

# Cardiovascular Risk Profile Earlier in Life and Medicare Costs in the Last Year of Life

Martha L. Daviglus, MD, PhD; Kiang Liu, PhD; Amber Pirzada, MD; Lijing L. Yan, PhD; Daniel B. Garside, BS; Philip Greenland, MD; Larry M. Manheim, PhD; Alan R. Dyer, PhD; Renwei Wang, MD; James Lubitz, MPH; Willard G. Manning, PhD; James F. Fries, MD; Jeremiah Stamler, MD

**Background:** Health care costs are generally highest in the year before death, and much attention has been directed toward reducing costs for end-of-life care. However, it is unknown whether cardiovascular risk profile earlier in life influences health care costs in the last year of life. This study addresses this question.

**Methods:** Prospective cohort of adults from the Chicago Heart Association Detection Project in Industry included 6582 participants (40% women), aged 33 to 64 years at baseline examination (1967-1973), who died at ages 66 to 99 years. Medicare billing records (1984-2002) were used to obtain cardiovascular disease-related and total charges (adjusted to year 2002 dollars) for inpatient and outpatient services during the last year of life. Participants were classified as having favorable levels of *all* major cardiovascular risk factors (low risk), that is, serum cholesterol level lower than 200 mg/dL (<5.2 mmol/L), blood pressure 120/80 mm Hg or lower and no antihypertensive medication, body mass index (cal-

culated as weight in kilograms divided by the square of height in meters) lower than 25, no current smoking, no diabetes, and no electrocardiographic abnormalities, or unfavorable levels of any 1 only, any 2 only, any 3 only, or 4 or more of these risk factors.

**Results:** In the last year of life, average Medicare charges were lowest for low-risk persons. For example, cardiovascular disease-related and total charges were lower by \$10 367 and \$15 318 compared with those with 4 or more unfavorable risk factors; the fewer the unfavorable risk factors, the lower the Medicare charges (*P* for trends <.001). Analyses by sex showed similar patterns.

**Conclusion:** Favorable cardiovascular risk profile earlier in life is associated with lower Medicare charges at the end of life.

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**Author Affiliations:** Departments of Preventive Medicine (Drs Daviglus, Liu, Pirzada, Yan, Greenland, Dyer, Wang, and Stamler and Mr Garside), and Medicine, Division of Geriatrics (Drs Daviglus and Liu), and the Institute for Health Services Research and Policy Studies (Dr Manheim), Feinberg School of Medicine, Northwestern University, Chicago, Ill; Department of Health Economics and Management, Guanghua School of Management, Peking University, Beijing, China (Dr Yan); National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, Md (Mr Lubitz); Harris School of Public Policy Studies, University of Chicago, Chicago (Dr Manning); and Department of Medicine, Stanford University School of Medicine, Palo Alto, Calif (Dr Fries).

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**H**EALTH CARE COSTS ARE generally highest at the end of life; a disproportionately large percentage of all Medicare expenditures is for the year prior to death.<sup>1-3</sup> While decedents comprise approximately 5% of all Medicare beneficiaries, expenses in the last year of life account for up to 31% of total Medicare expenditures.<sup>1-3</sup> Moreover, each year cardiovascular disease (CVD) accounts for almost 39% of all deaths in the United States.<sup>4</sup> With the proportion of Americans 65 years and older increasing rapidly, Medicare spending at the end of life is an important issue.

Much attention has been directed toward reducing costs for end-of-life care,<sup>5-8</sup> but little research has focused on identifying factors related to lower health care utilization as a means of cost containment. It has been shown that the benefits of having favorable levels of all

major CVD risk factors (ie, low risk in young adulthood and middle age) encompass not only lower age-specific risk of mortality<sup>9,10</sup> but also favorable economic impact on *average annual* Medicare charges.<sup>11</sup> However, previous studies on health care costs incurred at the end of life are limited mostly to the effects of sociodemographic factors.<sup>3,12-14</sup> To our knowledge, no data exist on whether the benefits of low CVD risk profile at younger ages extend to lower Medicare expenditures in the last year of life, reflecting lower disease and disability even in the period before death. We address this question with data from the Chicago Heart Association Detection Project in Industry (CHA) study on men and women aged 32 to 64 years at baseline in 1967 through 1973, who died at ages 66 to 99 years and had Medicare coverage for at least 1 year in 1984 through 2002.

## BASELINE EXAMINATION AND MORTALITY FOLLOW-UP

During 1967 through 1973, the CHA study screened 39 522 men and women 18 years or older employed by 84 Chicago-area organizations. Standardized methods were used.<sup>15</sup> Briefly, trained staff measured height, weight, supine blood pressure, and serum cholesterol.<sup>16</sup> Participants completed a questionnaire about demographic characteristics, smoking history, medical diagnoses, and treatment. Resting electrocardiograms (ECGs) were classified as showing major, minor, or no abnormalities.<sup>17,18</sup> With use of data from the National Death Index,<sup>19</sup> vital status was ascertained through 2002 (average, 32 years follow-up). The study protocol has received periodic institutional review board approval. Appropriate administrative and physical safeguards were established to protect confidentiality of the data.

### MEDICARE CHARGES DATA

Medicare fee-for-service claims data were obtained from the Centers for Medicare and Medicaid Services for participants aged 65 and older who were eligible for Medicare benefits from 1984 (the first year data were available for research use) through 2002. Centers for Medicare and Medicaid Services data for each participant were cross-referenced by social security number, sex, and birth date. Records include—for each medical service billed to Medicare—date of service, total charges, diagnostic-related group, primary diagnosis, and up to 9 other diagnoses coded according to the *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)*. Claims related to inpatient, skilled nursing facility, and outpatient hospital-related care were available for 1984 through 2002; physician visit claims (part B), durable medical equipment, home health agency, and hospice claims for 1992 through 2002.

### ELIGIBILITY AND STUDY COHORT

Persons with a history of myocardial infarction and major ECG abnormality at baseline were excluded because data from these individuals could not only skew costs but also obscure the relationship of baseline risk profile with subsequent CVD-related expenditures. Among 23 926 participants aged 32 to 64 years at baseline, free of myocardial infarction and major ECG abnormalities, 9860 deaths occurred through 2002. Of these, 6921 decedents aged 66 to 99 years with at least 1 full year of Medicare coverage during 1984 through 2002 were eligible for this study. Of these decedents, 383 were excluded owing to missing data on risk factors and other variables used in the models. One decedent with total charges exceeding \$2 million (almost double the next highest amount—clearly an outlier) was also excluded. Thus, the study cohort includes 6582 decedents (40.4% women).

### CARDIOVASCULAR RISK GROUPS

Participants were classified according to baseline CVD risk status as low risk, that is, having favorable levels of *all* major risk factors: blood pressure 120/80 mm Hg or lower and not receiving antihypertensive medication,<sup>20</sup> serum cholesterol level lower than 200 mg/dL (<5.2 mmol/L),<sup>21</sup> body mass index (BMI; calculated as weight in kilograms divided by the square of height in meters) lower than 25.0,<sup>22</sup> not currently smoking, no diagnosed diabetes, and no minor ECG abnormalities.<sup>9-11</sup> Individuals not at low risk were grouped as having any 1 only, any 2

only, any 3 only, or 4 or more of the risk factors unfavorable, that is, blood pressure higher than 120/80 mm Hg or receiving antihypertensive medication, serum cholesterol level 200 mg/dL or higher ( $\geq 5.2$  mmol/L) or receiving cholesterol-lowering medication, BMI 25.0 or greater, currently smoking, diagnosed diabetes, and presence of minor ECG abnormalities.

### STATISTICAL ANALYSIS

Medicare claims were used to estimate health care spending. For each beneficiary, hospital-related charges (1984-2002) or charges from all types of services covered by Medicare (1992-2002) in the 1-year period before date of death were summed. Charges related to CVD were defined as those for health care services with primary discharge diagnosis coded as *ICD-9-CM* 390 through 459.

Baseline characteristics were compared across risk groups. Either  $\chi^2$  (for categorical variables) or F tests (for continuous variables) were used to detect statistically significant differences. Mean CVD-related and total charges in the year before death were computed for each risk stratum by the general linear model method, with adjustment for sex, race, education, and age at death because Medicare expenditures in the last year of life tend to be lower at older ages.<sup>12,13</sup> Given the skewed nature of charge data, a modified Cox regression procedure<sup>11</sup> was used to assess statistical significance. This approach assumes a semiparametric model for associations of medical costs with cardiovascular risk strata and other factors. In this approach, health care charges are first inverted by subtracting each person's charge from the maximal charge. Inverted charges are then substituted for survival time in the Cox model so that people with the highest charges are treated as having the shortest survival times and those with no charges are considered censored at the maximal charge (equivalent to the longest survival time). With this method linear trends across risk factor groups are assessed using an ordinal variable with values 1 to 5 in Cox regressions.

To account for inflation, all charges were adjusted to year 2002 dollars with use of the hospital and related services component of the Consumer Price Index.<sup>23</sup> This correction also helps to control for changes in costs stemming from advances in medical technology over time. To estimate costs, annual cost-to-charge ratios for hospital patient care services obtained from the Medicare Payment Advisory Commission were applied to each year's Medicare charges.<sup>24</sup> Cost-charge ratios from 1984 through 2002 ranged from 0.800 to 0.413. Sensitivity analyses substituting estimated costs for charges were conducted. In addition, analyses were performed excluding beneficiaries enrolled in managed care plans.

Analyses were also repeated for the subsample of decedents (n=4876) with data on charges from all types of claims (1992-2002) and for subcohorts of decedents without minor ECG abnormalities and diabetes at baseline (n=5827 with hospital-related charges; n=4378 with charges for all types of services). All analyses were conducted using SAS statistical software version 8.02 (SAS Institute Inc, Cary, NC).

## RESULTS

### BASELINE CHARACTERISTICS

By definition, risk groups differed in average blood pressure, serum cholesterol level, BMI, and prevalence of smoking, diabetes, and minor ECG abnormalities (**Table 1**). Low-risk decedents were also younger and more educated.

**Table 1. Baseline Characteristics of Study Participants (1967-1973)\***

Characteristic	Baseline Risk Status†				
	Low Risk (n = 108)	Not Low Risk			
		Any 1 Risk Factor Only (n = 609)	Any 2 Risk Factors Only (n = 1944)	Any 3 Risk Factors Only (n = 2606)	≥4 Risk Factors (n = 1315)
Age, y	50.5 (7.2)	51.4 (7.3)	52.8 (7.0)	53.1 (6.6)	51.6‡ (6.8)
Women	49.1	52.4	45.7	39.0	29.4‡
Race, white	94.4	94.9	94.4	94.4	91.7‡
Education, y	13.3 (2.8)	12.6 (2.6)	12.3 (2.6)	12.2 (2.6)	11.9‡ (2.5)
In the risk definition					
Systolic BP, mm Hg	114.9 (6.4)	126.5 (16.5)	139.0 (20.2)	146.1 (19.5)	149.3 (18.6)
Diastolic BP, mm Hg	70.4 (6.4)	75.9 (10.1)	81.7 (11.6)	85.5 (11.4)	87.2 (11.3)
Hypertension Rx	0	2.5	6.7	9.6	9.0
Serum Chol, mg/dL	175.8 (17.1)	193.2 (32.9)	205.8 (38.2)	227.0 (36.5)	234.2 (32.7)
BMI	22.6 (1.7)	23.3 (2.7)	25.4 (4.1)	27.5 (4.1)	28.8 (3.5)
Minor ECG abnormalities	0	1.0	2.3	5.8	25.3
Currently smoking	0	19.4	28.5	40.0	83.3
Diabetes mellitus	0	0.2	1.3	2.8	11.0

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); BP, blood pressure; Chol, Cholesterol; ECG, electrocardiogram; Rx, prescription.

SI conversion factor: To convert Chol to millimoles per liter, multiply by 0.0259.

\*Data are given as percentage of patients or mean (SD) value unless otherwise specified.

†With exclusions of persons with prior myocardial infarction or major ECG abnormalities, participants were classified as low risk (Chol level <200 mg/dL [ $<5.2$  mmol/L], BP  $\leq$ 120/80 mm Hg and no antihypertensive medication, BMI <25, no minor ECG abnormalities, no current smoking, and no diabetes) or as having any 1 only, any 2 only, any 3 only, or 4 or more of the above risk factors unfavorable.

‡ $P < .01$  from F (continuous variables) or  $\chi^2$  tests (categorical variables) for overall group differences (for sex, race, baseline age, and education). No tests were performed for all other factors because they were included in the definition of baseline risk status.

**Table 2. Adjusted\* Mean Medicare Hospital-Related† Charges in the Last Year of Life (1984-2002) by Baseline (1967-1973) Risk Status**

Baseline Risk Status‡	No. of Persons (N = 6582)	Age at Death, Mean (SD), y	CVD§ Charges, \$	Total Charges, \$
Low risk	108	78.1 (7.9)	8151	42 801
Not low risk				
Any 1 risk factor only	609	77.4 (7.5)	11 642	55 517
Any 2 risk factors only	1944	77.9 (7.1)	12 608	51 702
Any 3 risk factors only	2606	77.9 (7.0)	14 863	54 457
≥4 Risk factors	1315	75.7   (6.6)	18 518	58 119
P for trend		<.001	<.001	<.001

\*Cardiovascular (CVD)-related and total charges were adjusted for age at death, race, sex, and education.

†Hospital-related charges are for inpatient, skilled nursing facility, and outpatient care.

‡For abbreviations and risk definitions, see footnotes to Table 1.

§Charges from claims with a primary diagnosis of CVD based on *International Classification of Diseases, Ninth Revision, Clinical Modification* codes 390 through 459.

|| $P < .05$  for comparison with the low-risk group based on linear model (age at death) or a modified Cox regression method (charges).

¶ $P$  values for trend based on a modified Cox regression method with "risk status" as an ordinal variable with values from 1 to 5.

## AGE AT DEATH AND MEDICARE CHARGES

On average, persons with 4 or more risk factors died at a younger age compared with others (**Table 2**). Average health care charges for inpatient and outpatient care in the last year of life were lowest for low-risk individuals compared with persons with unfavorable levels of any 1 or more risk factors (Table 2). For example, CVD and total charges for low-risk individuals were less by \$10 367 and \$15 318 compared with those with 4 or more risk factors; the fewer the unfavorable risk factors, the lower the Medicare charges ( $P$  for trends  $< .001$ ). Results for men and women sepa-

rately were consistent with those for the total sample;  $P$  for trends ranged from .009 to  $< .001$  (**Figure**).

For the subcohort with charge data on all types of services covered by Medicare ( $n = 4876$ ), patterns of associations were generally similar, that is, lower CVD and total average Medicare charges in the last year of life for low-risk persons compared with others (**Table 3**). For example, CVD-related and total charges for low-risk decedents were lower by \$14 684 and \$8868 compared with those with 4 or more risk factors ( $P$  for trends  $< .001$  and .01, respectively). Analyses by sex using charge data on all types of services showed similar patterns (data not shown).

Exclusion of beneficiaries enrolled in managed care plans (ranging from 1.7% in 1991 to 7.4% in 2002) had little impact on the observed relationship of risk status with Medicare charges ( $P$  for trends ranged from .03 to  $<.001$ ).

With dollar amounts lower for estimated Medicare costs, differences in health care costs across risk groups were similar to those with Medicare charges. For example, adjusted total average annual costs for low-risk persons and those with 4 or more risk factors were \$23 235 and \$34 453, a relative difference of 48.3%, similar to that seen with charges (35.8%) (data not shown). For decedents without minor ECG abnormalities and diabetes at baseline, favorable levels of all 4 cardiovascular risk factors (serum cholesterol, blood pressure, BMI, and no smoking) were also associated with lower Medicare charges in the last year of life compared with those with unfavorable levels of these risk factors ( $P$  for trends  $<.004$ ) (data not shown).

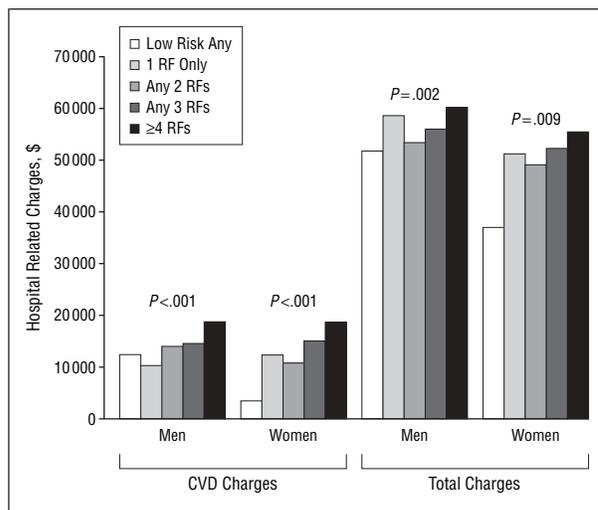
Charges in the last year of life for hospital inpatient and outpatient care (**Table 4**) and for all types of services covered by Medicare (**Table 5**) were stratified by sex, age at death, race, and education. In concordance with published data,<sup>1,3</sup> Medicare expenditures in the last year of life were generally lower for CHA participants who died after age 75 years<sup>1</sup> compared with younger decedents (ie, age  $<70$ -74 years) and higher among blacks.<sup>3</sup>

## COMMENT

Among both men and women, we found a significant graded positive association between cardiovascular risk profile in young adulthood or middle age and CVD-related and total Medicare charges in the last year of life. In general, cardiovascular and total end-of-life health care expenditures for hospital-related services were lowest for low-risk persons and increased with number of unfavorable risk factors. Similar results were observed in analyses by sex and for expenditures from all types of Medicare-covered services.

High health care costs incurred by persons at the end of life have generated concern as an important contributor to rising medical expenditures by older persons,<sup>25,26</sup> and almost one third of Medicare costs is incurred in the last year of life.<sup>1-3</sup> With most persons—including those at high risk for CVD—surviving past age 65 years,<sup>27</sup> and the projected increase in the proportion of the population 65 years and older from 12% in 2000 to 20% by 2050,<sup>28</sup> absolute number of deaths in older persons and total dollars spent on care at the end of life are bound to increase, with important implications for future Medicare expenditures.

Approaches to control costs at the end of life have included use of advanced directives and establishment of hospital guidelines to identify and reduce unnecessary care.<sup>5-8</sup> However, some argue that cost savings from such health care practices are unlikely to be substantial, for example, an estimated 6% for Medicare and 3% for total health care spending at the end of life.<sup>29</sup> Major cardiovascular risk factors measured in young adulthood and middle age strongly predict cardiovascular and all-cause mortality long-term.<sup>9,10</sup> In addition, CVD risk profile at younger ages predicts morbidity and health-related quality of life in older age.<sup>30,31</sup> Furthermore, both cumulative disability and disability in the 1 to 2 years be-



**Figure.** Adjusted mean Medicare hospital-related charges in the last year of life (1984-2002) by baseline (1967-1973) risk status for 3920 men and 2662 women. Adjusted for age at death, race, and baseline education. Hospital-related charges are for inpatient, skilled nursing facility, and outpatient care. Cardiovascular disease (CVD)-related charges include only charges from claims with primary diagnoses codes 390 through 459, *International Classifications of Diseases, Ninth Revision, Clinical Modification*. With exclusions of persons with prior myocardial infarction or major electrocardiographic abnormalities, participants were classified as low risk (cholesterol level  $<200$  mg/dL [ $<5.2$  mmol/L], blood pressure  $\leq 120/80$  mm Hg and no antihypertensive medication, body mass index [calculated as weight in kilograms divided by the square of height in meters]  $<25$ , no minor electrocardiographic abnormalities, no current smoking, and no diabetes), or as having any 1 only, any 2 only, any 3 only, or 4 or more of the above risk factors (RFs) unfavorable.  $P$  values for trend across 5 risk strata were based on a modified Cox regression method with risk status as an ordinal variable with values from 1 to 5.

fore death are lower in persons previously with low or moderate risk (based on levels of smoking, BMI, and exercise) compared with high-risk individuals.<sup>32,33</sup>

Unfortunately, low-risk individuals comprised only a small minority ( $<10\%$ ) of the CHA population at baseline. Low-risk status was similarly rare in the National Health and Nutrition Examination Surveys (NHANES) and continues to be uncommon among adult Americans. Data from NHANES for US adults aged 18 to 79 years, with low-risk defined as BP lower than 120/80 mm Hg, cholesterol level lower than 200 mg/dL ( $<5.2$  mmol/L), and not smoking (among nondiabetic persons without history of myocardial infarction), show low-risk population rates of 6% in 1971 through 1975, 8% in 1976 through 1980, and 17% in both 1988 through 1994 and 1999 through 2000.<sup>34</sup>

While genetic makeup undoubtedly influences the propensity to be at low risk, extensive data have shown that in populations with little or no CVD, adoption of adverse lifestyles results in increase of BMI, blood pressure, cholesterol level, and diagnosed diabetes.<sup>35</sup> Owing to advances in medicine and increases in life expectancy, higher proportions of persons with adverse risk factors earlier in life survive to experience their deleterious consequences in older age, including disease, disability, and higher health care costs. Our findings suggest that preventive measures at younger ages, that is, adherence to a healthy lifestyle, including a healthy diet, regular physical activity, and abstinence from smoking, can lead to a healthier older population with less disability and greater ability to function independently, hence potentially lowering costs for care at

**Table 3. Adjusted\* Mean Medicare Charges for All Types of Services Covered by Medicare† in the Last Year of Life (1992-2002) by Baseline (1967-1973) Risk Status**

Baseline Risk Status‡	No. of Persons (n = 4876)	Age at Death, Mean (SD), y	CVD Charges,‡ \$	Total Charges, \$
Low risk	94	78.9 (7.6)	11 643	86 908
Not low risk				
Any 1 risk factor only	496	78.5 (7.5)	1796	89 810
Any 2 risk factors only	1470	79.2 (7.1)	20 179	90 951
Any 3 risk factors only	1941	79.4 (6.9)	23 603	94 868
≥4 Risk factors	875	77.2§ (6.9)	26 327	95 776
P for trend		<.001	<.001	.01

Abbreviations: For abbreviations and risk definitions, see footnotes to Table 1.

\*Cardiovascular (CVD)-related and total charges were adjusted for age at death, race, sex, and education.

†All types of services include claims from inpatient, outpatient, hospice, home health care, skilled nursing facility, physician visits, and durable medical equipment.

‡Charges from claims with a primary diagnosis of CVD based on *International Classification of Diseases, Ninth Revision, Clinical Modification* codes 390 through 459.

§P<.05 for comparison with the low-risk group based on linear model (age at death) or a modified Cox regression method (charges).

||P values for trend based on a modified Cox regression method with "risk status" as an ordinal variable with values from 1 to 5.

**Table 4. Mean Medicare Hospital-Related\* Charges in the Last Year of Life (1984-2002) by Sex, Age at Death, Race, and Education**

Variable	Men			Women			Men and Women		
	No.	CVD Charges, \$	Total Charges, \$	No.	CVD Charges, \$	Total Charges, \$	No.	CVD Charges, \$	Total Charges, \$
Sex	3920	15 105	56 344	2662	13 656	51 245	6582	14 519	54 281
Age at death, y									
66-69	707	13 681	53 083	341	13 399	60 785	1048	13 589	55 589
70-74	928	17 674	66 192	459	16 251	65 318	1387	17 203	65 903
≥75	2285	14 503	53 353	1862	13 063	46 028	4147	13 856	50 034
Race									
White	3681	15 019	55 851	2502	13 497	50 294	6183	14 403	53 602
Black	197	13 954	60 958	137	17 907	68 318	334	15 576	63 977
Education, y									
<12	1152	14 558	54 049	896	15 706	54 053	2048	15 060	54 050
12	1251	15 231	57 817	1234	12 251	49 215	2485	13 751	53 545
13-15	650	17 165	61 632	353	14 665	54 290	1003	16 285	59 048
≥16	867	14 107	53 303	179	11 092	45 177	1046	13 591	51 912

Abbreviation: CVD, cardiovascular disease.

\*Hospital-related charges are for inpatient, skilled nursing facility, and outpatient care.

older ages, even in the year immediately preceding death. Not only do low-risk individuals have less disease and disability,<sup>30-33</sup> our results suggest that they also experience lower acceleration in the functional decline common before death, which is reflected by their lower costs in the last year of life, lending further credence to the compression of morbidity hypothesis.<sup>36</sup>

Few studies have linked health habits or CVD biomedical risk factors to health care costs among older persons, and in general risks were measured only a few years before costs were incurred.<sup>37,38</sup> Nonsmoking, higher exercise level, and other healthy habits were associated with lower medical costs<sup>37</sup>; elevated levels of cardiovascular risk factors (ie, systolic blood pressure, serum cholesterol level, and smoking) were related to higher annual Medicare costs.<sup>38</sup> A previous report on 13 796 CHA participants showed that total and CVD- and cancer-related average annual Medicare charges over an 11-year period were much lower for persons with favorable

risk status in middle age than for others (eg, for low-risk men and women, total average annual Medicare charges were lower by \$1615 and \$1885; CVD-related charges lower by \$979 and \$556, respectively).<sup>11</sup> Recent findings on 2013 CHA participants (baseline ages 36-52 years) also suggest that compared with persons with 1 or more adverse risk factors, those without cardiovascular risk factors in middle age incurred lower cumulative Medicare expenditures from age 65 years to the point of death or to advanced ages, despite greater longevity.<sup>39</sup>

Research on health care costs at the end of life has been limited mostly to the effects of sociodemographic factors (eg, age, sex, and race),<sup>3,12-14</sup> various medical conditions,<sup>14</sup> or functional status and disability assessed mostly in the period just before death.<sup>40</sup> Among 261 decedents drawn from patients attending a fee-for-service group practice, total medical expenses in the last year of life did not differ greatly by functional status; hospital costs were lower, and nursing home and home health care costs were higher with

**Table 5. Mean Medicare Charges for All Types of Services Covered by Medicare\* in the Last Year of Life (1992-2002) by Sex, Age at Death, Race, and Education**

Variable	Men			Women			Men and Women		
	No.	CVD Charges, \$	Total Charges, \$	No.	CVD Charges, \$	Total Charges, \$	No.	CVD Charges, \$	Total Charges, \$
Sex	2798	23 130	97 100	2078	21 085	87 907	4876	22 259	93 182
Age at death, y									
66-69	381	14 914	81 788	171	23 810	109 788	552	17 670	90 462
70-74	579	24 569	105 635	303	22 786	101 040	882	23 956	104 057
≥75	1838	24 380	97 585	1604	20 474	83 094	3442	22 559	90 832
Race									
White	2629	23 243	96 979	1950	20 804	86 296	4579	22 205	92 430
Black	133	20 731	101 259	113	27 016	119 232	246	23 618	109 515
Education, y									
<12	767	22 105	86 985	678	24 134	90 744	1445	23 057	88 749
12	885	23 454	101 496	970	19 001	85 412	1855	21 125	93 086
13-15	478	24 487	105 729	282	21 931	92 024	760	23 539	100 644
≥16	668	22 906	96 713	148	19 168	83 424	816	22 228	94 303

Abbreviation: CVD, cardiovascular disease

\*All types of services include claims from inpatient, outpatient, hospice, home health care, skilled nursing facility, physician visits, and durable medical equipment.

poorer functional status.<sup>40</sup> To our knowledge, the impact of risk status earlier in life on health care costs incurred in the last year of life has not been previously examined.

The current findings extend our previous report on health care costs<sup>11</sup> and demonstrate that CVD risk profile at younger ages also relates to Medicare expenditures in the year prior to death. Associations persisted when decedents with minor ECG abnormalities or diabetes at baseline were excluded and with adjustment for age at death, a major factor influencing end-of-life medical costs.<sup>12,13</sup> Furthermore, the present study also includes BMI in the risk definition; this is of great public health importance because prevalence of overweight and obesity—a major independent CVD risk factor<sup>41</sup>—has increased markedly in the United States during the last few decades and continues to rise.<sup>42,43</sup>

For the CHA cohort, only 1 set of cardiovascular risk factor measurements was made, with no interim assessments of risk factors. Lack of repeat measures would likely lead to underestimation of the impact of baseline risk status, that is, bias results toward the null. Diet and physical activity were not assessed; therefore, it is not possible to determine the relation of these behaviors with end-of-life expenditures. Another limitation is lack of data on use of health services not covered by Medicare, most importantly, long-term nursing home care and prescription drugs. Among CHA participants 65 and older, adverse levels of cardiovascular risk factors measured earlier in life were associated with lower mental, social, and physical functioning in older age and higher use of prescription drugs.<sup>30</sup> Thus, potential bias from this limitation is likely to be toward underestimation of health care costs of unfavorable risk factors levels. Data on out-of-pocket payments are not included either; however, these constitute only a small proportion of total expenditures. In addition, Medicare data do not capture expenditures for decedents younger than 65 years. Nevertheless, the changing demographics of the US population (ie, increasing numbers of older persons)

and the fact that most Americans (67%) die at 65 years or older<sup>44</sup> and that Medicare spends more than \$220 billion per year in the health care of enrollees<sup>45</sup> warrants the study of costs incurred by older decedents. Finally, the use of only fee-for-service Medicare data may lead to underestimates of actual total health care expenditures because health care costs incurred outside the Medicare system are not accounted for. However, Medicare is the largest single source of health care spending in the United States, and exclusion of beneficiaries enrolled in managed care plans did not alter the observed positive relationship between risk profile and Medicare charges.

In conclusion, these data indicate that persons with favorable levels of all major cardiovascular risk factors in young adulthood or middle age have lower health care costs in the last year of life. Among those with unfavorable risk factors, the fewer the risk factors, the lower the Medicare expenditures in the year before death. Current treatments (including drug treatment and lifestyle modifications) to control adverse levels of cardiovascular risk factors, while effective, do not typically reduce morbidity and mortality to levels observed in low-risk individuals.<sup>46,47</sup> Our findings underscore the importance of a comprehensive national public health policy emphasizing concurrent primary prevention of all major cardiovascular risk factors from early life on as an important strategic priority for controlling health care costs in older ages and at the end of life.

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Correspondence: Martha L. Daviglus, MD, PhD, Department of Preventive Medicine, Feinberg School of Medicine, Northwestern University, 680 N Lake Shore Dr, Suite 1102, Chicago, IL 60611 (daviglus@northwestern.edu).

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