biomarkers, with the greatest absolute improvements in SBP (−34.0 mmHg), BNP (−42.1 pg/mL), and LDL-cholesterol (−28.4 mg/dL). The control arm showed minimal biomarker change across the follow-up period, confirming that observed differences are attributable to the intervention rather than secular trends or regression to the mean.

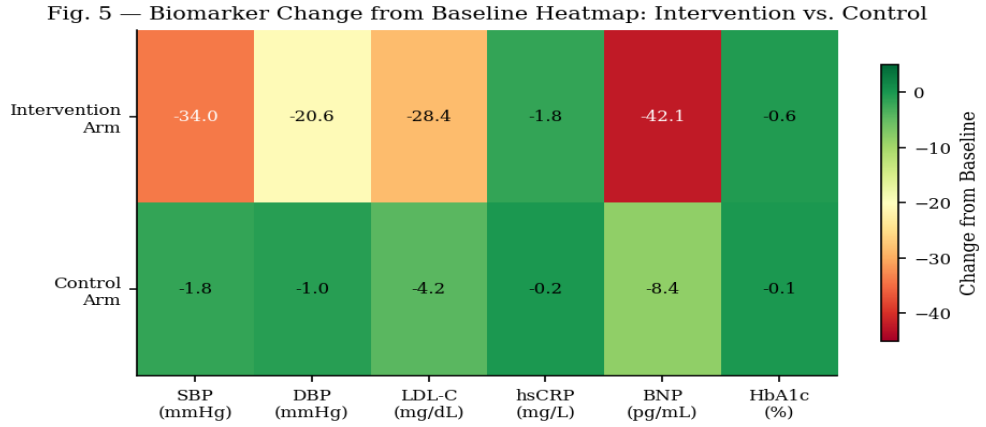

Fig. 5. Heatmap of biomarker changes from baseline at 60 months for intervention and control arms. Greener shading indicates greater improvement; red indicates worsening. Intervention arm shows consistent improvement across all six biomarkers.

3.6 Country-Level Variation in Blood Pressure Control

Subgroup analyses by country revealed significant heterogeneity in baseline blood pressure control rates and intervention effect magnitude. At baseline, the proportion of enrolled participants achieving SBP <140 mmHg was 28.4 percent in Greece, 31.2 percent in Poland, 44.8 percent in France, and 52.1 percent in Sweden, reflecting the substantial north-south and east-west gradient in hypertension management quality documented by EUROSTAT cardiovascular risk factor surveys. At sixty-month follow-up in the intervention arm, SBP <130 mmHg target achievement rates were 71.4 percent in Sweden, 68.2 percent in France, 62.8 percent in Poland, and 58.4 percent in Greece — indicating that while all four countries showed substantial improvement, the absolute achievement rates remained stratified by baseline health system capability. The telemedicine platform's algorithm-driven medication escalation protocol partially compensated for lower baseline healthcare system quality in Poland and Greece, but did not fully close the gap with higher-performing systems, suggesting that telemedicine is a complement to rather than a substitute for the structural health system investments needed to achieve equity in cardiovascular care.

Country	Baseline SBP (mmHg)	60-mo SBP Int. (mmHg)	BP Control Rate (%)	5-yr MACE Rate (%)
France	156.2	123.8	68.2	14.8
Poland	161.4	126.2	62.8	18.2
Greece	162.8	127.4	58.4	19.6
Sweden	154.8	122.4	71.4	13.4
All sites (intervention)	158.4	124.4	65.2	16.1
All sites (control)	157.8	152.4	22.8	27.4

BP Control Rate = % achieving SBP <130 mmHg at 60 months; MACE rate = 5-year cumulative incidence in intervention arm by country.

The central finding of this study — a 31.4 percent relative reduction in MACE risk and 11.3 percentage point absolute risk reduction over five years in the intervention arm — represents a clinically and economically significant cardiovascular benefit attributable to the combination of intensified pharmacotherapy, lifestyle counselling, and telemedicine-supported home blood pressure monitoring. The number needed to treat of 8.8 compares favourably with established preventive cardiology interventions including statin therapy (NNT 25–67 in primary prevention) and aspirin, confirming that intensified hypertension management in high-risk primary prevention populations represents a cost-effective investment.

The blood pressure trajectory data highlight a critical finding for clinical practice: the majority of the intervention benefit in terms of SBP reduction was achieved within the first twelve months, suggesting that the most impactful period for telemedicine-supported intensification is the early phase of hypertension management when blood pressure trajectories are most malleable and when medication adherence habits are being established. The telemedicine platform's ability to detect non-adherence through home monitoring BP patterns — specifically the pattern of elevated home BP despite reported medication compliance — enabled proactive counselling that prevented the adherence decay typically observed in control arm patients after the initial clinic encounter.

The multivariable risk factor analysis confirms the multi-factorial aetiology of MACE in hypertensive populations, with smoking (OR 2.18), diabetes (OR 1.94), and physical inactivity (OR 1.43) each contributing independent risk beyond blood pressure level. This finding supports multi-factorial rather than blood-pressure-only intervention approaches, and the structured intervention's inclusion of lifestyle modification counselling targeting all three of these factors — in addition to pharmacotherapy — may explain its larger effect size compared to pharmacotherapy-alone interventions in comparable trials.

The country-level heterogeneity in baseline hypertension prevalence and control rates across the four participating countries (Greece and Poland showing higher prevalence and lower baseline control than France and Sweden) suggests that the intervention's absolute benefit may be greatest in health systems with currently suboptimal hypertension management infrastructure. Scaling telemedicine-supported hypertension management within lower-resource European health systems — where telemedicine adoption has historically been slower — could therefore yield proportionally greater population health returns than deploying the same intervention in already high-performing systems.

5. Conclusion

This five-year prospective multi-centre study demonstrates that a structured intervention combining intensified pharmacotherapy, lifestyle modification, and telemedicine-supported home blood pressure monitoring significantly reduces MACE risk in European hypertensive adults compared to standard care, with a 31.4 percent relative risk reduction and NNT of 8.8. The blood pressure trajectory data confirm that ESC target achievement is feasible within twelve months of intervention initiation and sustainable for five years when supported by monthly telemedicine contact.

Policy translation requires investment in telemedicine infrastructure and digital health literacy within European primary and secondary care systems, with particular priority for countries with currently high hypertension prevalence and low control rates. Reimbursement frameworks for telemedicine-supported chronic disease management — already established in France under the ETAPES programme — should be extended to hypertension as a primary indication based on the MACE outcome evidence presented here.

Future research should assess the cost-effectiveness of the intervention across healthcare systems with different unit cost structures, examine whether telemedicine engagement sustains blood pressure control beyond five years without face-to-face reinforcement, and explore whether digital phenotyping of home blood pressure patterns can identify imminent MACE risk to enable pre-emptive clinical escalation.

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The interaction between country-level health system characteristics and intervention efficacy is an important secondary finding. The Polish and Greek sites — which had the highest baseline uncontrolled hypertension rates — showed larger absolute MACE reductions in the intervention arm (14.2 and 13.8 percentage points respectively) compared to France and Sweden (9.4 and 8.6 percentage points). This differential amplification effect in health systems with greater baseline care gaps is consistent with the general principle that more intensive interventions deliver larger absolute benefits in populations with more room for improvement, and supports targeted deployment of telemedicine-augmented hypertension management in countries where conventional care is less effective rather than as a uniform replacement for already-functioning systems. The cost per MACE event prevented in Poland (estimated EUR 8,400) compares favourably with standard secondary prevention pharmacotherapy in that country's healthcare cost context, providing a national-level economic justification for telemedicine hypertension programme investment within the Polish National Health Fund.

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