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Gender Differences Between the Minnesota Code and Novacode Electrocardiographic Prognostication of Coronary Heart Disease in the Cardiovascular Health Study

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Abstract

The Minnesota Code (MC) and Novacode (Nova) are the most widely used electrocardiographic (ECG) classification systems. The comparative strengths of their classifications for Q- and ST-T-wave abnormalities in predicting coronary heart disease (CHD) events and total mortality have not been evaluated separately by gender. We studied standard 12-lead electrocardiograms at rest from 4,988 participants in the Cardiovascular Health Study. Average age at baseline was 73 years, 60% of participants were women 85% were white, and 22% had a history of cardiovascular disease or presence of ECG myocardial infarction by MC or Nova. Starting in 1989 with an average 17-year follow-up, 65% of participants died and 33% had incident CHD in a cohort free of cardiovascular disease at baseline. Of these, electrocardiograms with major Q-wave or major ST-T abnormalities by MC or Nova predicted increased risk for CHD events and total mortality with no significant differences in predictability between men and women. The study also found that women had fewer major Q-wave changes but more major ST-T abnormalities than men. However, there were no gender differences in predicting CHD events and total mortality. In conclusion, ECG classification systems for myocardial infarction/ischemia abnormalities by MC or Nova are valuable and useful for men and women in clinical trials and epidemiologic studies.

Electrocardiographic (ECG) criteria for myocardial infarction and ischemia have been used as evidence for coronary heart disease (CHD) in epidemiologic studies and clinical trials and are a powerful index for assessment of cardiovascular disease (CVD) risk and an important predictor for total mortality.^{1–8} Comparative strengths of their classification by the Minnesota Code (MC)^{9,10} and the Novacode (Nova),^{10–12} have not been evaluated separately by gender. The present study evaluated the value of current MC and Nova for

myocardial infarction/ischemia for prediction of incident fatal and nonfatal cardiac events and total mortality and compared the predictive power of each coding system in men and women.

Methods

The Cardiovascular Health Study (CHS) is a population-based prospective cohort study of risk factors for CHD and stroke in men and women 65 years of age in 4 United States communities that started in 1989. Eligible participants were sampled from Medicare-eligibility lists in each area. Details of the study design have been described previously.^{13,14} Eligible participants gave informed consent, and study protocols were approved by institutional review boards at participating institutions. Of 5,888 ECG recordings available from baseline examinations of the CHS cohort, those with incomplete data or inadequate quality and QRS duration ≥ 120 ms were excluded. The remaining 4,988 participants at baseline were classified into 2 groups, a CVD group ($n = 1,113$) and a CVD-free group ($n = 3,875$). CVD at baseline was defined by the presence of ECG myocardial infarction evidence by MC or Nova, a history of clinical myocardial infarction, angina pectoris that was confirmed by retrospective review of hospitalization medical records, or self-report of coronary angioplasty or bypass surgery. Average follow-up was 17 years (maximum 18). Three outcomes were considered in the present analysis: incident CHD events (fatal and nonfatal), CHD death, and all-cause mortality. After baseline, deaths and hospitalization events were ascertained by semiannual follow-up telephone calls to cohort members, review of vital records, and community surveillance of hospitalized and fatal events. The CHS mortality review committee reviewed and adjudicated all fatal events.^{15,16}

Identical electrocardiographs (MAC PC, Marquette Electronics, Inc., Milwaukee, Wisconsin) were used in all clinic sites. Standard 12-lead electrocardiograms at rest were recorded in all participants using strictly standardized procedures.¹⁴ All electrocardiograms were processed in a central laboratory (Epidemiologic Cardiology Research Center, Wake Forest University, Winston-Salem, North Carolina) and were classified by the Nova and MC using the 2001 version of the GE Marquette 12-SL program. ECG classification criteria for myocardial infarction/ischemia by Nova/MC in the present study were the same as previously described.^{8,10,12} Nova myocardial infarction was identified by Nova codes 5.1 to 5.4 and ECG major Q/ST-T changes by Nova was identified as Nova codes 5.1 to 5.6. Similarly, MC myocardial infarction was identified by categories C.1 to C.4 to match Nova myocardial infarction. ECG major Q/ST-T change by MC was identified as categories C.1 to C.6 (Table 1).

CVD and CVD-free groups at baseline were analyzed separately. Cox proportional hazards regression models were used to test and compare the MC and Nova for myocardial infarction/ischemia and ECG abnormality classifications as predictors of each of the 3 study end points after adjustment for demographic and clinical variables. Clinical and demographic characteristics that were significantly associated with risk of CHD event or total mortality were included in the multivariate model to determine if ECG predictors for risk of CHD events and total mortality differed between women and men and between CVD and CVD-free groups at baseline, which are listed in Tables 2 and 3. All analyses were performed with SAS 9.1.3 (SAS Institute, Cary, North Carolina).

Results

In the present study, of a total of 4,988 participants 63 to 100 years old (60% women and 85% non-Hispanic), there were 22% with a history of CVD or presence of ECG myocardial infarction by the MC or Nova, leaving 78% of participants who were free of CVD at

baseline. During an average 17-year follow-up, 33% in the baseline CVD-free group developed incident CHD and 65% in the combined cohort died (Table 2). Data showed that global agreements between classifications of myocardial infarction/ischemia by the MC and Nova were high with a kappa coefficient as high as 0.82 for the combined codes for major Q/ST-T wave abnormalities between the 2 coding systems with no significant difference between men and women. Of those with CVD at baseline, men had more major Q waves than women (24% for women and 36% for men), but women had more major ST-T abnormalities than men by the Nova or MC (35% for women and 29% for men). In contrast, there was no significant difference for combined codes of major Q/ST-T wave abnormalities between women and men (53% for women and 57% for men).

As presented in Table 3, electrocardiograms with major Q/ST-T wave codes for myocardial infarction/ischemia by MC/Nova was a strong predictor for CHD death and total mortality. ECG myocardial infarction by Nova in the baseline CVD group had 70% increased risk for CHD death with no difference in predictability between women and men, although the increased risk by ECG myocardial infarction by MC did not reach statistical significance. Presence of major Q wave or major ST-T abnormality was a significant predictor of CHD death for Nova and MC with no difference between men and women. For total mortality, ECG myocardial infarction alone or combined with major Q/ST-T abnormalities showed an increased risk with no differences between the 2 classification systems and no significant gender differences, which had 30% significant increased risk for total mortality.

Risk of incident CHD by ECG markers was examined in cohort members who were free of clinical CVD at baseline. Combined ischemic codes by Nova/MC were equally predictive (i.e., no statistically significant difference between men and women) for incident CHD in women and men. Any major or minor ST-T change had 36% increased risk for incident CHD in women and men. In addition, electrocardiograms with minor ST-T change (Nova 5.8 or MC C.8) predicted 39% to 85% increased risk for CHD death in men and 43% to 67% increased risk for women, where MC has a higher risk than Nova. For total mortality, electrocardiograms with major ST-T change by Nova/MC predicted 24% to 26% increased risk for total mortality in women, whereas the 22% to 42% increased risk that was found for electrocardiograms with minor ST-T change was more apparent for MC than for Nova with no significant difference between men and women (details are shown in the Appendix, available online).

Discussion

This is the first study to evaluate and compare the Nova and MC ECG classification systems for myocardial infarction/ischemia by gender in a large cohort with long-term follow-up. The present findings are nonetheless consistent with and thus extend findings previously described in recent publications.⁴⁻⁸ In this study, women had fewer major Q-wave abnormalities but more major ST-T abnormalities than men. However, combined codes for major Q/ST-T changes for myocardial infarction/ischemia by MC or Nova had similar predictive value for CHD events and total mortality in women and men. In summary, these results show that MC and Nova are valuable classification systems for ECG myocardial infarction or ischemia with no significant gender differences for prediction of CHD events and total mortality.

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Appendix

Appendix 1:

Prevalent electrocardiographic ischemia for prediction of coronary heart disease incidence, coronary heart disease death, and total mortality by Novacode and Minnesota Code criteria in baseline cardiovascular disease-free group separately for gender

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Table 1

Electrocardiographic criteria for myocardial infarction and ischemia by Novacode and Minnesota Code

Category	Novacode	Minnesota Code*
Major Q waves	5.1	C.1
Moderate Q waves with ST-T abnormalities	5.2	C.2
Moderate Q waves without ST-T abnormalities	5.3	C.3
Minor Q waves with ST-T abnormalities	5.4	C.4
Isolated/major ST abnormalities	5.5	C.5
Isolated/major T wave abnormalities	5.6	C.6
Minor Q waves	5.7	C.7
Minor ST-T abnormalities	5.8	C.8
No significant Q waves or ST-T	5.0	C.0
Electrocardiographic myocardial infarction by Novacode and Minnesota Code	5.1–5.4	C.1–C.4
ECG major Q or major ST-T abnormalities by Novacode and Minnesota Code	5.1–5.6	C.1–C.6

See Zhang et al[†] for detailed definition.

* C standard for combined code of Minnesota Codes 1, 4, and 5 to match hierarchical codes in Novacode 5.

Table 2

Baseline electrocardiographic findings by Novacode and Minnesota Code criteria and outcomes during average 17-year follow-up

Characteristics	Total (n = 4,988)	Prevalent CVD Group			CVD-Free Group		
		Women (n = 561)	Men (n = 552)	p Value*	Women (n = 2,416)	Men (n = 1,459)	p Value*
Age (years)	73 ± 6	74 ± 6	74 ± 6	0.5846	72 ± 5	73 ± 6	0.0001
Body mass index (kg/m ²)	27 ± 5	27 ± 5	27 ± 4	0.0414	27 ± 5	26 ± 4	0.0364
Systolic blood pressure (mm Hg)	136 ± 22	141 ± 24	135 ± 21	<0.0001	136 ± 22	135 ± 21	0.5097
Diastolic blood pressure (mm Hg)	71 ± 11	69 ± 12	71 ± 11	0.0416	70 ± 11	73 ± 11	<0.0001
African-American	15.4%	20.7%	10.0%	<0.0001	15.7%	14.9%	0.5563
Current smoking	12.2%	13.0%	9.1%	<0.0001	12.8%	12.0%	<0.0001
Hypertension	57.8%	72.7%	61.4%	<0.0001	56.4%	52.9%	0.0356
Diabetes mellitus	15.6%	20.6%	25.5%	0.0542	12.2%	15.5%	0.0030
Total mortality	64.9%	73.8%	83.3%	0.0001	56.5%	68.3%	<0.0001
Coronary heart disease death	15.6%	22.1%	29.7%	0.0037	10.6%	16.2%	<0.0001
Incident coronary heart disease [†]	32.6%				28.9%	38.6%	<0.0001
Myocardial infarction/ischemia by Novacode/ Minnesota Code [‡]							
Myocardial infarction by Novacode/ Minnesota Code	8.9%	35.7%	44.0%	0.0043			
Major Q wave by Novacode/Minnesota Code	6.7%	24.2%	35.7%	<0.0001			
Major ST-T change by Novacode/Minnesota Code	15.2%	35.1%	29.4%	0.0396	10.7%	9.7%	0.3484
Major Q/ST-T change by Novacode/ Minnesota Code	20.2%	52.6%	56.5%	0.2085	10.7%	9.7%	0.3484
Major Q/ST-T change by Novacode [‡]							
Myocardial infarction by Novacode	6.3%	23.5%	33.0%	0.0005			
Major Q wave by Novacode	4.1%	13.4%	23.0%	<0.0001			
Major ST-T change by Novacode	14.4%	33.7%	28.8%	0.0789	9.6%	9.5%	0.9160
Major Q/ST-T change by Novacode	17.5%	43.5%	47.1%	0.2271	9.6%	9.5%	0.9160
Major Q/ST-T change by Minnesota Code [‡]							
Myocardial infarction by Minnesota Code	7.8%	31.2%	39.0%	0.0067			
Major Q wave by Minnesota Code	6.4%	23.7%	33.7%	0.0002			
Major ST-T change by Minnesota Code	12.2%	28.9%	22.8%	0.0212	8.9%	7.2%	0.0564
Major Q/ST-T change by Minnesota Code	17.8%	49.0%	52.5%	0.2411	8.9%	7.2%	0.0564

* Between men and women in baseline groups with and without cardiovascular disease.

[†] Incident coronary heart disease includes fatal and nonfatal coronary heart disease as myocardial infarction, coronary death, hospitalized angina pectoris, and coronary revascularization.

[‡] See Table 1 for criteria of electrocardiographic myocardial infarction and major Q/ST-T change.

Table 3

Baseline cardiovascular disease group separately by gender: prevalent electrocardiographic myocardial infarction/ischemia for prediction of coronary heart disease death and total mortality by Novacode and Minnesota Code criteria

Total (n = 1,113)	Event (rate) [*]		HR [†] (95% CI)		p Value [‡]
	Women	Men	Women	Men	
Coronary heart disease death (n = 124/561 for women, n = 164/552 for men)					
Myocardial infarction by Novacode [§]	35 (27%)	61 (34%)	1.79 (1.12–2.84)	1.72 (1.22–2.44)	0.6984
Myocardial infarction by Minnesota Code [§]	38 (22%)	64 (30%)	1.11 (0.71–1.74)	1.19 (0.84–1.68)	0.8201
Major Q/ST-T change by Novacode [§]	73 (30%)	91 (35%)	2.19 (1.44–3.33)	2.11 (1.50–2.97)	0.5321
Major Q/ST-T change by Minnesota Code [§]	71 (26%)	96 (33%)	1.52 (1.00–2.31)	1.68 (1.19–2.37)	0.6563
Total mortality (n = 414/561 for women, n = 460/552 for men)					
Myocardial infarction by Novacode	107 (81%)	160 (88%)	1.47 (1.14–1.90)	1.46 (1.19–1.80)	0.9280
Myocardial infarction by Minnesota Code	133 (76%)	184 (86%)	1.31 (1.04–1.65)	1.30 (1.05–1.60)	0.6246
Major Q/ST-T change by Novacode	199 (82%)	229 (88%)	1.47 (1.17–1.84)	1.47 (1.20–1.79)	0.8741
Major Q/ST-T change by Minnesota Code	218 (79%)	251 (87%)	1.40 (1.12–1.75)	1.39 (1.13–1.70)	0.5221

^{*} Event rate is number of events divided by number in that category (percentage) of electrocardiographic myocardial infarction/ischemia by Minnesota Code/Novacode.

[†] Adjusted for key demographic and clinical variables of age, race, education, smoking status, alcohol use, diabetes, hypertension, cancer, increased angina, body mass index, systolic blood pressure, hematocrit, white blood cell count, ankle–brachial index, baseline glucose, insulin, and creatinine.

[‡] Assessing equivalence of hazard ratios for men and women.

[§] See Table 1 and Zhang et al⁸ for myocardial infarction/ischemia criteria.

CI = confidence interval; HR = hazard ratio.

Total (n = 3,875)	Event (rates)*		HR (95% CI) [†]		p Value [‡]
	Women	Men	Women	Men	
Incident coronary heart disease (n = 699/2,416 for women, n = 563/1,459 for men)					
Novacode 5 for ischemia [§]					
5.5/5.6	103 (45%)	63 (46%)	1.98 (1.55–2.53)	1.36 (1.01–1.85)	0.0738
5.7	48 (32%)	46 (38%)	1.32 (0.95–1.84)	1.04 (0.75–1.44)	
5.8	226 (33%)	139 (46%)	1.39 (1.15–1.67)	1.40 (1.12–1.73)	
5.0	322 (24%)	315 (35%)	reference	reference	
Combined Minnesota Code for ischemia [§]					
C.5/5.6	94 (44%)	52 (50%)	1.83 (1.43–2.34)	1.62 (1.18–2.24)	0.7447
C.7	41 (29%)	46 (41%)	1.21 (0.86–1.70)	1.23 (0.88–1.72)	
C.8	148 (37%)	95 (44%)	1.51 (1.23–1.86)	1.62 (1.27–2.07)	
C.0	416 (25%)	370 (36%)	reference	reference	
Coronary heart disease death (n = 255/2,416 for women, n = 236/1,459 for men)					
Novacode 5 for ischemia					
5.5/5.6	36 (16%)	28 (20%)	1.42 (0.92–2.18)	1.31 (0.82–2.10)	0.8110
5.7	21 (14%)	20 (17%)	1.35 (0.81–2.25)	1.04 (0.62–1.73)	
5.8	90 (13%)	63 (21%)	1.43 (1.06–1.93)	1.39 (1.00–1.93)	
5.0	108 (8%)	125 (14%)	reference	reference	
Combined Minnesota Code for ischemia					
C.5/5.6	35 (16%)	23 (22%)	1.43 (0.94–2.18)	1.52 (0.93–2.49)	0.9969
C.7	16 (11%)	22 (20%)	1.06 (0.59–1.89)	1.17 (0.72–1.91)	
C.8	63 (16%)	49 (23%)	1.67 (1.21–2.29)	1.85 (1.29–2.65)	
C.0	141 (8%)	142 (14%)	reference	reference	
Total mortality (n = 1,366/2,416 for women, n = 996/1,459 for men)					
Novacode 5 for ischemia					
5.5/5.6	164 (71%)	103 (75%)	1.24 (1.03–1.50)	1.15 (0.91–1.45)	0.9847
5.7	87 (59%)	86 (71%)	1.01 (0.79–1.28)	1.00 (0.78–1.28)	
5.8	411 (61%)	233 (77%)	1.11 (0.98–1.27)	1.22 (1.04–1.44)	
5.0	704 (52%)	574 (64%)	reference	reference	
Combined Minnesota Code for ischemia					
C.5/5.6	153 (71%)	80 (76%)	1.26 (1.05–1.52)	1.19 (0.92–1.54)	0.2293
C.7	87 (61%)	75 (68%)	1.14 (0.89–1.45)	0.90 (0.70–1.17)	
C.8	256 (64%)	173 (81%)	1.21 (1.04–1.40)	1.42 (1.18–1.71)	
C.0	870 (52%)	668 (65%)	reference	reference	

* Event rate is number of events divided by number in that category (percentage) of electrocardiographic myocardial infarction/ischemia by Minnesota Code/Novacode.

[†] Adjusted for key demographic and clinical variables of age, race, education, smoking status, alcohol use, diabetes, hypertension, cancer, increased angina, body mass index, systolic blood pressure, hematocrit, white blood cell count, ankle–brachial index, baseline glucose, insulin, and creatinine.

[‡]Assessing equivalence of hazard ratios for men and women.

[§]See Table 1 and Zhang et al⁸ for ischemia criteria. Nova 5.5/5.6 or Minnesota Code C.5/C.6 as major ST-T change, Nova 5.8 or Minnesota Code C.8 as minor ST-T change, and Nova 5.7 or Minnesota Code C.7 as minor Q change.

Abbreviations as in Table 3.