
There may be differences between this version and the published version. You are advised to consult the publisher’s version if you wish to cite from it.

http://eprints.gla.ac.uk/144921/

Deposited on: 27 July 2017
LDL-Cholesterol Lowering for the Primary Prevention of Cardiovascular Disease Among Men with primary elevations of LDL-cholesterol levels of 190 mg/dL or above

Analyses from the WOSCOPS 5-year Randomised Trial and 20-year Observational Follow-Up

Running title: LDL-C Lowering for Primary Prevention in LDL-C ≥190

Authors: Antonio J. Vallejo-Vaz¹, MD, PhD; Michele Robertson², BSc; Alberico L. Catapano³, PhD; Gerald F. Watts⁴, DSc, MD, PhD; John J. Kastelein⁵, MD, PhD; Chris J. Packard⁶, DSc; Ian Ford², PhD; Kausik K. Ray¹, MD, MPhil.

Affiliations:

(1) Imperial Centre for Cardiovascular Disease Prevention (ICCP), Department of Primary Care and Public Health, School of Public Health, Imperial College London, London, UK. (2) Robertson Centre for Biostatistics, University of Glasgow, Glasgow, UK. (3) Department of Pharmacological and Biomolecular Sciences, Università degli Studi di Milano and IRCCS Multimedica, Milan, Italy. (4) Lipid Disorders Clinic, Department of Cardiology, Royal Perth Hospital, School of Medicine and Pharmacology, University of Western Australia, Perth,
Australia. (5) Department of Vascular Medicine, Academic Medical Centre, Amsterdam, The Netherlands. (6) College of Medical, Veterinary and Life Sciences, University of Glasgow, Glasgow, UK

Corresponding author: Prof. Kausik K. Ray

Imperial Centre for Cardiovascular Disease Prevention, Department of Primary Care and Public Health, School of Public Health, Imperial College London; Reynolds Building, St Dunstan’s road, London, W6 8RP, United Kingdom. Phone: +44 2075 940 716. E-mail: k.ray@imperial.ac.uk

Word count:

- Abstract (max. 350): 347.
- Clinical Perspective (Q1 and Q2 max. 100 words each): Q1: 93 words; Q2: 102 words.
- Main text (max. 5000 words): 4334.

Figures/Tables (max. 8 in total): 5 figures/3 tables.

References: 31 references.

Date of revision (revision submitted): July, 2017
Question: Is the lowering of LDL-cholesterol in the primary prevention of patients with LDL-cholesterol ≥190 mg/dL beneficial?

Findings: in this post-hoc analysis from the WOSCOPS randomised trial of 2560 men with primary elevations of LDL-cholesterol ≥190 mg/dL but without vascular disease, pravastatin (vs. placebo) reduced the risk of coronary heart disease (CHD) by 27% and of major adverse cardiovascular events by 25% over 4.9-years. Randomisation to pravastatin significantly reduced the risk of CHD death (28%), cardiovascular death (25%) and all-cause mortality (18%) over a total of 20-years (extended observational long-term follow-up) among those with LDL-cholesterol ≥190 mg/dL.

Meaning: we provide for the first time evidence from a randomised trial demonstrating the benefit of LDL-cholesterol lowering for the primary prevention of individuals with primary elevations of LDL-cholesterol ≥190 mg/dL.
ABSTRACT

Background: Patients with primary elevations of LDL-C ≥190 mg/dL are at a higher risk of atherosclerotic cardiovascular disease as a result of long-term exposure to markedly elevated LDL-C levels. Therefore, initiation of statin therapy is recommended for these individuals. However, there is a lack of randomised trial evidence supporting these recommendations in primary prevention. In the present analysis we provide hitherto unpublished data on the cardiovascular effects of LDL-C lowering among a primary prevention population with LDL-C ≥190 mg/dL.

Methods: we aimed to assess the benefits of LDL-C lowering on cardiovascular outcomes among individuals with primary elevations of LDL-C ≥190 mg/dL without pre-existing vascular disease at baseline. We carried out post-hoc analyses from the West Of Scotland Coronary Prevention Study (WOSCOPS) randomised, placebo-controlled trial, and observational post-trial long-term follow-up, after excluding individuals with evidence of vascular disease at baseline. WOSCOPS enrolled 6595 men aged 45-64 years, who were randomised to pravastatin 40 mg/d or placebo. In the present analyses, 5529 participants without evidence of vascular disease were included, stratified by LDL-C levels into those with LDL-C <190 mg/dL (n=2969; mean LDL-C 178±6 mg/dL) and those with LDL-C ≥190 mg/dL (n=2560; mean LDL-C 206±12 mg/dL).

The effect of pravastatin versus placebo on coronary heart disease (CHD) and major adverse cardiovascular events (MACE) were assessed over the 4.9-year randomised-controlled trial phase and on mortality outcomes over a total of 20-years of follow-up.
Results: among 5529 individuals without vascular disease, pravastatin reduced the risk of CHD by 27% (p=0.002) and MACE by 25% (p=0.004) consistently among those with and without LDL-C ≥190 mg/dL (p-interaction >0.9). Among individuals with LDL-C ≥190 mg/dL, pravastatin reduced the risk of CHD by 27% (p=0.033) and MACE by 25% (p=0.037) during the initial trial phase and the risk of CHD death, cardiovascular death and all-cause mortality by 28% (p=0.020), 25% (p=0.009) and 18% (p=0.004), respectively, over a total of 20-years of follow-up.

Conclusions: the present analyses provide robust novel evidence for the short and long-term benefits of lowering LDL-C for the primary prevention of cardiovascular disease among individuals with primary elevations of LDL-C ≥190 mg/dL.

[* Note: Trial Registration: the original WOSCOSP trial was carried out between 1988 and 1995 and so it preceded the formal trial registration era. Nevertheless, the protocol and statistical analysis plan related to the original WOSCOPS trial was pertinently published in an international peer-reviewed journal and can be consulted as follows: J Clin Epidemiol 1992;45(8):849-60. The results we are reporting in the present manuscript are post hoc analyses not envisaged in the original protocol; therefore, we provide in the present manuscript a detailed description of the post hoc analyses design, methods and statistical analyses carried out.]

Keywords: lipids and lipoproteins; statin therapy; primary prevention; cardiovascular disease prevention
CLINICAL PERSPECTIVE

1) What is new?

- The present analysis from the WOSCOPS trial reports for the first time new information on over 2500 men with LDL-cholesterol ≥190 mg/dL without pre-existing vascular disease (a group lacking randomised trial evidence for statin therapy) and their subsequent risk of cardiovascular events.

- Individuals with a LDL-Cholesterol ≥190 mg/dL have a 2-fold higher observed risk of major cardiovascular events than would be predicted from a risk calculator.

- We provide compelling novel evidence from a randomised trial supporting the benefit of LDL-cholesterol lowering on cardiovascular events among a primary prevention population with LDL-Cholesterol ≥190 mg/dL.

2) What are the clinical implications?

- The present analysis provides novel supporting evidence from a randomised trial to reinforce current recommendations of initiation of lipid-lowering therapy in the primary prevention of individuals with primary elevations of LDL-C ≥190 mg/dL without the need for risk estimation.

- Although these analyses are post-hoc, this approach is the only one that allows us to address this question currently, since (i) nowadays it would be unethical to perform a placebo-controlled trial in the population with LDL-C ≥190 mg/dL, and (ii) there is no other randomised trial in primary prevention with statins including such a significant proportion of patients with an LDL-C ≥190 mg/dL.
Introduction

Patients with primary elevations of low-density lipoprotein cholesterol (LDL-C) ≥190 mg/dL (to convert values for cholesterol to mmol/L, multiply by 0.02586) are at a higher risk of atherosclerotic cardiovascular disease (ASCVD) as a result of a long-term exposure to markedly elevated LDL-C levels, even in the absence of pre-existing ASCVD (i.e. primary prevention).\textsuperscript{1,2} This has been recently further supported by observations from the Cardiovascular Lifetime Risk Pooling Project where these individuals, who were even referred to as “FH phenotype” (eTable 1 in the Supplement), were observed to have an accelerated risk of coronary heart disease (CHD) and ASCVD compared to individuals with “average” levels of LDL-C.\textsuperscript{3} As such, initiation of statin therapy (and more recently also of proprotein convertase subtilisin/kexin type 9 (PCSK9) inhibitors to further reduce LDL-C levels) is recommended for individuals with primary elevations of LDL-C ≥190 mg/dL without the need for risk assessment.\textsuperscript{1,2,4} However, there is a lack of published randomised trial evidence supporting these recommendations in primary prevention with available evidence extrapolated from the Cholesterol Treatment Trialist (CTT) meta-analyses (where lower LDL-C cut-off points were used and patients with established vascular disease were included in the high LDL-C category).\textsuperscript{5,6}

Currently it would be unethical to perform a placebo-controlled trial of LDL-C lowering therapy among individuals with LDL-C ≥190 mg/dL. Nonetheless, we can address this question using data from the West Of Scotland Coronary Prevention Study (WOSCOPS), which aimed to assess the benefits of statin therapy among men with...
hypercholesterolaemia and enrolled a significant proportion of patients with LDL-C ≥190 mg/dL (mean LDL-C 192 mg/dL). Although WOSCOPS excluded individuals with apparent myocardial infarction (MI), a proportion of participants still had evidence of other vascular diseases at baseline.

In the present analysis, we provide hitherto unpublished data on the cardiovascular effects of LDL-C lowering among a population with primary elevation of LDL-C ≥190 mg/dL after restricting analyses to participants without evidence of vascular disease at baseline. Furthermore, clinical guidelines have differed on whether to recommend percentage reductions in LDL-C or specific LDL-C levels among such patients. To provide practical insights into desirable reductions in LDL-C among these individuals, we also conducted an observational analysis which assessed the relationship between reductions in LDL-C (in relative or absolute terms) and on-treatment LDL-C levels with subsequent clinical events.

Methods

Randomised trial

Details of the design of WOSCOPS have been described in detail elsewhere. Briefly, WOSCOPS enrolled 6595 men aged 45-64 years (mean age 55 years) without evidence of prior MI and with a LDL-C ≥155 mg/dL not receiving lipid lowering therapy (mean LDL-C 192 mg/dL). Patients likely to have an elevated LDL-C due to secondary causes or with LDL-C >232 mg/dL on two fasting lipid measurements during the screening phase were excluded (supplementary eMethods, eFigure 1). Subjects were then randomised (double-blind) to pravastatin 40 mg once daily or placebo. Mean follow-up was 4.9 years (range 3.1-6.1).

To assess a purely primary prevention population the present analyses adopted more rigorous criteria than those used in the main WOSCOPS trial and additionally excluded those
individuals with any evidence of vascular disease at baseline (n=1066) namely, evidence of angina, intermittent claudication, stroke, transient ischemic attack, and minor ECG abnormalities (classified by Minnesota code).\textsuperscript{7,8,11} Patients were then stratified by LDL-C levels at baseline into those with LDL-C <190 mg/dL and those with LDL-C ≥190 mg/dL, eFigure 1, eTable 1. The following principal endpoints were considered for the present analysis in order to maximise power (given the smaller sample size resulting from the stricter exclusion criteria and further restricting analysis to approximately half of the remaining individuals, i.e. participants with LDL-C ≥190 mg/dL): (i) the composite of definite or suspected non-fatal MI plus definite or suspected CHD death, hereinafter referred to as CHD (same co-principal endpoint as the original WOSCOPS trial); (ii) the composite of cardiovascular death, non-fatal MI (definite or suspected) and non-fatal stroke (major adverse cardiovascular events [MACE]). Endpoint definitions including definite and suspected coronary events are shown in the supplementary methods. Other outcomes explored include the principal endpoints but restricted to definite-only coronary events, MACE including coronary revascularisation, mortality endpoints (CHD death, cardiovascular death and all-cause mortality), coronary revascularization, and cerebrovascular events (fatal/non-fatal stroke and transient ischemic attack).

Extended observational long-term follow-up

After completion of the randomised trial phase an extended observational follow-up of the WOSCOPS cohort is now ongoing, through linkage to national mortality and electronic hospital discharge records held by the National Health Service for Scotland.\textsuperscript{12,13} Further details are available in the supplementary methods, but briefly at 5 years after the initial trial finished approximately one third of individuals originally allocated to pravastatin or
placebo were on statins. In the present analysis we compared long-term mortality outcomes (including deaths from CHD, cardiovascular causes, and any-cause) between those originally randomised to pravastatin compared with placebo among individuals without evidence of vascular disease at baseline stratified by hypercholesterolaemia status.

**Ethics**

The ethics committees from the University of Glasgow and participating health boards in Scotland approved the original WOSCOPS trial. The corresponding committees from the Glasgow Royal Infirmary and Privacy Advisory Committee of the National Health Service for Scotland approved the extended follow-up study. The participants in each phase of WOSCOPS provided informed consent to partake in the trial and review of their medical records.

**Statistical analysis**

**Effect of statin therapy on outcomes**

The effect of therapy (pravastatin vs. placebo) among those with and without LDL-C ≥190 mg/dL was calculated for both the initial trial period and the extended follow-up. Estimates of hazard ratios and 95% confidence intervals with corresponding p-values were obtained by means of Cox proportional-hazards model with randomised therapy as the only covariate. A test for interaction was performed to assess whether the effect of therapy was consistent across the LDL-C strata pre-specified for this analysis. The p-value obtained from the treatment by LDL-C subgroup interaction term was reported. Time-to-event curves were estimated using the Kaplan-Meier method based on the original treatment arm and LDL-C strata. Tests were 2-sided and statistical significance defined as p<0.05.
Changes in LDL-C and outcomes

To elucidate the extent to which the magnitude of LDL-C reduction from pravastatin therapy influenced outcomes among those with LDL-C \(\geq 190\) mg/dL, observational analyses were performed. Therefore, we assessed changes in LDL-C levels and pravastatin effect during the randomised trial restricted to those subjects with LDL-C \(\geq 190\) mg/dL at baseline. The placebo group was taken as the reference category for the models. The relationship between absolute LDL-C fall (mean baseline level minus mean on-treatment value) or percentage LDL-C reduction and risk of events were assessed using multivariable Cox regression models (Wald test) for the different groups (placebo and pravastatin subgroups), accounting for the following covariates: age, smoking, blood pressure, history of hypertension, diabetes mellitus, and body mass index, as previously published.\(^5,14\) LDL-C reductions were modelled as categorical variables based on previous WOSCOPS and CTT publications.\(^5,6,14\) For the assessment of the relative fall in LDL-C, above and below 30% was used (consistent with the perceived average potency of pravastatin 40 mg/day: moderate-intensity statin therapy).\(^1\)

On-treatment LDL-C and outcomes

The relationship between on-treatment LDL-C levels achieved with therapy on the risk of events was studied following similar analyses to those described above. Consistent with previous WOSCOPS analyses,\(^14\) “on-treatment lipid levels” were defined as the mean of all lipid values measured after randomisation until the patient had an event or reached the end of the trial. On-treatment LDL-C analyses excluded individuals with events in the first 6 months of the trial as first on-treatment lipid measurements were at 6 months after randomisation.
Participants with a predicted 10-year ASCVD risk below 7.5% and no diabetes

Finally, we performed additional analyses among participants without an indication of statin therapy based on global cardiovascular risk estimation and who were free from diabetes in whom LDL-C was ≥190 mg/dL (and for comparison below 190 mg/dL), to specifically assess the impact of LDL-C related-cardiovascular risk. To assess global cardiovascular risk we applied the Pooled Cohort Risk Equations\textsuperscript{15} to the WOSCOPS cohort who were free from ASCVD and diabetes, restricted to those with a predicted 10-year ASCVD risk below 7.5%. To maximise power we focused on MACE during the 5-year on-trial period and 20-year extended follow-up.

The statistical analyses were performed using SAS v9.2 (SAS Institute Inc., USA).

Results

A total of 5529 patients without prior evidence of vascular disease were included in the present analyses; of these, 2560 individuals had LDL-C ≥190 mg/dL (placebo n=1274; pravastatin n=1286). The baseline characteristics, stratified by presence or absence of LDL-C ≥190 mg/dL, comparing pravastatin to placebo treatment groups are shown in table 1. Overall, patients had a mean age of 55 years and there were no significant differences between placebo and pravastatin treated groups in any of the characteristics.

Lipid levels

LDL-C levels at baseline, 1 year and end of trial, as well as percentage changes from baseline to year 1 and to end of trial, are shown in table 1. Mean (±SD) LDL-C at baseline was 206±12 mg/dL among patients with LDL-C ≥190 mg/dL, and 178±6 mg/dL among those with LDL-C <190 mg/dL. LDL-C levels at year 1 and end of trial were significantly lower among
pravastatin treated subjects compared to placebo across cohorts (p<0.001). The percentage reduction in LDL-C from baseline with pravastatin (accounting for the effect of placebo) among those with and without LDL-C ≥190 mg/dL was of a similar magnitude (approximately 23% at year 1 and 19.5-20% at end of trial), eFigure 2. The effects on other lipids are shown in eTable 2.

**Initial trial phase**

The effect of pravastatin versus placebo on cardiovascular outcomes over 4.9 years stratified by LDL-C <190 or ≥190 mg/dL is shown in figure 1, table 2 and eTable 3. Overall, both CHD and MACE were reduced in the 5529 patients without vascular disease. Analyses stratified by LDL-C status showed no evidence of heterogeneity between cohorts for the principal endpoints or for the additional outcomes explored (interaction p-value all >0.2) (interaction results did not materially change when using LDL-C as a continuous measure rather than categorical, eTable 4). The corresponding Kaplan-Meier curves are shown in figures 2-3 and eFigures 3-5. Among individuals with LDL-C ≥190 mg/dL, pravastatin significantly reduced the risk of CHD by 27% (p=0.033) with a 25% risk reduction in MACE (p=0.037).

**Long-term follow-up**

The effect of initial randomisation to pravastatin or placebo on mortality endpoints during a total of 20-years of follow-up (from randomisation to end of extended follow-up) is shown in figure 4, and eFigures 6-8. Overall, amongst all subjects initially allocated to pravastatin CHD death, cardiovascular death and all-cause mortality were significantly reduced by 22%, 17% and 12% respectively (table 2). Long-term risk of CHD death, cardiovascular death and all-cause mortality were significantly reduced by 28%, 25% and 18%, respectively, among
those with LDL-C ≥190 mg/dL originally randomised to pravastatin. The absolute reduction in the risk (ARR) of death at 20 years from CHD, cardiovascular causes and from any-cause was at least two-fold greater among patients with LDL-C ≥190 mg/dL (ARR 2.34%, 3.25% and 5.39%, respectively) compared with those with LDL-C <190 mg/dL (Table 2). Analysis considering specifically the post-trial period only (15-year end of randomised trial to end of extended follow-up period) did not materially change the results (eTable 5).

**Change in LDL-C and outcomes**

Among individuals with LDL-C ≥190 mg/dL, reduction in LDL-C of greater than 30% or 39 mg/dL (1 mmol/L) were associated with a lower risk of CHD and MACE compared to placebo (figure 5, eTables 6-7). In contrast, those individuals allocated to pravastatin whose LDL-C reduction was less than 30% or 39 mg/dL were not significantly different from placebo. Consistent with earlier publications from WOSCOPS, we did not observe a continuous relationship between lower achieved LDL-C and outcomes (figure 5, eTables 6-8).

**Participants with a predicted 10-year ASCVD risk below 7.5% and no diabetes**

Using the Pooled Cohort Risk Equations\textsuperscript{15} participants were stratified into those free from diabetes and with a 10-year predicted risk of MACE at baseline of <7.5% but with a LDL-C ≥190 mg/dl (n=1714), representing 67% of the initial primary prevention cohort with LDL-C ≥190 mg/dl (table 3). During the 5-year trial period MACE was significantly reduced to 4.8% among those allocated to pravastatin in contrast to a rate of 7.5% among placebo, representing a 38% reduction in risk (HR 0.62, 95%CI 0.42, 0.92, p=0.018). During the 20-year extended follow up the corresponding rates were 18.76% vs 24.18%, representing a risk reduction of 27% (HR 0.73, 95%CI 0.60, 0.90, p=0.003). There was no evidence of
heterogeneity among those with LDL-C less than 190 mg/dL and a predicted 10-year risk less
than 7.5% treated with pravastatin (table 3 and eTable 9).

Discussion

Observational data support the assertion that having a LDL-C ≥190 mg/dL is associated with
increased cardiovascular risk, even in the absence of other risk factors. However, current
guidelines recognise the paucity of evidence for primary prevention among these individuals
and, specifically, the lack of evidence from randomised trials which include only patients
with LDL-C ≥190 mg/dL. Instead, indirect evidence derived from the extrapolation of other
data is used to support this viewpoint. Indeed, the largest evidence base is derived from the
CTT meta-analyses, where a significant reduction in major coronary events and major
vascular events per 39 mg/dL reduction in LDL-C with statins were observed across different
categories of baseline LDL-C, including those with LDL-C ≥135 mg/dL or with LDL-C >174
mg/dL; but these groups included patients with established vascular disease. Thus, while
the primary prevention of adults with primary LDL-C ≥190 mg/dL is identified as one of the
groups where the benefit of statin therapy exceeds the risk of adverse events the data
currently available from randomised clinical trials are still limited. The present analyses from the WOSCOPS study provide for the first time, evidence from a
randomised trial supporting the benefit of LDL-C reduction in the primary prevention of
ASCVD in those with LDL-C ≥190 mg/dL. Specifically, we provide three lines of evidence for
the benefit of LDL-C lowering with statins in these patients: (i) randomised trial evidence
that LDL-C reduction by approximately one quarter with statins reduces the risk of CHD by
27% and of MACE by 25%; (ii) extended follow-up evidence that the early benefits extend to
reductions in CHD death by 28%, cardiovascular death by 25%, and all-cause mortality by
18% over 20 years; the greater absolute benefit and smaller numbers needed-to-treat in patients with LDL-C ≥190 mg/dL likely reflect the higher lifetime cardiovascular risk due to the cumulative atherosclerotic burden compared with those with LDL-C <190 mg/dL; (iii) observational data showing that reductions above 30% or 39 mg/dL are associated with lower risk of CHD and MACE compared to placebo. Another consideration of our results is that LDL-C does not appear to be an effect modifier of outcomes at either 5 years or at 20 years of follow-up (all interaction p-values >0.18); in addition, there is not much difference in event rates based on LDL-C cut-off of 190 mg/dL during the initial 5 year trial period.

While these data provide support for statin therapy for primary prevention in subject with LDL-C ≥190 mg/dL, the data also provide support for the use of statin therapy for those with LDL-C <190 mg/dL (lower limit for inclusion being 155 mg/dL).

To assess the importance of LDL-C to cardiovascular risk we conducted an analysis among the primary prevention cohort in WOSCOPS who were free from diabetes at baseline and who on the basis of the current Pooled Cohort Risk Equations would be considered at low risk (i.e. 10-year predicted risk below 7.5%) and otherwise would be ineligible for statin therapy (approximately two thirds). Among placebo-treated patients with LDL-C ≥190 mg/dL the observed risk of MACE at 5 years was already 7.5%, i.e. double what would have been predicted using a risk calculator. In comparison, among those with a LDL-C between 155 and 190 mg/dL the 5-year risk of MACE was 5.7% in the placebo group. These data reinforce the notion that among patients with a LDL-C ≥190 mg/dL the observed risk is much greater than would be predicted through a risk calculator, and thus global risk estimation is not necessary. During the 5-year randomised trial period patients with a LDL-C ≥190 mg/dL but with a 10-year predicted risk below 7.5% derived a statistically significant 2.7% ARR in MACE with pravastatin (relative risk reduction 38%).
We studied a primary prevention population with a LDL-C ≥190 mg/dL, also defined by some guidelines as primary severe hypercholesterolaemia. Some have also referred to patients with LDL-C ≥190 mg/dL as FH phenotype (eTable 1). However, FH does not have a “gold standard” definition and its prevalence may ultimately depend on the LDL-C threshold and the presence of a pathogenic gene variant. Notwithstanding this, individuals with LDL-C ≥190 mg/dL are more likely to have FH by clinical and/or genetic criteria (eTable 1). However, according to a recent study, only a small proportion of people with severe hypercholesterolaemia in the community have an identifiable FH mutation. In the present study we lacked genetic data and indeed relevant clinical information to help define FH in the WOSCOPS population according to accepted diagnostic criteria; however, the number of individuals who fulfil the strict clinical or genetic criteria for FH in the present analyses is likely to have been small, as WOSCOPS excluded patients with LDL-C >232 mg/dL or with prior MI. Hence, a number of patients with more severe manifestations of FH (in terms of higher LDL-C levels or coronary disease at an earlier age) might have been excluded.

Nevertheless, our results are applicable to the broader FH population, based on (i) that there was no heterogeneity in treatment effect between patients with and without LDL-C ≥190 mg/dL, (ii) our observation that individuals with primary elevation of LDL-C ≥190 mg/dL and likely greater lifetime burden from elevated LDL-C derive significant risk reductions from LDL-C lowering, (iii) a number of observational studies that suggest FH patients benefit of statins.

The ACC/AHA cholesterol guidelines recommend high-intensity statin therapy for individuals with LDL-C ≥190 mg/dL1 and whilst the present analyses provide direct evidence for the benefits for approximately a 23% reduction in LDL-C (i.e. a low-intensity statin regimen), there are no trials presently capable of providing similar evidence for the benefit of even
greater percentage reductions or higher intensity statin therapy in this population. Whilst the current paradigm is that lower on-treatment LDL-C levels and/or greater reductions in LDL-C are associated with a lower risk of ASCVD, we did not find evidence for a continuous relationship between on-treatment LDL-C and better outcomes, which is consistent with earlier analyses from the overall WOSCOPS cohort. To what degree this reflects studies of pravastatin and its relevance to more contemporary statin use is uncertain. Since the inclusion criteria was an LDL-C of 155-232 mg/dL and the average LDL-C reduction at 1 year was approximately 23%, we did not have the data to validate or refute the current recommendation for a LDL-C target of 100 mg/dL in some guidelines.

When LDL-C reductions in the pravastatin group were analysed as a binary trait, the present analyses suggested that those individuals who derived >30% reduction or >39 mg/dL absolute lowering in LDL-C, appeared to derive significant benefit compared to placebo. It should however be recognised that there was considerable overlap in the observed benefits between this group and those achieving lesser reductions on pravastatin. We also need to acknowledge that a fair number of people in the lower effect group never took the treatment or withdrew from treatment. We know that 9% of the original WOSCOPS cohort never took the treatment and about 30% were off treatment by 5 years (no significant difference in the withdrawal rates between pravastatin and placebo arms). Many of these people attended the annual visits and got their lipids assessed because they saw the study doctor and had ECGs recorded. Hence, we cannot say that any trends to differences seen are differences in statin response.

The high baseline LDL-C and the limited potency of pravastatin 40 mg/day limit the extent of the analyses which can be performed in WOSCOPS. Direct evidence for the benefit of even
greater reductions in LDL-C among patients with LDL-C ≥190 mg/dL in primary prevention may be inferred indirectly from the recently reported “Studies of PCSK9 Inhibition and the Reduction of Vascular Events” (SPIRE)-2 trial, evaluate the efficacy of PCSK9 inhibition with bococizumab in reducing the risk of major cardiovascular events in subjects with LDL-C ≥100 mg/dL despite maximally tolerated statin therapy. With a mean baseline LDL-C level of 134 mg/dL and assuming a 50% reduction in LDL-C from intensive-statin therapy it suggests that many participants in the SPIRE-2 trial likely started with untreated LDL-C levels ≥190 mg/dL. Therapy with bococizumab led to a reduction in LDL-C levels of around 55% and 40% at 14 and 52 weeks, respectively. Although the trial was prematurely stopped due to the development of high rates of antidrug antibodies and attenuation of the cholesterol lowering effect over time, a significant 21% risk reduction of cardiovascular events was observed in those treated with bococizumab (compared to placebo) after a median follow-up of 12 months, with no significant differences in analyses stratified by the presence or absence of clinical evidence of cardiovascular disease. Of note, the USA National Lipid Association has recently recommended that therapy with PCSK9 inhibitors may be considered to further reduce LDL-C in patients with LDL-C ≥190 mg/dL. A major strength of the present analysis is that it explores a group of higher risk individuals (LDL-C ≥190 mg/dL) specifically highlighted in guidelines, but one in which clinical trial evidence is lacking. Thus, the present results from a randomised trial provide novel information and evidence to support guideline recommendations. Additionally, since high lipid levels like those included in WOSCOPS (LDL-C ≥155 mg/dL) may be present in a significant proportion of the population, the results of the present study may impact on the care of a significant number of patients; for instance, recent surveys from USA have estimated a prevalence of 16%–33% for LDL-C ≥155-160 mg/dL and of 5.6%–10.4% for LDL-C.
≥190 mg/dL (depending on the characteristics of the population scrutinised) in the adult
population.\textsuperscript{30,31} That said, some aspects of the present analyses warrant further discussion.

This is an analysis of a subgroup of the overall WOSCOPS cohort which was not pre-specified
and, whilst the findings are consistent with the original trial publications,\textsuperscript{8,12-14} the present
findings remain post-hoc. The lack of statistically significant reductions in additional
endpoints in the group with LDL-C ≥190 mg/dL (figure 1) may reflect a limited power
resulting from restricting the original sample size. In addition, it should be noted that the
LDL-C levels in those with LDL-C <190 mg/dL were still high (mean LDL-C at baseline 178
mg/dL overall; at year 1: 177 and 135 mg/dL in placebo and pravastatin arms, respectively)
and not markedly different than in those with LDL-C ≥190 mg/dL (mean LDL-C at baseline
206 mg/dL overall; at year 1: 199 and 157 mg/dL in placebo and pravastatin arms,
respectively); as such, the difference in absolute risk reduction between these groups may
not have been as wide as could be observed in current populations where mean LDL-C levels
(in those with LDL-C <190 mg/dL) are significantly lower.

The extended long-term follow-up reports data among individuals enrolled in the original
trial and, although the comparisons provided are for the original randomised groups, it
should be recognised that the data from the additional 15 years of follow-up after the
original trial was completed are observational and might be confounded by the lack of
ongoing information regarding medication use. For instance, those participants with LDL-C
≥190 mg/dL may have been more likely kept on treatment than those with lower LDL-C
levels after the completion of the trial. Nevertheless, it provides valuable information on
what a period of treatment may confer in terms of long-term risk reduction benefit ("legacy
effect" or "reset of the atherosclerotic event clock" based on the original trial).

Nevertheless, without excluding the possibility of confounding factors it is not possible to
fully characterize the long-term follow-up estimates as either underestimates or overestimates since it cannot be assumed that the outcomes are only modulated by statin use or non-use. Notwithstanding this, we consider the former is more likely due to the fact that (i) many actively treated patients during the trial phase may have no longer received statin therapy and (ii) the expected increased cross-over in the original placebo arm to statin therapy during follow-up; as such, the results of the extended follow-up may likely underestimate the benefits of longer-term therapy due to reduced differential statin use over time, and so likely the benefit for those ≥190 mg/dL may be larger than that implied by the trial (especially if one were to use a statin regimen of greater potency to that used in WOSCOPS). On the other hand, the high prevalence of smokers in the WOSCOPS population might mean that a similar study today might not show as strong an effect with a statin regimen of similar potency.

Regarding the exploratory analyses evaluating LDL-C change on treatment versus outcome (compared with placebo), it cannot completely rule out the influence of non-compliance to medication. That said, to be included in the analysis men had to attend to have their blood sample taken; many non-compliers did not do so (which is why the achieved LDL-C rose slightly over time). Thus, there is some allowance for non-compliance in the analysis as performed. Finally, the analyses of reductions in LDL-C on pravastatin and outcomes are observational in nature and should be interpreted as such as residual confounding cannot be excluded despite statistical adjustment.

**Conclusion**

Among men with primary elevations of LDL-C levels ≥190 mg/dL, primary prevention with pravastatin reduced the risk of cardiovascular events. Thus, the present analyses from a
randomised clinical trial provides for the first time evidence for the benefits of LDL-C lowering for the primary prevention of individuals with primary elevations of LDL-C ≥190 mg/dL, which may help reinforce current recommendations for this group of patients.
Funding Sources

The present analyses have been partly funded by a grant from Sanofi to Imperial College London (Medical and Educational Goods and Services Grant, reference number UKME-15-00020). The WOSCOPS trial was originally funded by Bristol-Myers Squibb and Sankyo.

Role of authors and funding source

The present analyses were conceived by KKR and AJVV. MR and IF performed the statistical analyses. CP and IF conducted the original WOSCOPS trial and extended follow-up. KKR and AJVV wrote the draft of the present paper. All authors critically reviewed the manuscript and approved its submission. IF and MR had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Funding organizations had no influence on the design and conduct of the study; collection, management, analyses, and interpretation of the data; preparation, review or approval of the manuscript; or the decision to submit the manuscript for publication.

Disclosure of potential conflicts of interests

Dr. Catapano reports grants and/or personal fees from Merck, Sanofi, Amgen, Pfizer, Mylan, Kowa, Sigma Tau, Astra Zeneca, Recordati, and Doc Generici, outside the submitted work.

Dr. Ford reports grants from Imperial College London, during the conduct of the study, and from Merck, outside the submitted work.
Dr. Kastelein reports personal fees from Regeneron, Sanofi, Amgen, Pfizer, Eli Lilly, Ionis Pharmaceuticals, AstraZeneca, CSL Behring, Cerenis, Esperion, The Medicines Company, Kowa, Affiris, UniQure, Madrigal, Akcea Therapeutics, Staten Biotech, Akarna, Corvidia, and Gemphire, outside the submitted work.

Dr. Packard reports grants and/or personal fees from MSD, Pfizer, Sanofi, and Roche, outside the submitted work.

Dr. Ray reports grants and/or personal fees from Pfizer, MSD, Astra Zeneca, Sanofi, Aegerion, Regeneron, Abbvie, Kowa, Cerenis, Medicines Company, Lilly, Esperion, Amgen, Cipla, and Algorithm, outside the submitted work.

Dr. Robertson reports grants from Imperial College London, during the conduct of the study.

Dr. Vallejo-Vaz has nothing to disclose.

Dr. Watts reports grants and/or personal fees from Sanofi, Amgen, and Regeneron, outside the submitted work.

Previous presentation of the information reported in the manuscript

The work reported in the present manuscript was selected for presentation at the late-breaking science session “Clinical Trials Update – Prevention” during the 2016 European Society of Cardiology (ESC) Congress held in Rome, Italy, 27-31 August, 2016.
REFERENCES


4 – Orringer CE, Jacobson TA, Saseen JJ, Brown AS, Gotto AM, Ross JL, Underberg JA. Update on the use of PCSK9 inhibitors in adults: Recommendations from an Expert Panel of the


the European Society of Cardiology (ESC) and European Atherosclerosis Society (EAS).

Atherosclerosis 2016;253:281-344.


Figure 1. Endpoints during the randomised trial period, overall and stratified by LDL-cholesterol levels at baseline.

Effect of therapy (vs. placebo) shown as hazard ratio (HR) and corresponding 95% confidence interval (95% CI). (*) Including coronary events (i.e. non-fatal MI and CHD death) as definite only. CHD: coronary heart disease. LDL-C: low-density lipoprotein cholesterol.

MACE: major adverse cardiovascular events, defined as the composite of cardiovascular death, non-fatal myocardial infarction and non-fatal stroke. TIA: transient ischemic attack.

To convert values for cholesterol to mmol/L, multiply by 0.02586.

Figure 2. Coronary heart disease risk: Kaplan-Meier curves during the randomised trial period stratified by LDL-cholesterol levels at baseline and treatment allocation.

5-year follow-up Kaplan-Meier analysis for coronary heart disease (CHD) endpoint, stratified by LDL-cholesterol at baseline (<190 or ≥190 mg/dL) and treatment allocation at randomisation (pravastatin or placebo). Number of events in each group were as follows:

placebo, LDL-C <190 mg/dL: n=104; pravastatin, LDL-C <190 mg/dL: n=75; placebo, LDL-C ≥190 mg/dL: n=107; pravastatin, LDL-C ≥190 mg/dL: n=80. CI: confidence interval. HR: hazard ratio. To convert values for cholesterol to mmol/L, multiply by 0.02586.
Figure 3. Major adverse cardiovascular events risk: Kaplan-Meier curves during the randomised trial period stratified by LDL-cholesterol levels at baseline and treatment allocation.

5-year follow-up Kaplan-Meier analysis for major adverse cardiovascular disease events (MACE) endpoint, stratified by LDL-cholesterol levels at baseline (<190 or ≥190 mg/dL) and treatment allocation at randomisation (pravastatin or placebo). Number of events in each group were as follows: placebo, LDL-C <190 mg/dL: n=119; pravastatin, LDL-C <190 mg/dL: n=90; placebo, LDL-C ≥190 mg/dL: n=121; pravastatin, LDL-C ≥190 mg/dL: n=93. MACE: major adverse cardiovascular events, defined as the composite of cardiovascular death, non-fatal myocardial infarction and non-fatal stroke. CI: confidence interval. HR: hazard ratio. To convert values for cholesterol to mmol/L, multiply by 0.02586.

Figure 4. Long-term mortality endpoints at 20 years of follow-up, overall and stratified by LDL-cholesterol levels at baseline.

Effect of therapy (vs. placebo) shown as hazard ratio (HR) and corresponding 95% confidence interval (95% CI). CHD: coronary heart disease. LDL-C: low-density lipoprotein cholesterol. To convert values for cholesterol to mmol/L, multiply by 0.02586.

Figure 5. Principal endpoints during the randomised trial period based on different categories of LDL-C levels with pravastatin in subjects with LDL-cholesterol ≥190 mg/dL at baseline.
Effect of therapy (vs. placebo) shown as hazard ratio (HR) and corresponding 95% confidence interval (95% CI). Note that MACE plus coronary revascularisation endpoint was used here instead of MACE alone in order to increase the number of events in each stratum and so the power of the analysis in an otherwise restricted sample to those with LDL-C ≥190 mg/dL allocated to pravastatin further stratified in different groups as shown in the table. HR are adjusted for age, history of hypertension, history of diabetes, smoking status, systolic and diastolic blood pressure, and body mass index. On-treatment LDL-C levels are defined as the mean of all LDL-C values measured after randomisation until the patient had an event or reached the end of the study. On-treatment LDL-C analyses excluded individuals with events in the first 6 months of the trial as first on-treatment LDL-C measurement was at 6 months after randomisation. LDL-C: low-density lipoprotein cholesterol. MACE: major adverse cardiovascular events, defined as the composite of cardiovascular death, non-fatal myocardial infarction and non-fatal stroke. To convert values for cholesterol to mmol/L, multiply by 0.02586.
### Characteristics of the participants without vascular disease at enrolment stratified by LDL-cholesterol levels at baseline.

<table>
<thead>
<tr>
<th></th>
<th>Participants LDL-C &lt;190 mg/dL</th>
<th>Participants With LDL-C ≥190 mg/dL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Placebo</td>
<td>Pravastatin</td>
</tr>
<tr>
<td>Demographics at baseline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>n = 1493</td>
<td>n = 1476</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>54.8 ± 5.5</td>
<td>55.0 ± 5.6</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>134.8 ± 16.3</td>
<td>134.6 ± 17.0</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>83.8 ± 10.2</td>
<td>83.5 ± 10.5</td>
</tr>
<tr>
<td>History of hypertension, n (%)</td>
<td>194 (13.0)</td>
<td>199 (13.5)</td>
</tr>
<tr>
<td>History of diabetes, n (%)</td>
<td>13 (0.9)</td>
<td>12 (0.8)</td>
</tr>
<tr>
<td>Current smoker, n (%)</td>
<td>634 (42.5)</td>
<td>594 (40.2)</td>
</tr>
<tr>
<td>Lipid levels at baseline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDL-Cholesterol (mg/dL)</td>
<td>178.5 ± 6.5</td>
<td>178.2 ± 6.7</td>
</tr>
<tr>
<td>Total cholesterol (mg/dL)</td>
<td>258.0 ± 15.3</td>
<td>257.7 ± 15.7</td>
</tr>
<tr>
<td>HDL-Cholesterol (mg/dL)</td>
<td>44.3 ± 9.6</td>
<td>44.7 ± 9.7</td>
</tr>
<tr>
<td>Non-HDL-Cholesterol (mg/dL)</td>
<td>213.8 ± 16.2</td>
<td>213.0 ± 16.5</td>
</tr>
<tr>
<td>Triglycerides (mg/dL)</td>
<td>143.9 (108.5, 194.9)</td>
<td>139.5 (106.3, 190.4)</td>
</tr>
<tr>
<td>LDL-Cholesterol levels during the follow-up</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDL-C Year 1 (mg/dL)</td>
<td>177.8 ± 21.7</td>
<td>135.8 ± 29.2</td>
</tr>
<tr>
<td>LDL-C End of trial (mg/dL)</td>
<td>179.1 ± 24.3</td>
<td>142.9 ± 32.0</td>
</tr>
<tr>
<td>Percentage change from baseline to 1 year</td>
<td>-0.4 ± 11.9</td>
<td>-23.8 ± 16.2</td>
</tr>
<tr>
<td>Percentage change from baseline to end of trial</td>
<td>0.4 ± 13.4</td>
<td>-19.8 ± 17.7</td>
</tr>
</tbody>
</table>

Data shown as absolute and relative (%) number of subjects for categorical variables and as mean ± standard deviation or median (interquartile range) for continuous parameters. BP: blood pressure. HDL: high-density lipoprotein. LDL-C: low-density lipoprotein cholesterol. To convert values for cholesterol to mmol/L, multiply by 0.02586. To convert values for triglycerides to mmol/L, multiply by 0.01129.
**TABLE 2.** Principal and mortality endpoints during the randomised trial period, and long-term mortality endpoints from randomisation to 20 years of follow-up, stratified by LDL-cholesterol levels at baseline.

<table>
<thead>
<tr>
<th>Overall cohort</th>
<th>Participants with LDL-C &lt;190 mg/dL</th>
<th>Participants With LDL-C ≥190 mg/dL</th>
<th>Interaction p-value between LDL-C grouping at baseline and randomised treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Events [n (%)]</td>
<td>HR (95% CI), p-value</td>
<td>Events [n (%)]</td>
<td>HR (95% CI), p-value</td>
</tr>
<tr>
<td>Placebo (n=1493)</td>
<td>104 (6.97%)</td>
<td>107 (8.40%)</td>
<td>0.73 (0.59, 0.89), 0.002</td>
</tr>
<tr>
<td>Pravastatin (n=1476)</td>
<td>75 (5.08%)</td>
<td>80 (6.22%)</td>
<td>0.72 (0.54, 0.97), 0.032</td>
</tr>
<tr>
<td>Placebo (n=1274)</td>
<td>119 (7.97%)</td>
<td>121 (9.50%)</td>
<td>0.75 (0.62, 0.91), 0.004</td>
</tr>
<tr>
<td>Pravastatin (n=1286)</td>
<td>90 (6.10%)</td>
<td>93 (7.23%)</td>
<td>0.76 (0.58, 1.00), 0.048</td>
</tr>
<tr>
<td>CHD death</td>
<td>0.91 (0.56, 1.48), 0.704</td>
<td>18 (1.21%)</td>
<td>16 (1.26%)</td>
</tr>
<tr>
<td>Cardiovascular death</td>
<td>0.84 (0.54, 1.30), 0.434</td>
<td>24 (1.61%)</td>
<td>20 (1.57%)</td>
</tr>
<tr>
<td>All-cause mortality</td>
<td>0.87 (0.64, 1.17), 0.356</td>
<td>52 (3.48%)</td>
<td>40 (3.14%)</td>
</tr>
</tbody>
</table>

5-year randomised trial

| CHD | 0.73 (0.59, 0.89), 0.002 | 104 (6.97%) | 75 (5.08%) | 0.72 (0.54, 0.97), 0.032 | 107 (8.40%) | 80 (6.22%) | 0.73 (0.55, 0.98), 0.033 | 0.960 |
| MACE | 0.75 (0.62, 0.91), 0.004 | 119 (7.97%) | 90 (6.10%) | 0.76 (0.58, 1.00), 0.048 | 121 (9.50%) | 93 (7.23%) | 0.75 (0.57, 0.98), 0.037 | 0.958 |
| CHD death | 0.91 (0.56, 1.48), 0.704 | 18 (1.21%) | 17 (1.15%) | 0.95 (0.49, 1.85), 0.887 | 16 (1.26%) | 14 (1.09%) | 0.86 (0.42, 1.76), 0.684 | 0.838 |
| Cardiovascular death | 0.84 (0.54, 1.30), 0.434 | 24 (1.61%) | 20 (1.36%) | 0.84 (0.46, 1.52), 0.568 | 20 (1.57%) | 17 (1.32%) | 0.84 (0.44, 1.60), 0.590 | 0.992 |
| All-cause mortality | 0.87 (0.64, 1.17), 0.356 | 52 (3.48%) | 46 (3.12%) | 0.89 (0.60, 1.33), 0.576 | 40 (3.14%) | 34 (2.64%) | 0.84 (0.53, 1.32), 0.446 | 0.835 |

20-year long-term follow-up

| CHD | 0.74 (0.65, 0.84), <0.001 | 268 (17.95%) | 201 (13.62%) | 0.73 (0.61, 0.88), <0.001 | 261 (17.95%) | 203 (15.79%) | 0.74 (0.61, 0.89), 0.001 | 0.942 |
| MACE | 0.79 (0.71, 0.88), <0.001 | 383 (25.65%) | 306 (20.73%) | 0.77 (0.66, 0.89), <0.001 | 344 (27.00%) | 295 (22.94%) | 0.81 (0.69, 0.94), 0.007 | 0.642 |
| CHD death | 0.78 (0.64, 0.94), 0.011 | 115 (7.70%) | 96 (6.50%) | 0.84 (0.64, 1.10), 0.193 | 115 (7.70%) | 86 (6.69%) | 0.72 (0.54, 0.95), 0.020 | 0.453 |
| Cardiovascular death | 0.83 (0.71, 0.96), 0.015 | 177 (11.86%) | 161 (10.91%) | 0.91 (0.73, 1.13), 0.382 | 182 (14.29%) | 142 (11.04%) | 0.75 (0.60, 0.93), 0.009 | 0.211 |
| All-cause mortality | 0.88 (0.80, 0.96), 0.005 | 513 (34.36%) | 477 (32.32%) | 0.93 (0.82, 1.05), 0.247 | 460 (36.11%) | 395 (30.72%) | 0.82 (0.72, 0.94), 0.004 | 0.184 |

Effect of therapy (vs. placebo) shown as hazard ratios (HR) and corresponding 95% confidence intervals (95% CI) and p value. 5-year randomised trial: from randomisation to end of randomised trial (on-trial period). 20-year long-term follow-up: from randomisation to end of extended follow-up (on-trial plus post-trial periods). Results for the 15-year post-trial period only (from end of randomised trial to end of extended follow-up) did not materially differ from those in the 20-year long-term follow-up and are presented in eTable 5 in supplementary material. CHD: coronary heart disease. LDL-C: low-density lipoprotein cholesterol. MACE: major adverse cardiovascular events, defined as the composite of cardiovascular death, non-fatal myocardial infarction and non-fatal stroke. See main text and supplementary material for endpoints definitions. To convert values for cholesterol to mmol/L, multiply by 0.02586.
### TABLE 3. Risk of major adverse cardiovascular events in the subgroup of patients without diabetes and with a predicted 10-year ASCVD risk* below 7.5% at baseline.

<table>
<thead>
<tr>
<th></th>
<th>LDL-C &lt;190 mg/dL</th>
<th>LDL-C ≥190 mg/dL</th>
<th>Interaction p-value between LDL-C grouping at baseline and randomised treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Placebo (n=1085)</td>
<td>Pravastatin (n=1064)</td>
<td>HR (95% CI), p-value</td>
</tr>
<tr>
<td>5-year randomised trial period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MACE</td>
<td>62 (5.7%)</td>
<td>48 (4.5%)</td>
<td>0.79 (0.54, 1.15), 0.21</td>
</tr>
<tr>
<td>20-year long-term follow-up</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MACE</td>
<td>230 (21.20%)</td>
<td>178 (16.73%)</td>
<td>0.76 (0.62, 0.92), 0.005</td>
</tr>
</tbody>
</table>

* ASCVD risk according to the Pooled Cohort Equations risk calculator (ref. 15). Effect of therapy (vs. placebo) shown as hazard ratios (HR) and corresponding 95% confidence intervals (95% CI) and p value. 5-year randomised trial: from randomisation to end of randomised trial (on-trial period), 20-year long-term follow-up: from randomisation to end of extended follow-up (on-trial plus post-trial periods). ASCVD: atherosclerotic cardiovascular disease. LDL-C: low-density lipoprotein cholesterol. MACE: major adverse cardiovascular events, defined as the composite of cardiovascular death, non-fatal myocardial infarction and non-fatal stroke. To convert values for cholesterol to mmol/L, multiply by 0.02586.
Principal Endpoints

**Coronary Heart Disease**

Overall primary prevention cohort
- LDL-C <190 mg/dL
- LDL-C ≥190 mg/dL

**MACE**

Overall primary prevention cohort
- LDL-C <190 mg/dL
- LDL-C ≥190 mg/dL

Additional Endpoints explored

**Coronary Heart Disease** *

Overall primary prevention cohort
- LDL-C <190 mg/dL
- LDL-C ≥190 mg/dL

**MACE plus coronary revascularisation**

Overall primary prevention cohort
- LDL-C <190 mg/dL
- LDL-C ≥190 mg/dL

**MACE** * plus coronary revascularisation

Overall primary prevention cohort
- LDL-C <190 mg/dL
- LDL-C ≥190 mg/dL

**Coronary Heart Disease Death**

Overall primary prevention cohort
- LDL-C <190 mg/dL
- LDL-C ≥190 mg/dL

**Coronary Heart Disease Death** *

Overall primary prevention cohort
- LDL-C <190 mg/dL
- LDL-C ≥190 mg/dL

**Cardiovascular Death**

Overall primary prevention cohort
- LDL-C <190 mg/dL
- LDL-C ≥190 mg/dL

**All-cause Mortality**

Overall primary prevention cohort
- LDL-C <190 mg/dL
- LDL-C ≥190 mg/dL

**Coronary Revascularisation**

Overall primary prevention cohort
- LDL-C <190 mg/dL
- LDL-C ≥190 mg/dL

**Fatal or Non-fatal Stroke or TIA**

Overall primary prevention cohort
- LDL-C <190 mg/dL
- LDL-C ≥190 mg/dL

**Interaction**

- p-value
- HR (95% CI), p-value

-0.5 0 0.5 1 1.5 2 2.5

...
Coronary Heart Disease

- **Placebo, LDL-C <190 mg/dL**
- **Pravastatin, LDL-C <190 mg/dL**
- **Placebo, LDL-C ≥190 mg/dL**
- **Pravastatin, LDL-C ≥190 mg/dL**

### Numbers at risk

<table>
<thead>
<tr>
<th></th>
<th>Placebo, LDL-C &lt;190</th>
<th>Pravastatin, LDL-C &lt;190</th>
<th>Placebo, LDL-C ≥190</th>
<th>Pravastatin, LDL-C ≥190</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placebo, LDL-C &lt;190:</td>
<td>1493</td>
<td>1469</td>
<td>1446</td>
<td>1415</td>
</tr>
<tr>
<td>Pravastatin, LDL-C &lt;190:</td>
<td>1476</td>
<td>1457</td>
<td>1440</td>
<td>1415</td>
</tr>
<tr>
<td>Placebo, LDL-C ≥190:</td>
<td>1274</td>
<td>1248</td>
<td>1219</td>
<td>1201</td>
</tr>
<tr>
<td>Pravastatin, LDL-C ≥190:</td>
<td>1286</td>
<td>1267</td>
<td>1253</td>
<td>1231</td>
</tr>
</tbody>
</table>

**HR (95%CI) Pravastatin vs. Placebo in those with LDL-C <190 mg/dL:** 0.72 (0.54, 0.97), p=0.032

**HR (95%CI) Pravastatin vs. Placebo in those with LDL-C ≥190 mg/dL:** 0.73 (0.55, 0.98), p=0.033

**Interaction p-value between cohorts:** p=0.960
Major Adverse Cardiovascular Events

Numbers at risk
Placebo, LDL-C <190: 1493 1468 1444 1413 1216 560
Pravastatin, LDL-C <190: 1476 1453 1435 1409 1235 585
Placebo, LDL-C ≥190: 1274 1246 1217 1194 1036 474
Pravastatin, LDL-C ≥190: 1286 1266 1247 1223 1080 486

HR (95%CI) Pravastatin vs. Placebo in those with LDL-C <190 mg/dL: 0.76 (0.58, 1.00), p=0.048
HR (95%CI) Pravastatin vs. Placebo in those with LDL-C ≥190 mg/dL: 0.75 (0.57, 0.98), p=0.037
Interaction p-value between both cohorts: p=0.958
**CHD death**

Overall primary prevention cohort
- LDL-C <190 mg/dL
  - p = 0.453
  - HR (95% CI): 0.78 (0.64, 0.94), p = 0.011
- LDL-C ≥190 mg/dL
  - HR (95% CI): 0.84 (0.64, 1.10), p = 0.193
  - p = 0.72 (0.54, 0.95), p = 0.020

**Cardiovascular death**

Overall primary prevention cohort
- LDL-C <190 mg/dL
  - p = 0.211
  - HR (95% CI): 0.83 (0.71, 0.96), p = 0.015
- LDL-C ≥190 mg/dL
  - HR (95% CI): 0.91 (0.73, 1.13), p = 0.382
  - p = 0.75 (0.60, 0.93), p = 0.009

**All-cause mortality**

Overall primary prevention cohort
- LDL-C <190 mg/dL
  - p = 0.184
  - HR (95% CI): 0.88 (0.80, 0.96), p = 0.005
- LDL-C ≥190 mg/dL
  - HR (95% CI): 0.93 (0.82, 1.05), p = 0.247
  - p = 0.82 (0.72, 0.94), p = 0.004
### Coronary Heart Disease

**Absolute reduction in LDL-C levels**
- Placebo
  - Absolute fall <39 mg/dL
  - Absolute fall ≥39 mg/dL

**Relative reduction in LDL-C levels**
- Placebo
  - Percentage reduction <30%
  - Percentage reduction ≥30%

**On-treatment LDL-C levels**
- Placebo
  - On-treatment ≥174 mg/dL
  - On-treatment 145 to <174 mg/dL
  - On-treatment <145 mg/dL

### MACE plus coronary revascularisation

**Interaction p-value**
- HR (95% CI), p-value
  - Ref. group
  - p = 0.030 0.89 (0.57, 1.40), p = 0.612
  - p = 0.047 0.61 (0.42, 0.88), p = 0.008
  - p = 0.015 1.09 (0.69, 1.71), p = 0.724
  - p = 0.014 0.56 (0.35, 0.89), p = 0.014

- p = 0.086 0.88 (0.58, 1.32), p = 0.524
- p = 0.106 0.70 (0.51, 0.96), p = 0.027

- p = 0.106 0.80 (0.57, 1.10), p = 0.171
- p = 0.054 0.68 (0.46, 1.01), p = 0.054

- p = 0.046 1.06 (0.70, 1.60), p = 0.772
- p = 0.064 0.67 (0.44, 1.02), p = 0.064
- p = 0.027 0.64 (0.43, 0.95), p = 0.027