**Lipid levels, atrial fibrillation and the impact of age:**

**Results from the LIPIDOGRAM2015 study**

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**Abstract**

*Background and aims:* An inverse relationship between cholesterol and atrial fibrillation (AF) has been suggested, but whether the association is upheld for all age groups remains unclear. The aim was to examine associations between lipid levels and AF by age groups in a nationwide study in Poland.

*Methods:* Multivariate Poisson regression models were used to estimate prevalence ratios (PRs) for AF by lipid levels. Low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), total cholesterol (TC), non-HDL-C and LDL-C/HDL-C ratios were grouped into quartiles.

*Results:* Of the 13,724 participants, 5.2% (n=708) had AF. People with AF were older with more comorbidities, but lower lipid levels (all *p*<0.05). The prevalence of AF was inversely associated with LDL-C (Adjusted PR (95% Confidence Interval) highest versus lowest quartile: 0.60 (0.48, 0.75)), TC (0.61 (0.49, 0.75)) and non-HDL-C (0.63 (0.51, 0.78)). The prevalence of AF was inversely associated with HDL-C (0.58 (0.46, 0.74)), but this was not statistically significant for people aged 75 years and older. For the LDL-C/HDL-C ratio, the prevalence of AF was only inversely associated with higher levels for people aged 75 years and older (0.75 (0.61, 0.94)). There was no statistically significant difference in prevalence of AF by TG levels.

Conclusions: The results suggest an inverse relationship between lipid levels and AF. The inverse association between higher HDL-C and AF was only significant for people aged <75 years, whereas the inverse association between higher LDL-C/HDL-C ratio and AF was only significant for people aged 75 years and older.

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**Key words:** Atrial fibrillation, lipids, cholesterol, epidemiology, prevalence, age

**Introduction**

High blood lipid levels are known risk factors for atherosclerotic cardiovascular disease.1 High levels of low-density lipoprotein cholesterol (LDL-C) and low levels of high-density lipoprotein cholesterol (HDL-C) have been associated with a higher risk of coronary heart disease (CHD) and other cardiovascular conditions.2 Conversely, several epidemiological studies have suggested an inverse association between lipid levels and AF.3-5

AF is the most common heart arrhythmia worldwide and an estimated 14-17 million people in Europe will have AF by 2030.6 AF increases a person’s risk of stroke five-fold and there were 80 million prevalent cases of stroke globally in 2016.7 Several models have been developed to predict risk of AF, but no one model is recommended for use in clinical practice.8-10 Risk factors for AF usually mirror risk factors for cardiovascular disease including age, hypertension, obesity and diabetes mellitus,11 yet some observational studies have suggested that high blood lipid levels appear to be an exception. A recent meta-analysis of large cohort studies suggested an inverse association between total cholesterol (TC), LDL-C and HDL-C and incident AF, whereas there was no statistically significant association between triglyceride (TG) levels and AF.4 However, a slightly older systematic review in 2017 highlighted some inconsistencies in studies of lipid levels and AF.12 A large-scale community-based study has demonstrated conflicting results, with no significant association between TC or LDL-C and risk of AF observed, but higher TG levels were associated with a greater risk of AF and lower HDL-C levels were associated with a lower risk of AF.13

Although previous studies have examined the association between lipid levels and AF, some inconsistencies in their results suggest that there is a need for further research. This includes stratifying results by population demographics such as age to determine if the association is upheld for all groups. This would help to refine our understanding of the association between lipid levels and AF and identify groups to target intervention strategies as required.

In the current study, we examined associations between lipid levels and AF in a large nationwide study in Poland. We stratified the results to determine whether associations between lipids and AF differed depending on the age of the participants. We hypothesised that associations between lipid levels and AF would be influenced by age.

**Patients and methods**

**Study participants**

The LIPIDOGRAM2015 study was a nationwide cross-sectional survey of cardiovascular health for adults in Poland. Adults aged 18 years and older were recruited in 2015 and 2016 by 438 participating family physicians. The LIPIDOGRAM study was run previously in 2004 and 2006. The same methodology was applied for the 2004, 2006, and 2015 studies and has been described elsewhere.14-16 Briefly, each participating physician completed individual training before commencing data collection, which involved completion of study questionnaires and taking measurements as specified in the study protocol.

**Lipid levels**

Blood samples were taken from the participants following fasting for ≥12 hours. Analysis was performed on blood samples that were transported in cooled containers to the designated central laboratory within 12 hours of collection. Measurements of TC, TG, HDL-C (the direct immunological method), and LDL-C (the direct immunological method) were performed using the same methodology and the same analyser and reagents for all samples.16 The LDL-C/HDL-C ratio was subsequently calculated based on the LDL-C and HDL-C measurements and non-HDL-C was calculated as TC minus HDL-C.

**Atrial fibrillation**

A diagnosis of AF was based on the medical records of the participant and length of AF diagnosis was based on the date of the first recording of AF.

**Covariates**

Covariates included 1) demographic factors including age and sex; 2) measures related to current health status including waist-to-hip ratio and blood pressure; 3) cardiovascular-related health conditions including history of CHD, myocardial infarction and stroke taken from the medical records of the participant; hypertension defined as a record of elevated systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg, and/or the use of antihypertensive medications; and diabetes mellitus based on the medical records of the participant and on international recommendations (a recorded increased fasting plasma glucose >7 mmol/L, or random plasma glucose >11.1 mmol/L, or the use of oral hypoglycaemic medications or insulin); 4) lifestyle factors including smoking status (never, past, or current) and alcohol intake (never (not drinking at all), moderate (defined as up to 1 drink per day for women and up to 2 drinks per day for men: 1 drink = 10-15g of ethanol = 250 ml of beer = 150 ml of wine = 30 ml of vodka) or high (defined as >1 drink per day for women and >2 drinks per day for men)) which were self-reported by the participant at the time of data collection; 5) cardiovascular-related medications including treatment of dyslipidaemia (exposure to statins and/or fibrates) and antihypertensives. For all medications, exposure was defined as at least 30 days prior to date of data collection.

**Statistical analysis**

Characteristics of all participants and by AF status (yes/no) were presented as proportions and total numbers or medians and interquartile ranges (IQRs), as appropriate. Chi-squared tests for categorical variables and Mann-Whitney U tests for continuous variables were used to examine differences by AF status. Multivariate Poisson regression models with robust variance were used to estimate prevalence ratios (PRs) for AF with 95% confidence intervals (CIs) for participants with lipid levels grouped into quartiles. Lipid measures including LDL-C, HDL-C, TG, TC, LDL-C/HDL-C ratios and non-HDL-C were grouped into quartiles with the lowest quartile as the reference group. Models were adjusted for potential confounding factors including age, sex, waist-to-hip ratio, smoking, alcohol intake, regular physical activity, hypertension, antihypertensive medication use and treatment of dyslipidaemia. Results were presented for all participants and stratified by age groups and sex. We only included participants aged 50 years and over in the age stratified analyses due to the low prevalence of AF in people aged <50 years. Age categories were 50-64 years, 65-74 years and 75 years and over. We did not further group older age categories because of relatively few participants aged over 85 years (0.9%, n=118 of the total participants). *p*<0.05 was considered to indicate statistical significance. All analyses were completed with Stata v.14.0 and v.15.0 (Stata Corp LP, College Station, TX, USA).

**Ethical approval**

All individuals provided written informed consent to participate in the study and gave permission to use anonymous questionnaire data, the results of their laboratory tests and secured biologic material for inclusion in statistical and scientific studies. The LIPIDOGRAM2015 study received a favourable opinion from the Bioethical Commission of the Chamber of Physicians on 02/12/2015 (No K.B.Cz.-0018/2015) and conforms to the principles outlined in the Declaration of Helsinki.

**Results**

**Characteristics of the participants**

There were 13,724 participants recruited to the LIPIDOGRAM2015 study. The characteristics of participants are presented in Table 1. The median [IQR] age was 58.0 [47.4-65.8] and 63.3% (n=8,690) were female. Of the total participants, 53.9% (n=7,390) self-reported current tobacco use, 40.3% (n=5,535) reported regular physical activity, 64.8% (n=8,896) reported moderate alcohol intake and only 0.7% (n=96) reported high alcohol intake. Almost half of participants (49.5%, n=6,788) were identified as having hypertension, 13.4% (n=1,843) had diabetes mellitus, 2.8% (n=385) had chronic kidney disease, 13.0% (n=1,787) had CHD, 2.1% (n=294) had a history of stroke and 4.6% (n=625) had a history of myocardial infarction. Almost half of participants (47.5%, n=6,515) were receiving antihypertensive medications and 34.3% (n=4,703) were receiving treatment for dyslipidaemia.

**Lipid levels and atrial fibrillation for all participants**

The median [IQR] lipid levels for all participants were 3.3mmol/L [2.6-4.0] for LDL-C, 1.4mmol/L [1.1-1.7] for HDL-C, 3.2mmol/L [2.3-4.4] for TG, 5.2mmol/L [4.4-5.9] for TC, 3.7mmol/L [3.0-4.5] for non-HDL-C and 2.4 [1.8-3.1] for LDL-C/HDL-C ratio. The median [IQR] lipid levels by quartile for each lipid measure are shown in the supplementary table.

Of the total participants, 5.2% (n=708; 95% CI: 4.8, 5.5) were identified as having a diagnosis of AF, with a median [IQR] 3 [1-8] years since diagnosis. Of the 708 participants identified as having AF, 43.5% (n=308) were not receiving oral anticoagulation; 21.6% (n=153) received acenocumarol, 18.6% (n=132) warfarin and 16.2% (n=115) NOACs.

Compared to participants without a diagnosis of AF, those with AF were statistically significantly older and had a higher waist-to-hip ratio, a lower proportion of females, a lower proportion of people who reported regular physical activity and a higher proportion of people with other cardiovascular-related conditions including CHD, myocardial infarction, stroke, chronic kidney disease and hypertension. Participants with AF also had a significantly higher proportion receiving anticoagulants, antihypertensives and treatment for dyslipidaemia. There were statistically significant differences in smoking status and alcohol intake between participants with and without a diagnosis of AF (Table 1).

Figure 1a shows the unadjusted proportions and 95% confidence intervals of AF according to lipid levels grouped into quartiles for all participants. After adjusting for potential confounding factors, compared to participants in the lowest quartile, a statistically significant lower prevalence of AF was estimated for participants in the highest quartile for LDL-C (PR (95% CI): 0.60 (0.48, 0.75), *p*<0.001), HDL-C (0.58 (0.46, 0.74), *p*<0.001), TC (0.61 (0.49, 0.75), *p*<0.001), non-HDL-C (0.63 (0.51, 0.78), *p*<0.001) and LDL-C/HDL-C ratio (0.75 (0.61, 0.94), *p*=0.010). Also, a statistically significant lower prevalence of AF was estimated for participants in the middle quartiles for LDL-C, HDL-C and TC compared to participants in the lowest quartile. No statistically significant difference in prevalence of AF was observed for participants across different quartiles for TG levels (Table 2). Upon stratifying results by sex, the results for lower prevalence of AF for the highest versus lowest quartile for LDL-C, HDL-C, TC, non-HDL-C and LDL-C/HDL-C ratios remained statistically significant for males and females. However, the PRs were all lower for males compared to females (Table 3).

**Lipid levels and atrial fibrillation stratified by age categories**

Of the total participants, 43.0% (n=5,903) were aged between 50 and 64 years, 19.7% (n=2,709) were aged between 65 and 74 years and 7.8% (n=1,071) were aged 75 years or older. The proportion of people with a diagnosis of AF were 3.9% (95%CI: 3.5, 4.5), 10.5% (95%CI: 9.4, 11.7) and 15.0% (95%CI: 13.0, 17.3), respectively, across these age categories.

Figures 1b-d show the unadjusted proportions and 95% confidence intervals of AF according to lipid levels grouped into quartiles for participants by age categories. For LDL-C, TC and non-HDL-C, the prevalence of AF remained statistically significantly lower for participants in the highest quartile compared to those in the lowest quartile across all age categories. For HDL-C, the prevalence of AF was not statistically significantly lower for those in the highest quartile compared to the lowest quartile for those aged 75 years or older. For the LDL-C/HDL-C ratio, the prevalence of AF only remained statistically significantly lower for those in the highest quartile compared to the lowest quartile for people aged 75 years and older. Similar to the results for all participants, no statistically significant difference in prevalence of AF was observed for participants across different quartiles for TG levels for any age category (Table 2).

**Discussion**

In this study of almost 14,000 adults across Poland, we determined that higher levels of LDL-C, TC and non-HDL-C were associated with lower prevalence of AF. Second, we demonstrated that higher levels of HDL-C were inversely associated with AF for younger people only (<75 years) and higher LDL-C/HDL-C ratios were inversely associated with AF for older people only (75 years or older). Third, there was no significant association observed between TG levels and the prevalence of AF in this study.

There have been inconsistencies in previous studies examining the association between lipid levels and AF. One systematic review of prospective population-based cohorts found 4 of 13 included studies reported a significant inverse association between TC and AF with relative risks (95% confidence intervals) from 0.76 (0.59, 0.98) to 0.94 (0.90, 0.97), and 8 of 13 reports found non-significant inverse associations.12 One previous large study of two community-based studies in the United States did not find a significant association between LDL-C or TC and risk of AF13, but many other previous studies have found an inverse association,5, 17-20 which is in line with the results of this current study. The study which did not find an association between LDL-C or TC and AF reported that AF was primarily based on hospital discharge codes and bias may have occurred in AF ascertainment.13

There have been greater inconsistencies in the findings reported between studies for the associations between HDL-C or TG and AF. Some studies have reported inverse associations between HDL-C or TG and AF,5, 17 some studies have reported no statistically significant associations18-20 and one study reported an inverse association between HDL-C and AF, but a positive association between TG levels and AF.13

Unlike other lipid measures, HDL-C is considered a protective factor for atherosclerotic cardiovascular disease. Forty-five years ago, the Framingham Heart Study was the first large-scale observational study to report an inverse association between HDL-C levels and CHD.21 More recently, a cross-sectional study suggested that HDL promotes reverse cholesterol transport from macrophages which was strongly and inversely associated with both subclinical atherosclerosis and obstructive CHD.22 CHD is also a risk factor for AF.8 Finding an inverse association with HDL-C and AF suggests a similar association as seen with other cardiovascular outcomes. It remains unclear why HDL-C and LDL-C show the same inverse relationship with AF, but the opposite relationship with other cardiovascular conditions.

When we examined the results by sex only, we found the significance of the results remained consistent for males and females; however, the prevalence ratios were lower for males. This suggests the inverse association between lipid levels and AF may be greater for males. Similarly to the results of this study, some previous studies have also found no difference in the association between lipid levels and AF when stratifying results by sex13, 20, but some studies have found differences. One large-scale study of four community-based European studies reported a greater risk reduction in incident AF for higher TC levels in women compared to men, whereas a large study in Korea found a greater risk reduction with high TG in men compared to women.23 In a large Japanese cohort, lower HDL-C levels were associated with a higher incidence of AF in women aged 50 years and older, but not in women aged <50 years or in men.17 We did not further stratify results in the current study by sex in addition to age, as this would have further reduced the power to detect significant associations for the older age group.

Age is an important modifier to consider when exploring associations between lipid levels and AF because the prevalence of AF increases substantially with age.6 Age has also been inversely associated with TC and LDL-C levels.24 Previous cross-sectional and longitudinal studies suggest TC and LDL-C levels increase until between 60 and 75 years, and then begin to decrease.24-27 In addition to age, declining cholesterol levels may be influenced by sex, weight loss and white blood cell count. Trends in HDL-C and TG levels by age are less well established.26 Declines in TC and LDL-C in older age groups may partly explain the inverse association between TC or LDL-C levels and AF. However, age was adjusted for in the current analyses, and the associations were significant in participants aged 50-64 years, therefore, other underlying mechanisms need to be considered.

Underlying mechanisms which may contribute to the inverse association between lipid levels and AF have been suggested, but the precise biological pathways involved remain unclear. The first proposed mechanism is derived from the knowledge that cholesterol levels influence cell membrane properties including membrane fluidity and permeability.28 In vitro evidence suggests lipid levels may increase cell membrane fluidity, alter the distribution of ion channels and change the resting potential across the membrane.29, 30 This may, in turn, increase the development of arrhythmias.31 Second, inflammatory pathways are associated with both cholesterol levels and AF. Increased levels of inflammatory biomarkers have been associated with AF. Endothelial activation or damage, production of tissue factor from monocytes, increased platelet activation, and increased expression of fibrinogen have all been suggested to underlie the association between inflammation and AF.32 The relationship between cholesterol levels and inflammatory pathways is complex with both pro- and anti-inflammatory pathways suggested.13, 33 Therefore, it is unclear if and how inflammation could play a role in the relationship between cholesterol levels and AF. Third, hyperthyroidism is associated with lower levels of TC and LDL-C34 and increased risk of AF.35 Consequently, hyperthyroidism may mediate some of the association seen, but this could not be further explored in the current study. Further investigation of the role of oxidative stress on the relationship between cholesterol levels and AF is also warranted. Oxidative stress has been suggested to promote the development of AF, and both increase with age.36 Oxidative stress may increase levels of Proprotein Convertase Subtilisin/Kexin type 9 (PCSK9) which impacts the number of LDL-receptors.37 When levels of PCSK9 are elevated there is a subsequent reduction in LDL-receptors and an increase in levels of LDL-C.38 Patients with AF who have higher levels of PCSK9 have a higher risk of cardiovascular events.37

**Strengths and limitations**

This study has several strengths and limitations. This is a national study of adults across Poland. Data collected included demographics, health measures, cardiovascular co-morbidities and medications, thereby allowing for adjustment of a wide range of potential confounding factors. The study included a wide age range of participants to enable stratification of results by age group, but there was a higher proportion of people aged 50-64 years compared to the older age groups, therefore, the results for the entire population may be driven by the findings for the younger age group. The main limitation is the cross-sectional design of the study, so no casual inference can be made about factors identified as being associated with AF. Residual confounding may be a possibility and some measures which were not collected in the study may impact the results such as estimated glomerular filtration rate and thyroid stimulating hormone levels. In addition, the cross-sectional design did not permit examination of the variability in lipid levels over time; high variability in lipid levels has been associated with a higher risk of AF previously.5 When stratifying by age groups, the older age group (75 years and older) had fewer participants than the other age groups, therefore, a reduction in power may have impacted the non-significant association seen between HDL-C and AF for the older age group. Furthermore, ascertainment of AF was based on medical records and some AF cases may be undetected.

**Conclusions**

In a large national cross-sectional survey of adults in Poland, higher levels of LDL-C, HDL-C, TC, non-HDL-C and LDL-C/HDL-C ratios were associated with a lower AF prevalence. When stratifying the results by age groups, the highest quartiles for LDL-C, TC and non-HDL-C levels remained significantly associated with a lower AF prevalence compared to the lowest quartiles. The current study also adds further evidence that there may be no significant association between TG and AF. Overall these findings provide further support of an inverse association between lipid levels and AF and emphasise the importance of stratifying results by age groups when investigating this association. Deciphering the relationship between lipid levels and AF has important implications for the development of potential primary and secondary intervention strategies for AF.

**Conflict of interest**

GYHL: Consultant for Bayer/Janssen, BMS/Pfizer, Medtronic, Boehringer Ingelheim, Novartis, Verseon and Daiichi-Sankyo. Speaker for Bayer, BMS/Pfizer, Medtronic, Boehringer Ingelheim, and Daiichi-Sankyo. No fees are directly received personally. DAL has received investigator-initiated educational grants from Bristol-Myers Squibb (BMS); has been a speaker for Boehringer Ingelheim and BMS/Pfizer; and has consulted for BMS/Pfizer, Boehringer Ingelheim, and Daiichi-Sankyo. MB has received research grant(s)/support from Amgen, Mylan, Sanofi and Valeant, and has served as a consultant for Akcea, Amgen, Daiichi-Sankyo, Freia Pharmaceuticals, KRKA, MSD, Mylan, Novartis, Polfarmex, Polpharma, Sanofi-Aventis, Servier, Esperion, and Resverlogix. JJJ has received research grant/support from Valeant, and has served as a consultant or speaker for Valeant, Amgen, Teva, Servier, Boehringer Ingelheim, Celgene, Bioton, Microlife and ALAB Laboratories. SLH: None declared. MM: None declared.

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**Author contributions**

JJ and MB designed the LIPIDOGRAM2015 study and completed the acquisition of data. SLH conducted the analyses for the study and completed the first draft of the manuscript. GYHL made a substantial contribution to the concept of the study. GYHL, DAL and SLH made a substantial contribution to the interpretation of data. GYHL, DAL, MB, MM, SK, and JJJ revised the article critically for important intellectual content. All authors gave final approval of the work have participated sufficiently in the work and take public responsibility for appropriate portions of the content.

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**Figure 1 a, b, c and d. Prevalence of atrial fibrillation by differing lipid levels for all participants and by age categories in the LIPIDOGRAM2015 study (n=13,724).**

(A) All participants (n=13,724) (B) Aged 50-64 years (n=5,903)

(C) Aged 65-74 years (n=2,709) (D) Aged 75 years and older (n=1,071)

Abbreviations LDL-C, low-density lipoprotein cholesterol, HDL-C, high-density lipoprotein cholesterol, TG, triglycerides; TC, total cholesterol. Results are unadjusted proportions and 95% confidence intervals.

**Table 1. Characteristics of participants in the LIPIDOGRAM2015 study, overall and with and without AF.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | All participants  (n=13,724) | Atrial Fibrillation  (n=708) | No Atrial Fibrillation  (n=13,016) | *p-value* |
| Age (years), median [IQR] | 58.0 [47.4-65.8] | 67.7 [62.4-74.4] | 57.4 [46.8-65.2] | <0.001 |
| Age categories (years) |  |  |  | <0.001 |
| <50 | 29.4 (4,041) | 4.4 (31) | 30.8 (4,010) |  |
| 50-64 | 43.0 (5,903) | 32.8 (232) | 43.6 (5,671) |  |
| 65-74 | 19.7 (2,709) | 40.1 (284) | 18.6 (2,425) |  |
| 75+ | 7.8 (1,071) | 22.7 (161) | 7.0 (910) |  |
| Female | 63.3 (8,690) | 57.9 (410) | 63.6 (8,280) | 0.002 |
| Waist-to-hip ratio, median [IQR] | 0.89 [0.83-0.96] | 0.92 [0.87-0.98] | 0.89 [0.83-0.95] | <0.001 |
| Smoking |  |  |  | <0.001 |
| Never | 16.8 (2,303) | 10.0 (71) | 17.2 (2,232) |  |
| Past | 29.4 (4,031) | 37.3 (264) | 28.9 (3,767) |  |
| Current | 53.9 (7,390) | 52.7 (373) | 53.9 (7,017) |  |
| Alcohol intake |  |  |  | <0.001 |
| Never | 34.5 (4,732) | 47.0 (333) | 33.8 (4,399) |  |
| Moderate | 64.8 (8,896) | 52.7 (373) | 65.5 (8,523) |  |
| High | 96 (0.7) | 2 (0.3) | 0.7 (4) |  |
| Regular physical activity | 40.3 (5,535) | 31.4 (222) | 40.8 (5,313) | <0.001 |
| Hypertension | 49.5 (6,788) | 77.3 (547) | 48.0 (6,241) | <0.001 |
| Diabetes mellitus | 13.4 (1,843) | 26.1 (185) | 12.7 (1,658) | <0.001 |
| Prior stroke | 2.1 (294) | 8.3 (59) | 1.8 (235) | <0.001 |
| Coronary heart disease | 13.0 (1,787) | 50.9 (360) | 11.0 (1,427) | <0.001 |
| Myocardial infarction | 4.6 (625) | 15.7 (111) | 4.0 (514) | <0.001 |
| Chronic kidney disease | 2.8 (385) | 8.5 (60) | 2.5 (325) | <0.001 |
| Anticoagulants |  |  |  | <0.001 |
| None | 93.5 (12,831) | 43.5 (308) | 96.2 (12,523) |  |
| NOAC | 1.7 (229) | 16.2 (115) | 0.9 (114) |  |
| Acenocumarol | 1.8 (245) | 21.6 (153) | 0.7 (92) |  |
| Warfarin | 3.1 (419) | 18.6 (132) | 2.7 (287) |  |
| Antihypertensives | 47.5 (6,515) | 75.1 (532) | 46.0 (5,983) | <0.001 |
| Treatment of dyslipidaemia | 34.3 (4,703) | 52.1 (369) | 33.3 (4,334) | <0.001 |
| LDL-C mmol/L, median [IQR] | 3.3 [2.6-4.0] | 2.8 [2.2-3.7] | 3.3 [2.6-4.0] | <0.001 |
| HDL-C mmol/L, median [IQR] | 1.4 [1.1-1.7] | 1.3 [1.1-1.5] | 1.4 [1.1-1.7] | <0.001 |
| TG mmol/L, median [IQR] | 3.2 [2.3-4.4] | 3.3 [2.5-4.6] | 3.2 [2.3-4.4] | 0.01 |
| TC mmol/L, median [IQR] | 5.2 [4.4-5.9] | 4.7 [4.0-5.5] | 5.2 [4.5-6.0] | <0.001 |
| Non-HDL-C mmol/L, median [IQR] | 3.7 [3.0-4.5] | 3.4 [2.7-4.1] | 3.7 [3.1-4.5] | <0.001 |
| LDL-C/HDL-C, median [IQR] | 2.4 [1.8-3.1] | 2.3 [1.7-2.9] | 2.4 [1.8-3.1] | 0.006 |

Results are % (n), unless otherwise stated. Abbreviations: HDL-C, high-density lipoprotein cholesterol, IQR, interquartile range, LDL-C, low-density lipoprotein cholesterol, NOAC, non-vitamin-K antagonist oral anticoagulant, TC, total cholesterol, TG, triglycerides.   
P-values comparing those with and without AF are from chi-squared tests for categorical variables and Mann-Whitney U tests for continuous variables.

**Table 2. Adjusted prevalence ratios (95% confidence intervals) of atrial fibrillation by lipid levels for all participants, by age group.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **LDL-C** | **HDL-C** | **TG** | **TC** | **Non-HDL-C** | **LDL-C/HDL-C** |
| **All participants** (n=13,724) | | | | | | |
| Lowest quartile | Ref | Ref | Ref | Ref | Ref | Ref |
| Quartile 2 | 0.80 (0.67, 0.97) | 0.79 (0.66, 0.95) | 1.21 (0.98, 1.50) | 0.82 (0.69, 0.99) | 0.90 (0.75, 1.07) | 0.95 (0.79, 1.15) |
| Quartile 3 | 0.82 (0.68, 0.99) | 0.81 (0.67, 0.98) | 1.12 (0.90, 1.38) | 0.60 (0.49, 0.74) | 0.79 (0.64, 0.96) | 1.05 (0.87, 1.27) |
| Highest quartile | 0.60 (0.48, 0.75) | 0.58 (0.46, 0.74) | 1.18 (0.95, 1.47) | 0.61 (0.49, 0.75) | 0.63 (0.51, 0.78) | 0.75 (0.61, 0.94) |
| **Aged >50 and ≤64 years** (n=5,903) | | | | | | |
| Lowest quartile | Ref | Ref | Ref | Ref | Ref | Ref |
| Quartile 2 | 0.57 (0.40, 0.82) | 0.68 (0.49, 0.94) | 1.21 (0.79, 1.83) | 0.82 (0.60, 1.14) | 0.74 (0.52, 1.04) | 0.98 (0.67, 1.42) |
| Quartile 3 | 0.60 (0.42, 0.85) | 0.57 (0.40, 0.82) | 1.36 (0.91, 2.04) | 0.39 (0.27, 0.58) | 0.57 (0.40, 0.81) | 1.06 (0.74, 1.52) |
| Highest quartile | 0.46 (0.33, 0.66) | 0.38 (0.25, 0.59) | 1.20 (0.80, 1.79) | 0.44 (0.31, 0.64) | 0.47 (0.33, 0.68) | 0.78 (0.53, 1.14) |
| **Aged 65-74 years** (n=2,709) | | | | | | |
| Lowest quartile | Ref | Ref | Ref | Ref | Ref | Ref |
| Quartile 2 | 0.82 (0.62, 1.09) | 0.83 (0.63, 1.10) | 1.33 (0.93, 1.90) | 0.78 (0.59, 1.04) | 0.90 (0.68, 1.18) | 0.93 (0.69, 1.27) |
| Quartile 3 | 0.78 (0.57, 1.06) | 0.87 (0.64, 1.17) | 1.23 (0.86, 1.76) | 0.60 (0.43, 0.83) | 0.80 (0.58, 1.09) | 1.10 (0.81, 1.48) |
| Highest quartile | 0.64 (0.45, 0.91) | 0.63 (0.43, 0.92) | 1.40 (0.98, 2.00) | 0.64 (0.45, 0.90) | 0.67 (0.47, 0.94) | 0.74 (0.52, 1.05) |
| **Aged ≥75 years** (n=1,071) | | | | | | |
| Lowest quartile | Ref | Ref | Ref | Ref | Ref | Ref |
| Quartile 2 | 0.86 (0.60, 1.23) | 0.90 (0.61, 1.32) | 1.03 (0.73, 1.47) | 0.70 (0.48, 1.03) | 0.86 (0.60, 1.23) | 0.78 (0.55, 1.10) |
| Quartile 3 | 0.95 (0.65, 1.39) | 0.99 (0.68, 1.46) | 0.67 (0.44, 1.01) | 0.85 (0.57, 1.26) | 0.91 (0.62, 1.34) | 0.79 (0.54, 1.16) |
| Highest quartile | 0.38 (0.21, 0.69) | 0.88 (0.56, 1.39) | 0.64 (0.40, 1.03) | 0.55 (0.34, 0.90) | 0.49 (0.29, 0.82) | 0.51 (0.32, 0.83) |

Models adjusted for age, sex, waist-to-hip ratio, smoking, alcohol intake, regular physical activity, hypertension, antihypertensive medications and treatment of dyslipidaemia.   
Abbreviations: HDL-C, high-density lipoprotein cholesterol, LDL-C, low-density lipoprotein cholesterol, NOAC, non-vitamin-K antagonist oral anticoagulant, TC, total cholesterol, TG, triglycerides. Ref is the reference group.

**Table 3. Adjusted prevalence ratios (95% confidence intervals) of atrial fibrillation by lipid levels for all participants, by sex.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **LDL-C** | **HDL-C** | **TG** | **TC** | **Non-HDL-C** | **LDL-C/HDL-C** |
| **Males** (n=5,034) | | | | | | |
| Lowest quartile | Ref | Ref | Ref | Ref | Ref | Ref |
| Quartile 2 | 0.61 (0.45, 0.81) | 0.77 (0.59, 1.01) | 1.16 (0.84, 1.60) | 0.70 (0.54, 0.92) | 0.83 (0.63, 1.08) | 0.85 (0.62, 1.17) |
| Quartile 3 | 0.66 (0.49, 0.88) | 0.97 (0.71, 1.31) | 0.94 (0.67, 1.30) | 0.41 (0.29, 0.58) | 0.54 (0.39, 0.74) | 0.88 (0.65, 1.19) |
| Highest quartile | 0.32 (0.21, 0.47) | 0.42 (0.23, 0.75) | 0.75 (0.54, 1.04) | 0.34 (0.23, 0.50) | 0.35 (0.24, 0.50) | 0.51 (0.37, 0.71) |
| **Females** (n=8,690) | | | | | | |
| Lowest quartile | Ref | Ref | Ref | Ref | Ref | Ref |
| Quartile 2 | 0.78 (0.61, 0.99) | 0.88 (0.68, 1.14) | 1.30 (0.98, 1.73) | 0.79 (0.62, 1.01) | 0.80 (0.63, 1.03) | 0.88 (0.69, 1.13) |
| Quartile 3 | 0.77 (0.60, 0.99) | 0.84 (0.65, 1.09) | 1.16 (0.86, 1.56) | 0.67 (0.51, 0.88) | 0.82 (0.63, 1.06) | 0.92 (0.71, 1.18) |
| Highest quartile | 0.68 (0.52, 0.89) | 0.70 (0.52, 0.93) | 1.22 (0.90, 1.65) | 0.70 (0.54, 0.90) | 0.71 (0.54, 0.92) | 0.75 (0.56, 0.99) |

Models adjusted for age, waist-to-hip ratio, smoking, alcohol intake, regular physical activity, hypertension, antihypertensive medications and treatment of dyslipidaemia.   
HDL-C: high-density lipoprotein cholesterol, LDL-C: low-density lipoprotein cholesterol, NOAC: non vitamin-K antagonist oral anticoagulant, TC: total cholesterol, TG: triglycerides. Ref is the reference group.

**Supplementary Table. Median values for lipid measures by quartiles.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Lowest Quartile** | **Quartile 2** | **Quartile 3** | **Quartile 4** |
| LDL-C mmol/L | 2.2 [1.9-2.4] | 2.9 [2.8-3.1] | 3.6 [3.4-3.8] | 4.6 [4.3-5.0] |
| HDL-C mmol/L | 1.0 [0.9-1.1] | 1.3 [1.2-1.3] | 1.5 [1.4-1.6] | 1.9 [1.7-2.1] |
| TG mmol/L | 1.9 [1.6-2.1] | 2.7 [2.5-2.9] | 3.7 [3.4-4.0] | 5.8 [5.0-7.4] |
| TC mmol/L | 4.0 [3.6-4.2] | 4.8 [4.6-5.0] | 5.5 [5.3-5.7] | 6.6 [6.2-7.0] |
| Non-HDL-C mmol/L | 2.6 [2.3-2.9] | 3.4 [3.2-3.5] | 4.1 [3.9-4.3] | 5.1 [4.7-5.6] |
| LDL-C/HDL-C | 1.4 [1.2-1.6] | 2.1 [1.9-2.2] | 2.7 [2.5-2.9] | 3.6 [3.3-4.1] |

Values are median [IQR]. HDL-C: high-density lipoprotein cholesterol, LDL-C: low-density lipoprotein cholesterol, TC: total cholesterol, TG: triglycerides.

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