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The association of education and household income with the lifetime risk of incident atrial fibrillation: The Framingham Heart study

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ABSTRACT

Background: Social determinants of health, in particular education and income, influence the incidence, management, and outcomes of cardiovascular diseases including atrial fibrillation (AF). Data are limited on the associations of socioeconomic status with lifetime risk of incident AF.

Methods: We selected 2172 FHS participants (51% women) who were free of AF at the index age of 55 years. We assessed educational attainment (≥college) at the last exam prior to index age and household income ($40k/50k/≥55k depending on the FHS cohort). We estimated the lifetime risk of AF as the cumulative incidence of AF, accounting for the competing risk of death, at age 95 years. We analyzed strata defined by education and household income separately, and by combining education and household income. We adjusted analyses for sex, height, weight, systolic and diastolic blood pressure, current smoking, alcohol consumption, use of antihypertensive medication, diabetes, history of myocardial infarction, and history of heart failure.

Results: Over a mean follow-up of 13 years, 265 participants developed incident AF. The lifetime risk of developing AF was 32.5% (95%CI, 26.5% to 38.5%) and 32.5% (95%CI, 28.7% to 38.3%) among participants with lower and higher education attainment (p=0.98). The lifetime risk of developing AF was 32.1% (95%CI, 26.7% to 37.5%) and 31.8% (95%CI, 26.6% to 36.9%) among participants with lower and higher household income (p=0.79). There was no evidence of interaction between education and income on lifetime risk of AF (p = 0.84). Results were similar in subgroups of women and men.

Conclusion: In our community-based sample, there was no evidence of an association between education or household income and lifetime risk of AF.

1. Introduction

With the advancing age of the United States population, the prevalence of atrial fibrillation (AF) is increasing. Age-standardized AF prevalence rate was 775.9 per 100,000 (95% UI: 592.4 to 990.8 per 100,000) in 1990 and 743.5 per 100,000 (95% UI: 571.2 to 938.3 per 100,000) in 2019. [1] It is also estimated that 12 million people in the US will have AF by 2030. [2] AF is associated with increased mortality rates [3] and substantial morbidity from heart failure, stroke, and poor quality of life. [4]

Despite improvement in AF management, strategies for identifying people at risk of AF and targeting them for risk factor modification are still needed. Many AF risk factors have been identified including cigarette smoking, alcohol consumption, hypertension, obesity, diabetes, history of myocardial infarction, and history of heart failure. [5, 6] However, the currently known risk factors only account for about half of the risk of AF, highlighting the need to identify additional risk factors for AF. [7–9]

Moreover, research on prevention of AF has mostly relied on the risk of developing AF within 5 or 10 years. The residual lifetime risk gives a measure of the absolute risk for developing AF over a person's remaining life time after attaining a certain index age. [10] In addition to short-term predicted risk, estimating the lifetime risk and the associated factors could improve patients' understanding of AF risk, and could motivate lifestyle and risk factor modification early on. [11]

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The lifetime risk of AF is about 1 in 3 among individuals of European ancestry for men and women 45 years of age and older, compared to a corresponding risk of 1 in 5 among Black individuals. [12, 13] Clinical risk factors and genetic predisposition influence the lifetime risk of AF. [14]

Social factors, in particular education and income, influence the incidence, management, and outcomes of cardiovascular diseases, including AF. [15–19] Mou et al. have examined the lifetime risk for developing AF according to income and education in the Atherosclerosis Risk in Community (ARIC) study. [13] The lifetime risk of AF was higher among individuals with higher income and higher education in most sex-race groups. This paradoxical association was driven by the increase in risk of AF after age 80 years in those with higher income and education categories.

To add to the existing knowledge on the association of socioeconomic status with the lifetime risk for developing AF, we assessed the lifetime risk of AF according to income and education jointly in the Framingham Heart Study (FHS). We hypothesized that lower socioeconomic status is associated with increased lifetime risk of AF.

2. Methods

2.1. Study sample

Details of the design and selection criteria of the FHS cohorts have been described elsewhere. [20] All FHS participants provided written informed consent, and the Boston University Medical Center Institutional Review Board approved the study. We included all participants enrolled in the FHS Offspring, Third Generation, New Offspring Spouse, and Omni 2 (multiethnic cohort) cohorts who had information on AF clinical risk factors, education, and income. We selected FHS participants who were 55 years or older and free of AF. We excluded participants who had a prevalent AF or died prior to the index age. We excluded individuals with missing information on clinical risk factors, education, or income. In particular, for index age 55 years, we excluded participants who did not have an FHS examination between ages 50 and <60 years.

2.2. Exposure of interest

Information on education was collected during the FHS research center examinations and categorized into no high school degree, high school degree only, some college, and college graduate. We used the last education ascertainment prior to the index age, considering that education attainment is usually stable among FHS participants. In our analyses, we dichotomized education into completed high school or less versus some college or more. Household income was also ascertained during FHS research center examinations. We used household income assessed within 5 years of the index age. Our objective was to limit misclassification, as changes in household income were likely over time. Income was collected as an ordinal variable, but the categories were different between the Offspring cohort, Third Generation/New Offspring Spouse/Omni 2 cohorts examination 1, and Third Generation/New Offspring Spouse/Omni 2 cohorts examination 2 (Appendix). In our analyses, we dichotomized household income into $40,000 or more versus less than $40,000 in the Offspring cohort, $50,000 or more versus less than $50,000 for Third Generation/New Offspring Spouse/Omni 2 cohorts examination 1, and $55,000 or more versus less than $55,000 for Third Generation/New Offspring Spouse/Omni 2 cohorts examination 2.

2.3. Outcome and follow-up

We combined atrial flutter and AF. Both were ascertained by evaluating electrocardiograms from FHS examinations, participants' medical appointments, or hospital records. As per FHS protocol, FHS cardiologists evaluated cases of newly diagnosed AF.

If household income and clinical risk factors were measured between age 50 and 55 years, the entry age was set as 55 years. If these variables were measured between age 55 and <60 years, the entry age was the specific age when risk factors were measured. We defined the exit age as the participant's age at the earliest of incident AF, death, 95th birthday, or December 31st 2018.

2.4. Clinical risk factors or covariates

Based on the CHARGE-AF simple clinical risk model, we considered the following AF clinical risk factors: height, weight, systolic and diastolic blood pressure, current smoking, alcohol consumption, use of antihypertensive medication, diabetes, and history of myocardial infarction at or prior to AF diagnosis, and history of heart failure. [21] Brachial blood pressure was measured using a standard mercury column sphygmomanometer and a cuff of appropriate size. The average of the 2 physician-obtained measurements on the right arm of the seated participants was used as the examination blood pressure. Diabetes mellitus was defined as having a fasting blood glucose of ≥126 mg/dl (7 mmol/L) or a non-fasting blood glucose level ≥ 200 mg/dL or being treated with insulin and/or any oral hypoglycemic medications. Current smoking status was defined as self-reported smoking at least one cigarette a day for the year preceding the FHS examination. Elevated alcohol consumption was defined as >14 units of alcohol per week for men and >7 units of alcohol per week for women. Body mass index was calculated as weight in kilograms divided by height in meters squared (kg/m^2). History of myocardial infarction or history of heart failure was obtained from FHS examinations, participants' medical appointments and hospital records and adjudicated by the FHS review panel as previously described. [22]

2.5. Statistical analysis

We estimated the lifetime risk of AF by using age as the time scale. We estimated the cumulative incidence function of AF, accounting for the competing risk of death by using the Aalen-Johansen estimator. We defined the lifetime risk as the cumulative incidence at age 95 years. We estimated the crude cumulative incidence curves and lifetime risks for AF in strata defined by education, and household income, and by combining education and household income. We also estimated cumulative incidence curves and lifetime risks for AF with adjustment for sex, height, weight, systolic and diastolic blood pressure, current smoking, elevated alcohol consumption, use of antihypertensive medication, diabetes, and history of myocardial infarction, and history of heart failure. We performed the adjustments by using inverse probability weighting. [23] We estimated the propensity of having lower education attainment or lower household income according to sex and the previous clinical AF risk factors by using logistic regression models. In the analysis stratified according to both education attainment and household income, we used multinomial logistic regression with higher education attainment and higher household income as the reference. We tested for the difference in lifetime risks for AF between groups by using a pseudo-value regression model. [24] We repeated the analyses separately in men and women.

Finally, we also compared the results from a Fine-Gray model, which assesses the relationship between education/income with the cumulative incidence function for AF, to those of a cause-specific proportional hazards model, which assesses the relationship between education/income with the cause-specific hazard of AF. The latter is equivalent to a conventional Cox proportional hazards model with participants who die without AF treated as being censored at the time of death. [25]

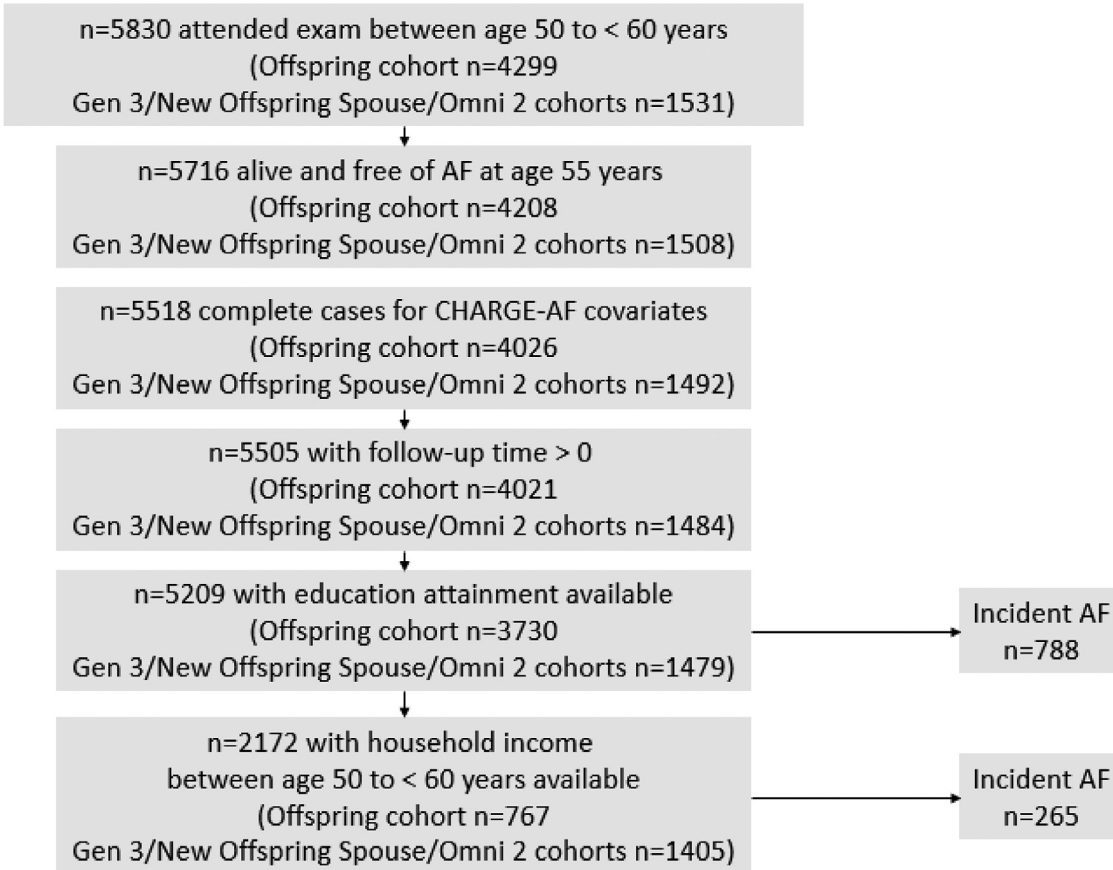

Figure 1. Selection of FHS participants at index age 55 years.

3. Results

3.1. Characteristics of selected participants

We selected 2,172 participants (Fig. 1). Characteristics of participants at index age 55 years according to educational attainment are shown in Table 1. Participants with high school education or less were more likely to smoke currently, to have elevated alcohol consumption, and to take hypertension medications. Characteristics of participants at index age 55 years according to household income are shown in Table 2. Participants with lower household income were more likely to be female and smoke currently and to have elevated alcohol consumption. Characteristics of participants grouped according to both education attainment and household income are presented in Appendix Table 1. Moreover, participants with and without information on household income available at index age 55 years were similar (Appendix Table 2).

Fig. 2, Fig. 3, Fig. 4

3.2. Association of educational attainment and income with lifetime risk of atrial fibrillation

Overall, there were 265 cases of incident AF over a mean of 13 years of follow-up (Q1, 8 to Q3, 30 years). There was no evidence of an association between education or household income and the lifetime risk of AF. In the multivariable-adjusted model, the lifetime risk of developing AF was 32.5% (95%CI, 26.5% to 38.5%) among participants with high school completion or less and 32.5% (95%CI, 28.7%, 38.3%) among participants with some college or more (p=0.98, Table 3). In the larger sample of 5,209 individuals with available information on education, regardless of the availability of information on income, results were similar (Appendix Table 3). Regarding household income, the adjusted lifetime risk of developing AF was 32.1% (95%CI 26.7% to 37.5%) among participants with lower household income and 31.8% (95%CI, 26.6%, 36.9%) among participants high household income (p=0.79, Table 3).

The findings were similar when stratified by subgroups of women and men. In women, the adjusted lifetime risk of developing AF was 26.4% (95%CI 19.7%, 33.2%) among participants with lower household income and 27.0% (95%CI, 19.5%, 34.5%) among participants high household income (p=0.89, Appendix Table 4). In men, the adjusted lifetime risk of developing AF was 37.4% (95%CI 29.1%, 45.6%) among participants with lower household income and 35.7% (95%CI, 28.9%, 42.5%) among participants high household income (p=0.56, Appendix Table 5). In both women and men, there was no statistically significant difference in lifetime risk of developing AF among participants in higher and lower education levels (p=0.80 in women and p=0.69 in men, Appendix Tables 4 and 5; Appendix Figures 7-9).

Finally, there was no evidence of an interaction between education and income on lifetime risk of AF (p = 0.84, Table 3). The lifetime risk of AF was similar across the 4 groups defined by education attainment and household income. All results were similar in unadjusted analyses (Table 3 and Appendix Figure 1-3).

Fine-Gray and Cox models showed consistent findings, with no evidence of association between education attainment or household income with either the cumulative incidence or cause-specific hazards of incident AF (Appendix Table 6).

4. Discussion

In the current study involving more than 2,000 community dwelling FHS participants followed for an average of 13 years, we observed that participants who have low household income had a similar lifetime risk of AF compared to those with high household income. Similarly, those

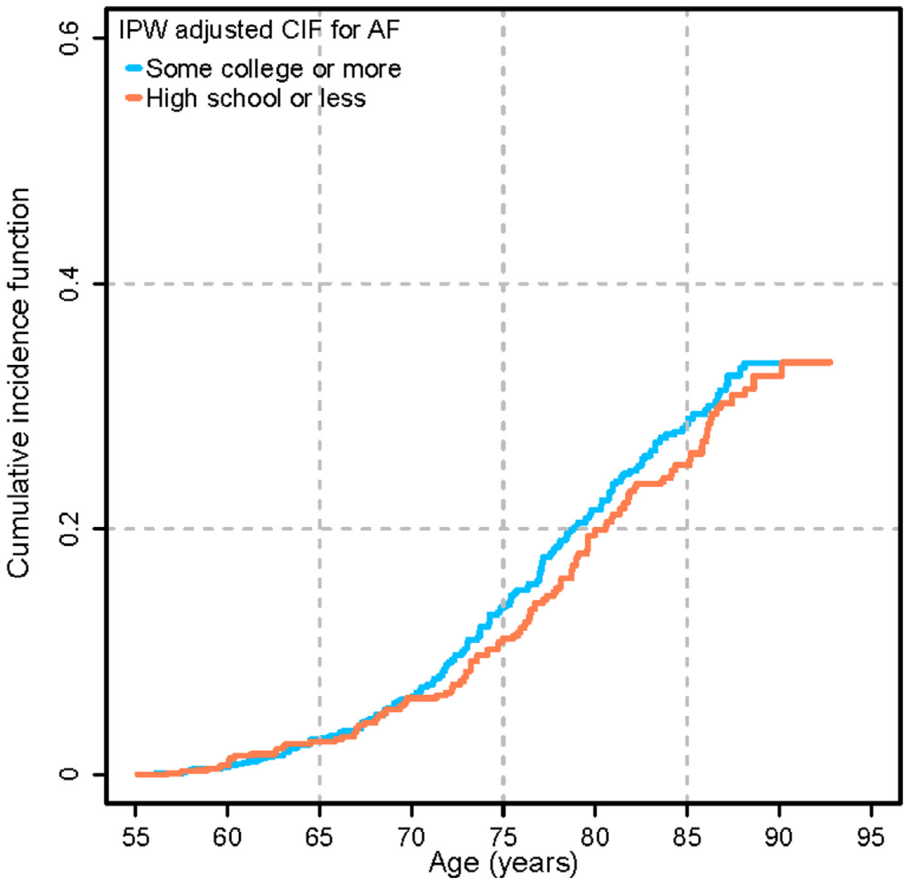

Figure 2. Cumulative incidence of atrial fibrillation after index age 55 years by education attainment
The cumulative incidence function of atrial fibrillation accounts for the competing risk of death and is further adjusted for sex, height, weight, systolic and diastolic blood pressure, current smoking, elevated alcohol consumption, use of antihypertensive medication, diabetes, and history of myocardial infarction, and history of heart failure. Adjustment for the covariates was performed by inverse probability weighting (IPW).

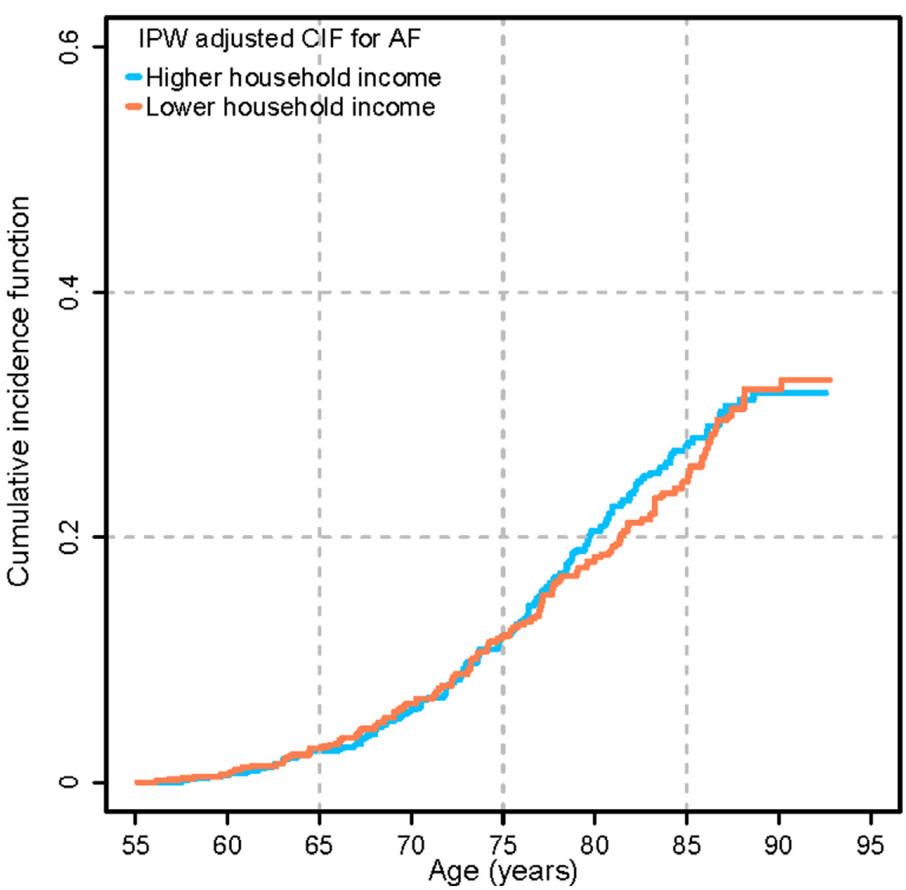

Figure 3. Cumulative incidence of atrial fibrillation after index age 55 years by household income
Household income categorized into: ≥\$40,000 vs <40,000 in the Offspring cohort; ≥\$50,000 vs < \$50,000 for Third Generation/New Offspring Spouse/Omni 2 cohorts exam 1; ≥\$55,000 Vs <\$55,000 for Third Generation/New Offspring Spouse/Omni 2 cohorts exam2
The cumulative incidence function of atrial fibrillation accounts for the competing risk of death and is further adjusted for sex, height, weight, systolic and diastolic blood pressure, current smoking, elevated alcohol consumption, use of antihypertensive medication, diabetes, and history of myocardial infarction, and history of heart failure. Adjustment for the covariates was performed by inverse probability weighting (IPW).

Table 1
Characteristics of participants at age 55 years according to education attainment

	High school completion or less n=581	Some college or more n=1591
Age, years	55.6 (0.9)	55.5 (1.0)
Female	304 (52.3)	802 (50.4)
Systolic blood pressure, mmHg	127 (17)	123 (16)
Diastolic blood pressure, mmHg	80 (10)	78 (9)
Height, inches	65.9 (3.7)	66.8 (3.7)
Weight, lbs	174.1 (40.3)	178.1 (41.5)
Current smoking	157 (27.0)	197 (12.4)
Elevated alcohol consumption	112 (19.3)	258 (16.2)
Diabetes	43 (7.4)	106 (6.7)
Hypertension treatment	149 (25.7)	347 (21.8)
Prior heart failure	0 (0)	4 (0.3)
Prior myocardial infarction MI	13 (2.2)	21 (1.3)
Hispanic or Latino	21 (3.6)	30 (1.9)
Race		
White	436 (75.0)	1367 (85.9)
Black	1 (0.2)	22 (1.4)
Asian	0 (0)	29 (1.8)
Native Hawaiian or Pacific Islander	0 (0)	1 (0.1)
American Indian or Alaskan Native	1 (0.2)	0 (0)
Other	0 (0)	4 (0.2)
Multiple	4 (0.7)	14 (0.9)
Unknown	139 (23.9)	154 (9.7)

Data are mean (standard deviation) or count (percentage).
Elevated alcohol consumption is defined as > 14 drinks/week for men and > 7 drinks/week for women.
Race and ethnicity were self-reported.

Table 2
Characteristics of AF participants at age 55 years according to household income

	Lower household income* n=719	Higher household income* n=1453
Age, years	55.5 (0.9)	55.5 (1.0)
Female	427 (59.4)	679 (46.7)
Systolic blood pressure, mmHg	125 (17)	123 (16)
Diastolic blood pressure, mmHg	79 (9)	78 (9)
Height, inches	65.6 (3.6)	67.0 (3.7)
Weight, lbs	170.1 (38.3)	180.5 (42.2)
Current smoking	186 (25.9)	168 (11.6)
Elevated alcohol consumption	110 (15.3)	260 (17.9)
Diabetes	43 (6.0)	106 (7.3)
Hypertension treatment	164 (22.8)	332 (22.9)
Prior heart failure	2 (0.3)	2 (0.1)
Prior myocardial infarction MI	18 (2.5)	16 (1.1)
Hispanic or Latino	31 (4.3)	20 (1.4)
Race		
White	547 (76.1)	1256 (86.5)
Black	5 (0.7)	18 (1.2)
Asian	3 (0.4)	26 (1.8)
Native Hawaiian or Pacific Islander	1 (0.1)	0 (0)
American Indian or Alaskan Native	1 (0.1)	0 (0)
Other	2 (0.3)	2 (0.1)
Multiple	4 (0.6)	14 (1.0)
Unknown	156 (21.7)	137 (9.4)

*≥$40,000 vs <40,000 in the Offspring cohort; ≥$50,000 vs < $50,000 for Third Generation/New Offspring Spouse/Omni 2 cohorts exam 1; ≥$55,000 Vs <$55,000 for Third Generation/New Offspring Spouse/Omni 2 cohorts exam2
Data are mean (standard deviation) or count (percentage).
Elevated alcohol consumption is defined as > 14 drinks/week for men and > 7 drinks/week for women.
Race and ethnicity were self-reported.

with lower educational attainment had a similar lifetime risk of AF compared to those with higher educational attainment. Furthermore, we found no evidence of interaction between education and income on lifetime risk of AF. The findings were similar among women and men separately.

While data are limited on lifetime risk of AF, several studies assessed the association between socioeconomic status and incident AF and they consistently found an inverse relationship between socioeconomic status and prevalent or incident AF. [17, 18, 26] In the ARIC study, Misialek et al. observed that lower income was associated with higher incidence of AF. The study also reported that lower education was associated with higher incidence of AF but only in women. [17] In a retrospective study including 379 community-based participants aged ≥65 years with AF, Ramkumar et al. found that regional socioeconomic status, defined by education and occupation, had an inverse association with the incidence of AF. [26] Another Danish retrospective cohort study based on record linkage data involving 2,173,857 participants (151,340 incident cases of AF over a follow-up period 13.6 years) reported that individuals with

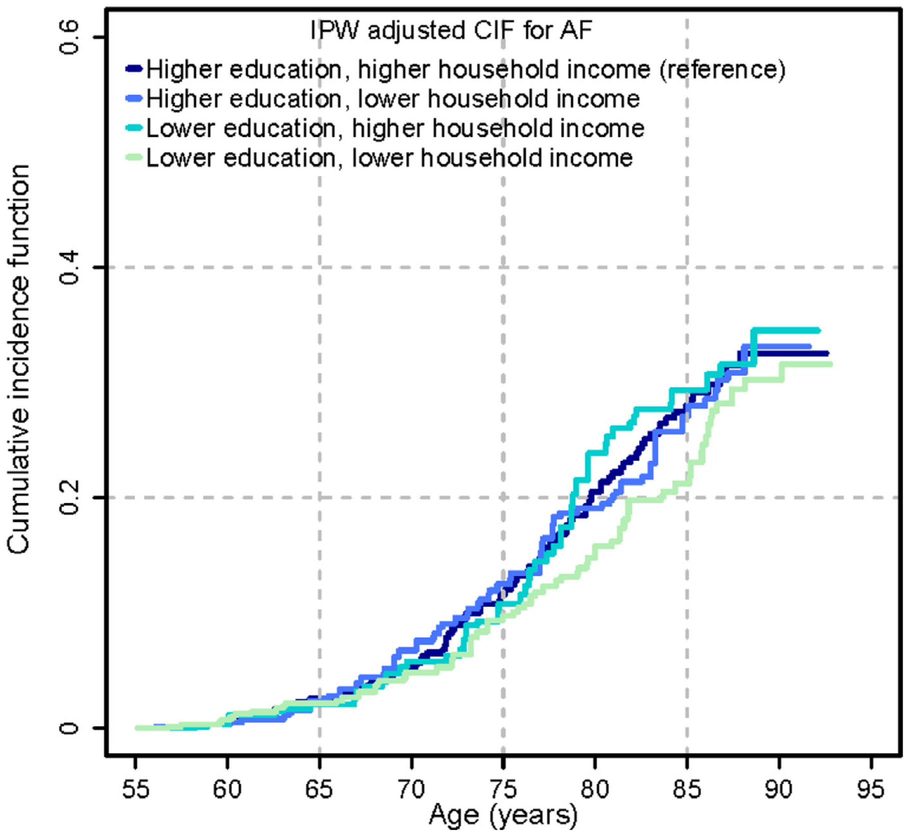

Figure 4. Cumulative incidence of atrial fibrillation after index age 55 years by education attainment and household income
Lower and higher education respectively defined as high school or less vs some college or more.
Household income categorized into ≥$40,000 vs <40,000 in the Offspring cohort; ≥$50,000 vs < $50,000 for Third Generation/New Offspring Spouse/Omni 2 cohorts exam 1; ≥$55,000 Vs <$55,000 for Third Generation/New Offspring Spouse/Omni 2 cohorts exam2
The cumulative incidence function of atrial fibrillation accounts for the competing risk of death and is further adjusted for sex, height, weight, systolic and diastolic blood pressure, current smoking, elevated alcohol consumption, use of antihypertensive medication, diabetes, and history of myocardial infarction, and history of heart failure. Adjustment for the covariates was performed by inverse probability weighting (IPW).

Table 3
Lifetime risk of AF according to education attainment and household income

	Unadjusted	P value	Adjusted†	P value
Education				
High school completion or less	32.9% (27.7%, 38.7%)	0.94	32.5% (26.5%, 38.5%)	0.98
Some college or more	32.6% (28.2%, 37.6%)		33.5% (28.7%, 38.3%)	
Household income*				
Lower income	32.3% (27.6%, 37.7%)	0.81	32.1% (26.7%, 37.5%)	0.79
Higher income	33.3% (28.5%, 38.7%)		31.8% (26.6%, 36.9%)	
Education attainment and household income*				
High school completion or less, lower household income	31.8% (25.5%, 39.3%)	0.69‡	30.3% (22.1%, 38.5%)	0.84‡
High school completion or less, higher household income	34.7% (26.4%, 44.7%)		34.5% (24.2%, 44.8%)	
Some college or more, lower household income	32.8% (26.0%, 40.9%)		33.1% (25.0%, 41.3%)	
Some college or more, higher household income	32.5% (26.8%, 39.1%)		32.5% (26.4%, 38.7%)	

Data are lifetime risk estimates with 95% confidence intervals
*≥$40,000 vs <40,000 in the Offspring cohort; ≥$50,000 vs < $50,000 for Third Generation/New Offspring Spouse/Omni 2 cohorts exam 1; ≥$55,000 Vs <$55,000 for Third Generation/New Offspring Spouse/Omni 2 cohorts exam2
† Analyses adjusted for sex, height, weight, systolic and diastolic blood pressure, current smoking, elevated alcohol consumption, use of antihypertensive medication, diabetes, and history of myocardial infarction, and history of heart failure
‡p value for the interaction test between education attainment and household income

higher and education had lower incidence of AF. [18] The study adjusted for diabetes mellitus, hyperthyroidism, alcoholism, obesity and congenital heart disease. The study also reported that the association of income with AF risk was weakest for the oldest age group of participants.

Mou et al. also studied the association of education and income with the lifetime risk of AF in the ARIC study. [13] Among 15,343 participants without AF at baseline and followed up for a mean of 21 years, the authors reported that the annual incidence rates of AF decreased from the lowest to the highest categories of income and education. On the other hand, they found the lifetime risk of AF increased in individuals with higher income and education in most sex-race groups. This was thought to have been driven by the increase in risk of AF after age 80 in those with higher income and education category. [13] These results are in contrast with our findings. The ARIC study participants entered the analysis between 45 and 64 years of age and the ascertainment of education and income was also obtained within this age range. In contrast, we include participants at the index age of 55 years. In addition, the ARIC study did not account for clinical risk factors at entry age. Their study population was more diverse including 26% African-American participants. [13] Our current investigation built on this study by adjusting for the known clinical risk factors and also by assessing the interaction of household income and education on the risk of incident AF.

The null finding in our study, with cumulative incidence of AF being similar between groups with lower and higher education attainment and household income, may be explained by the association between these very factors and death. This is because participants with lower socioeconomic status on average have higher mortality rates and may not live long enough to develop AF. The competing risk of death was also advanced as an explanation for the inverse relationship between socioeconomic status and the lifetime risk of AF in the ARIC study. [13] Another possible explanation is that there may be less variation in the socioeconomic structure of the Framingham Heart Study population; they reside predominantly in the state of Massachusetts. In addition, the socioeconomic indices of education and income may not capture other social determinants of health including housing, social support, language proficiency, or access to health care. [27]

The current study has several strengths which enable the current report to extend prior knowledge on the topic. We included all study participants at the index age of 55 years and we ascertained educational attainment at the last exam prior to the index age and household income within 5 years of the index age, which limits the possibility of misclassification bias. We performed analyses unadjusted and adjusted for known AF clinical risk factors, measured at the index age; these risk factors could be potential confounders of the observed association or lack thereof. Finally, we assessed the interaction between household income and educational attainment on the risk of AF.

The current study should also be considered in light of its limitations. First, we studied mostly White participants, and, therefore, our findings may not be generalizable to other racial and ethnic groups. Second, due to a large amount of missing data, we were not able to study occupation as a social determinant of health, which is an important component of socioeconomic status. Third, the distribution of education and income among women has changed dramatically over the last decades; a larger proportion of participants in our study were from the Offspring cohort (1972 – 2015), and our findings may not be generalizable to current populations in which more women work outside the home. Study participants were largely of European ancestry, mostly residing in New England, and working or middle class which may further limit generalizability to individuals of other races/ethnicities or communities with wider socioeconomic gaps.

In conclusion, in our community-based sample, we did not find evidence of association between educational attainment or household income, taken as measures of socioeconomic status, and lifetime incidence of AF among men and women after the index age of 55 years. The relations between educational attainment, income, and other measures of socioeconomic status and lifetime risk of AF merit examination in racially/ethnically and socioeconomically more diverse study samples.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Feven Ataklte: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Quixi Huang:** Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – review & editing. **Jelena Kornej:** Investigation, Methodology, Writing – review & editing. **Favel Mondesir:** Investigation, Methodology, Writing – review & editing. **Emelia J Benjamin:** Investigation, Methodology, Writing – review & editing. **Ludovic Trinquart:** Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Visualization, Writing – review & editing.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ajpc.2022.100314.

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