

Association of Major and Minor ECG Abnormalities With Coronary Heart Disease Events

Context In populations of older adults, prediction of coronary heart disease (CHD) events through traditional risk factors is less accurate than in middle-aged adults. Electrocardiographic (ECG) abnormalities are common in older adults and might be of value for CHD prediction.

Objective To determine whether baseline ECG abnormalities or development of new and persistent ECG abnormalities are associated with increased CHD events.

Design, Setting, and Participants A population-based study of 2192 white and black older adults aged 70 to 79 years from the Health, Aging, and Body Composition Study (Health ABC Study) without known cardiovascular disease. Adjudicated CHD events were collected over 8 years between 1997-1998 and 2006-2007. Baseline and 4-year ECG abnormalities were classified according to the Minnesota Code as major and minor. Using Cox proportional hazards regression models, the addition of ECG abnormalities to traditional risk factors were examined to predict CHD events.

Main Outcome Measure Adjudicated CHD events (acute myocardial infarction [MI], CHD death, and hospitalization for angina or coronary revascularization).

Results At baseline, 276 participants (13%) had minor and 506 (23%) had major ECG abnormalities. During follow-up, 351 participants had CHD events (96 CHD deaths, 101 acute MIs, and 154 hospitalizations for angina or coronary revascularizations). Both baseline minor and major ECG abnormalities were associated with an increased risk of CHD after adjustment for traditional risk factors (17.2 per 1000 person-years among those with no abnormalities, 29.3 per 1000 person-years; hazard ratio [HR], 1.35; 95% CI, 1.02-1.81; for minor abnormalities; and 31.6 per 1000 person-years; HR, 1.51; 95% CI, 1.20-1.90; for major abnormalities). When ECG abnormalities were added to a model containing traditional risk factors alone, 3.6% of intermediate-risk participants with both major and minor ECG abnormalities were correctly reclassified (overall net reclassification improvement [NRI], 2.4%; 95% CI, 3.1%-19.0%; integrated discrimination improvement, 0.99%; 95% CI, 0.32%-2.15%). After 4 years, 208 participants had new and 416 had persistent abnormalities. Both new and persistent ECG abnormalities were associated with an increased risk of subsequent CHD events (HR, 2.0; 95% CI, 1.33-3.02; and HR, 1.66; 95% CI, 1.18-2.34; respectively). When added to the Framingham Risk Score, the NRI was not significant (5.7%; 95% CI, -0.4% to 11.8%).

Conclusions Major and minor ECG abnormalities among older adults were associated with an increased risk of CHD events. Depending on the model, adding ECG abnormalities was associated with improved risk prediction beyond traditional risk factors.

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Table 1. Baseline Characteristics of the Study Population^a

Characteristics	No. (% of Participants)				P Value
	All (N = 2192)	No ECG Abnormality (n = 1410)	Minor ECG Abnormality (n = 276)	Major ECG Abnormality (n = 506)	
Age, mean (SD), y	73.5 (2.8)	73.4 (2.8)	73.5 (2.7)	73.8 (3.0)	.01
Women	1211 (55.3)	796 (56.5)	153 (55.4)	262 (51.8)	.19
White race	1292 (58.9)	896 (63.6)	139 (50.4)	257 (50.8)	<.001
Site					.21
Memphis, TN	1125 (51.3)	704 (49.9)	148 (53.6)	273 (53.9)	
Pittsburgh, PA	1067 (48.7)	706 (50.7)	128 (46.4)	233 (46.1)	
Education					<.001
<High school	532 (24.3)	299 (21.2)	79 (28.6)	154 (30.4)	
High school graduate	733 (33.5)	491 (34.8)	86 (31.2)	156 (30.8)	
Postsecondary	922 (42.2)	617 (43.8)	111 (40.2)	194 (38.3)	
Smoking status					.36
Never	1015 (46.3)	662 (46.9)	120 (43.5)	233 (46.0)	
Current	221 (10.1)	145 (10.3)	34 (12.3)	42 (8.3)	
Former	956 (43.6)	603 (42.8)	122 (44.2)	231 (45.7)	
Alcohol, drinks/wk					.46
<1	1534 (70.3)	969 (69.0)	195 (71.2)	370 (73.4)	
1-7	482 (22.1)	317 (22.6)	60 (21.9)	105 (20.8)	
>7	166 (7.6)	118 (8.4)	19 (6.9)	29 (5.8)	
Physical activity, kcal/wk					.007
<500	1147 (52.3)	697 (49.4)	163 (59.1)	267 (52.7)	
500-1499	598 (27.3)	409 (29.0)	87 (31.4)	122 (24.1)	
>1500	447 (20.4)	304 (21.6)	46 (16.7)	97 (19.2)	
Hypertension	1257 (57.3)	748 (53.0)	165 (59.8)	344 (68.0)	<.001
Diabetes mellitus	292 (13.3)	162 (11.5)	50 (18.2)	80 (15.8)	.002
BMI, mean (SD)	27.4 (4.9)	27.0 (4.7)	28.6 (5.4)	27.9 (5.0)	<.001
Systolic BP, mean (SD)	136 (21)	133 (20)	136 (19)	142 (28)	<.001
Diastolic BP, mean (SD)	72 (12)	71 (11)	72 (12)	73 (13)	<.001
Cholesterol, mean (SD), mg/dL					
Total	205 (98)	208 (39)	203 (37)	204 (37)	.51
HDL	55 (17)	56 (17)	54 (18)	55 (17)	.09
LDL	123 (34)	123 (35)	122 (35)	122 (33)	.81
Triglycerides, median (IQR)	116 (87-160)	116 (87-159)	120 (87-167)	115 (85-169)	.41
Creatinine, median (IQR), mg/dL	1.0 (0.9-1.1)	1.0 (0.8-1.1)	1.0 (0.9-1.2)	1 (0.9-1.2)	<.001
FRS, mean (SD), % ^b	12.6 (7.3)	12 (7.2)	13.2 (7.4)	13.9 (7.2)	<.001
Categories of FRS, %					<.001
<5.0	297 (13.6)	220 (15.6)	34 (12.3)	43 (8.5)	
5.0-9.9	526 (23.9)	353 (25.0)	62 (22.5)	110 (21.7)	
10.0-19.9	853 (38.9)	535 (38.0)	108 (39.4)	212 (41.9)	
≥20.0	517 (23.6)	302 (21.4)	74 (26.8)	141 (27.9)	
Medication use					
Lipid-lowering	228 (10.4)	138 (9.8)	39 (14.1)	51 (10.1)	.09
ACE inhibitors	272 (12.4)	168 (11.2)	37 (13.4)	77 (15.2)	.06
Hormone therapy in women	285 (23.5)	213 (26.8)	31 (20.3)	41 (15.7)	<.001
Aspirin	411 (18.8)	257 (18.2)	50 (18.1)	104 (20.6)	.50

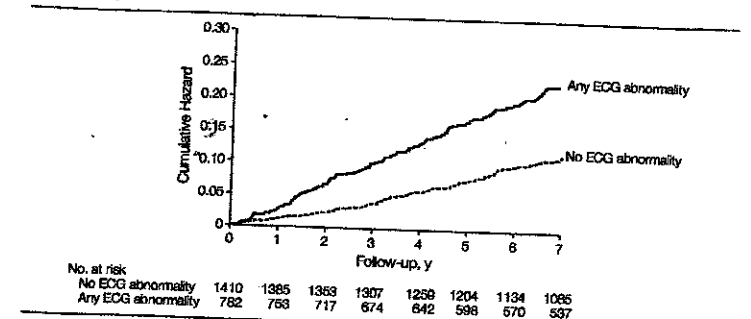
Abbreviations: ACE, angiotensin-converting enzyme; BMI, body mass index, calculated as weight in kilograms divided by height in meters squared; BP, blood pressure; ECG, electrocardiographic; FRS, Framingham Risk Score; HDL, high-density lipoprotein; IQR, interquartile range; LDL, low-density lipoprotein. SI conversions: To convert total, HDL, and LDL cholesterol to mmol/L, multiply by 0.0259; triglycerides to mmol/L, multiply by 0.0113; and creatinine to mmol/L, multiply by 88.4. ^aSee "Methods" section for definitions of hypertension and minor and major ECG abnormalities. Statistical analysis was by analysis of variance or χ^2 test. Systolic BP was used as a continuous variable. Mann-Whitney rank sum test was performed for triglycerides. Creatinine was used on log-transformed values. ^bEstimation of 10-year risk of coronary heart disease with information about age, sex, smoking status, total cholesterol, HDL cholesterol, and BP.²¹

Table 4. Hazard Ratios (HRs) for Incidence of CHD Events in Older Adults According to the Presence of Any ECG Abnormality at Baseline and Any Incident and Persistent ECG Abnormalities at Follow-up^a

	No ECG Abnormality (n = 902)	Abnormality at Baseline Only (n = 144)	Persistent Abnormality at 4-Year Follow-up (n = 416)	New Abnormality at 4-Year Follow-up (n = 208)	P Value ^b
CHD events (n = 185) ^c					
No. of events	77	18	57	33	
Rate per 1000 person-years (95% CI)	16.5 (12.3-20.6)	24.9 (14.7-39.2)	27.8 (21.0-36.0)	33.2 (22.8-46.6)	
Age-adjusted HR (95% CI)	1.00	1.51 (0.90-2.52)	1.66 (1.18-2.34)	2.01 (1.33-3.02)	.003
CVRFs, adjusted HR (95% CI) ^d	1.00	1.43 (0.85-2.39)	1.52 (1.07-2.16)	1.97 (1.31-2.96)	.01
All-cause mortality (n = 348)					
No. of events	172	22	100	54	
Rate per 1000 person-years (95% CI)	32.2 (27.6-37.4)	25.8 (16.2-39.0)	41.4 (33.7-50.3)	45.9 (34.4-59.9)	
Age-adjusted HR (95% CI)	1.00	0.83 (0.53-1.29)	1.25 (0.98-1.61)	1.45 (1.07-1.97)	.01
CVRFs, adjusted HR (95% CI) ^d	1.00	0.77 (0.49-1.20)	1.19 (0.92-1.53)	1.40 (1.03-1.91)	.02

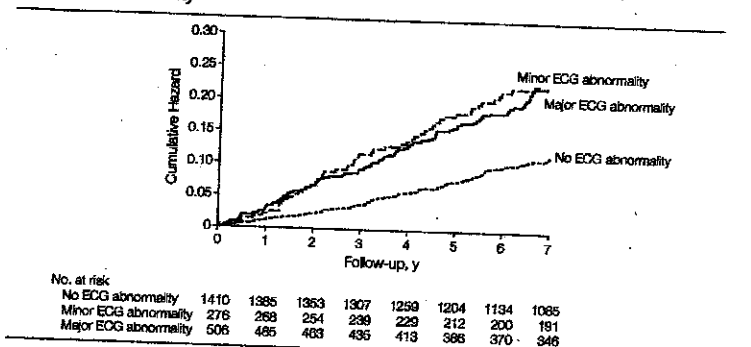
Abbreviations: CHD, coronary heart disease; CVRFs, cardiovascular risk factors; ECG, electrocardiographic. ^aAny ECG abnormality indicates major and/or minor ECG abnormality. Inclusion of 1670 participants without events during first 4 years of follow-up and ECG data at baseline and 4-year follow-up only. ^bp value for linear trend across no abnormality, abnormality at baseline, and persistent abnormality at follow-up. ^cIncludes acute myocardial infarction, coronary death, hospitalization for angina, angioplasty of coronary arteries, and coronary artery bypass graft surgery. ^dAdjusted for age, sex, total and high-density lipoprotein cholesterol, systolic blood pressure, smoking, and diabetes.

Figure 1. Kaplan-Meier Estimates of CHD Cumulative Hazard Over Time of Any vs No ECG Abnormality



CHD indicates coronary heart disease; ECG, electrocardiographic. Any ECG abnormality included minor, major, or both. All 351 CHD events were included.

Figure 2. Kaplan-Meier Estimates of CHD Cumulative Hazard Over Time of Major and Minor vs No ECG Abnormality



CHD indicates coronary heart disease; ECG, electrocardiographic. All 351 CHD events were included.

Table 3. Predicted Risk of CHD Events Using a Multivariate Risk Prediction Model With and Without Inclusion of ECG Data^a

Model Without ECG	Model With ECG			Total	Rate Reclassified, % ^b
	<7.5	7.5-15.0	≥15.0		
<7.5	4	2	0	6	-0.9
7.5-15.0	7	91	27	125	
≥15.0	0	25	195	220	
Total	11	118	222	351	
<7.5	74	17	0	91	8.3
7.5-15.0	129	678	149	956	
≥15.0	0	189	605	794	
Total	203	884	754	1841	

Abbreviations: CHD, coronary heart disease; ECG, electrocardiographic. ^aNet reclassification improvement (sum of the percentages of correctly reclassified participants with and without CHD events): 7.4%; 95% CI, 3.1%-19.0%. Identification discrimination improvement: 0.99%; 95% CI, 0.32%-2.15%. ^bProportion of all participants who were "correctly" reclassified minus the proportion of each group reclassified in the "wrong" direction.

Table 2. Incidence Rates and HRs for CHD Events and All-Cause Mortality in Older Adults According to ECG Abnormalities

	No ECG Abnormality (n = 1410)	Minor ECG Abnormality (n = 276)	Major ECG Abnormality (n = 506)	Any ECG Abnormality (n = 782)
CHD events (n = 351) ^a				
Rate per 1000 person-years (95% CI)	17.2 (14.8-19.8)	29.3 (22.2-38.0)	31.6 (26.0-38.0)	30.8 (26.3-35.8)
CVRFs, adjusted HR (95% CI) ^b	1.00	1.35 (1.02-1.81)	1.51 (1.20-1.90)	1.64 (1.32-2.03)
Multivariate-adjusted HR (95% CI) ^c	1.00	1.39 (1.04-1.85)	1.47 (1.16-1.86)	1.63 (1.31-2.02)
All-cause mortality (n = 602)				
Rate per 1000 person-years (95% CI)	31.0 (27.9-34.3)	32.9 (25.9-41.3)	37.8 (32.1-44.2)	36.1 (31.1-41.0)
CVRFs, adjusted HR (95% CI) ^b	1.00	0.95 (0.75-1.22)	1.17 (0.97-1.41)	1.11 (0.94-1.31)
Multivariate-adjusted HR (95% CI) ^c	1.00	0.97 (0.76-1.24)	1.09 (0.90-1.31)	1.06 (0.89-1.25)

Abbreviations: CHD, coronary heart disease; CVRFs, cardiovascular risk factors; ECG, electrocardiographic; HRs, hazard ratios. ^aIncludes acute myocardial infarction, coronary death, hospitalization for angina, angioplasty of coronary arteries, and coronary artery bypass graft surgery. ^bAdjusted for age, sex, total and high-density lipoprotein cholesterol, systolic blood pressure, smoking, and diabetes. ^cAdjusted for CVRFs (including age, sex, total and high-density lipoprotein cholesterol, systolic blood pressure, smoking, and diabetes) and race, education, site, low-density lipoprotein (LDL) cholesterol, creatinine (as natural logarithm), alcohol consumption, physical activity, statins, angiotensin-converting enzyme inhibitors, and estrogen use. A total of 2168 participants analyzed (23 participants with missing data for LDL cholesterol, 10 for alcohol consumption, 5 for education, and 1 for creatinine, resulting in 24 participants with 1 or more missing values excluded from the multivariate analysis).

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