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Cardiorespiratory Fitness in Middle Age and Health Care Costs in Later Life

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ABSTRACT

BACKGROUND Low cardiovascular risk factor burdens in middle age are associated with lower health care costs in later life. However, there are few data regarding the effect of cardiorespiratory fitness on health care costs independent of these risk factors.

OBJECTIVES This study sought to evaluate the association of health care costs in later life with cardiorespiratory fitness in midlife after adjustment for cardiovascular risk factors.

METHODS We studied 19,571 healthy individuals in the Cooper Center Longitudinal Study who underwent cardiorespiratory fitness assessment at a mean age of 49 years and received Medicare coverage from 1999 to 2009 at an average age of 71 years. Cardiorespiratory fitness was estimated by maximal metabolic equivalents (METs) calculated from treadmill time. The primary outcome was average annual health care costs obtained from Medicare standard analytical files.

RESULTS Over 126,388 person-years of follow-up, average annual health care costs were significantly lower for participants aged 65 years or older with high midlife fitness than with low midlife fitness in both men ($7,569 vs. $12,811; $p < 0.001$) and women ($6,065 vs. $10,029; $p < 0.001$). In a generalized linear model adjusted for cardiovascular risk factors, average annual health care costs in later life were incrementally lower per MET achieved in midlife in men (6.8% decrease in costs per MET achieved; 95% confidence interval: 5.7% to 7.8%; $p < 0.001$) and women (6.7% decrease in costs per MET achieved; 95% confidence interval: 4.1% to 9.3%; $p < 0.001$). These associations persisted when participants were separated into those who died during Medicare follow-up and those who survived.

CONCLUSIONS Higher cardiorespiratory fitness in middle age is strongly associated with lower health care costs at an average of 22 years later in life, independent of cardiovascular risk factors. These findings may have important implications for health policies directed at improving physical fitness. (J Am Coll Cardiol 2015;66:1876–85)

Physical inactivity is a global pandemic, with more than 30% of adults failing to achieve a meaningful level of daily activity (1). Moreover, physical inactivity is estimated to account for 6% to 10% of deaths from major noncommunicable diseases, such as coronary heart disease and type 2 diabetes (2). As such, physical inactivity represents a major burden on health care costs. The Medicare Board of Trustees has projected that Medicare costs will grow from 3.7% of the current U.S. gross domestic product to 5.7% by 2035 (3). Preventive health strategies with the potential to decrease health care costs, particularly with regard to Medicare, are of critical importance in the United States.

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Cardiorespiratory fitness is an objective measure of habitual physical activity and has been shown to be a risk factor for morbidity and mortality (4). Existing reports have examined the effects of fitness and physical activity on health care use and costs in the short term (5–7). Both cardiovascular risk factors (8) and an elevated body mass index (BMI) (9) in middle age are associated with increased health care costs in later life, suggesting that risk factor shifts in middle age could have implications for health care costs decades later.

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Because of the strong, independent association between fitness and long-term risk for both cardiovascular and noncardiovascular illnesses (4), we hypothesized that higher fitness levels in midlife would be associated with a lower burden of health care costs in later life. To test this hypothesis, we merged individual participant fitness data from the Cooper Center Longitudinal Study (CCLS) with Medicare administrative claims data, which allowed us to evaluate the association between fitness measured in midlife and health care costs decades later, in older age.

METHODS

STUDY POPULATION. The CCLS is an ongoing, prospective study at The Cooper Institute in Dallas, Texas that began in 1970 (10,11). Participants in the CCLS are self-referred or referred by other providers to the Cooper Clinic and are generally well-educated whites with access to health care. All patients seen at the Cooper Clinic are invited to participate in the study. CCLS participants receive a preventive medical examination that includes self-reported medical and lifestyle history, physical examination by a physician, anthropometric measurements, fasting laboratory studies, and a maximal treadmill exercise test. Participants sign an informed consent for inclusion in the research database. The study is reviewed and approved annually by the institutional review board of The Cooper Institute.

The study cohort initially consisted of 32,978 CCLS participants eligible for fee-for-service Part A and Part B Medicare coverage between 1999 and 2009 and who had been linked to Medicare research identifiable files. After excluding 4,019 participants who did not have a baseline exercise treadmill test between 1971 and 2009, we also excluded the following participants: 3,570 participants who lacked complete baseline data; 3,738 participants who did not have continuous fee-for-service Medicare coverage or received care from health maintenance organizations; 1,417 patients with previous myocardial infarctions, strokes, or cancer; and 663 participants who received Medicare coverage before age 65 years or who had a baseline examination after entering Medicare. This yielded a final study sample of 19,571 participants. Costs incurred after a participant changed to managed care or discontinued Part B Medicare coverage were censored. Participants were followed from the date of initiating Medicare coverage until death or the end of follow-up on December 31, 2009. Mortality data were obtained from the death indicator in Medicare data.

ABBREVIATIONS AND ACRONYMS

BMI = body mass index
CI = confidence interval
CVD = cardiovascular disease
MET = metabolic equivalent

MEASUREMENTS. Because of its objective nature and availability of data over decades in the CCLS, fitness was chosen as the primary explanatory risk factor. Cardiorespiratory fitness levels were estimated from the maximal time on a treadmill test using the modified Balke protocol (12). The test was terminated by volitional exhaustion reported by the participant or by the physician for medical reasons. The time on the treadmill with this protocol is highly correlated ($r = 0.92$) with measured maximal oxygen uptake in both men and women. Maximal metabolic equivalents (METs) (1 MET = 3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$) were estimated by regression from the final treadmill speed and grade (13).

In accordance with standard approaches to the analysis of fitness data, the CCLS has historically compared treadmill times with age- and sex-specific normative data on treadmill performance so that each participant can be classified into age- and sex-specific quintiles of fitness (Online Table 1). These quintiles were then combined into 3 mutually exclusive fitness groupings: “low fit”: quintile 1 (Q1); “moderate fit”: quintiles 2 to 3 (Q2 to Q3); and “high fit”: quintiles 4 to 5 (Q4 to Q5). Due to their historical use in multiple CCLS papers, the MET cutpoints for the entire CCLS (Online Table 1) were applied to the cohort in this study (11,14). Although no uniform consensus for the precise range of low fitness exists, in previous work, the low-fit category was the most highly associated with increased morbidity and mortality (15). The measurements of other baseline variables in the CCLS have been well-described and were obtained in accordance with standard protocols (11).

HEALTH CARE COSTS. CCLS participant data were matched via direct identifiers (Social Security numbers, dates of birth) to the Medicare Provider Analysis and Review file (which contains inpatient and skilled nursing facility claims) and the Carrier, Durable Medical Equipment, Home Health Agency, Hospice, and Outpatient standard analytical files

from the Center for Medicare and Medicaid Services. Together, these files contain 100% of claims reimbursed by Medicare. For each service billed to Medicare, records include the date of service, amount reimbursed by Medicare, the amount reimbursed by third-party insurance, and the amount the patient must pay for deductibles and co-payments. Each claim has a principal diagnosis coded according to the International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM). The Medicare Provider Analysis and Review and standard analytical files also contain information on hospitalizations and length of stay in both acute care hospitals and skilled nursing facilities. Of note, skilled nursing facility claims are only available for up to 100 days per episode (the duration of Medicare skilled nursing facility coverage). Claims data are available for CCLS participants who were 65 years of age or older from 1999 to 2009 and who were thus eligible for Medicare benefits.

We used actual amounts paid by Medicare and third-party insurance, in addition to the amounts for which patients were liable as a proxy for health care costs, consistent with other analyses using these data sets (16). Health care costs were also cumulated for individual diagnoses by primary claim ICD-9 codes. For example, cardiovascular disease (CVD)-related costs were attributed to codes 390.x to 459.x, which include ischemic heart disease and heart failure diagnoses. Costs were then annualized by dividing total costs by the number of years of Medicare coverage. To account for inflation, health care costs were adjusted to year 2009 dollars with the Hospital and Related Services component of the Consumer Price Index from the U.S. Bureau of Labor Statistics.

STATISTICAL ANALYSES. Average and median annual costs were calculated by fitness group and compared using the Kruskal-Wallis test. Hospitalization rates per 1,000 person-years and average length of stay for inpatient and skilled nursing facility were compared across fitness strata using Poisson regression. Because the cost distribution is characterized by zero mass and right skew, special care was taken in modeling associations between annual health care costs and midlife fitness. Average annual health care costs were modeled using generalized linear regression, specifying a Poisson distribution with log-link function (17). Median (50th) as well as 75th and 90th percentiles of annual health care costs were modeled using quantile regression. Quantile regression is well-suited for the analysis of economic outcomes because it allows for evaluation of variables with unequal dependence across the distribution of responses, and the 50th, 75th, and 90th percentiles are standard for modeling health care cost data (18). All models were stratified by sex and adjusted for average age during Medicare follow-up and age at the initial fitness examination; fitness was entered as a continuous variable. Additional models were adjusted for smoking status (current vs. nonsmoker), diabetes (yes/no),

TABLE 1 Characteristics of Cooper Center Longitudinal Study Participants With Medicare Coverage (N = 19,571)

	Men (n = 15,524)				Women (n = 4,047)			
Fitness Category	**Low (n = 2,902)**	**Moderate (n = 6,536)**	**High (n = 6,086)**	**p Value***	**Low (n = 578)**	**Moderate (n = 1,545)**	**High (n = 1,924)**	**p Value***
Age at CCLS examination	45.7 ± 8.4 (40, 46, 51)	48.2 ± 8.5 (42, 48, 55)	50.1 ± 8.5 (44, 51, 57)	<0.001	47.9 ± 9.4 (41, 48, 56)	50.2 ± 9.1 (44, 50, 58)	52.3 ± 8.2 (47, 53, 59)	<0.001
Average Medicare age	71.2 ± 5.3 (68, 70, 75)	71.6 ± 5.7 (67, 70, 75)	71.3 ± 5.7 (67, 69, 75)	0.003	71.8 ± 5.9 (68, 70, 76)	71.4 ± 5.9 (67, 70, 75)	70.4 ± 5.3 (67, 69, 73)	<0.001
Person-yrs of follow-up	18,623	42,894	38,963	N/A	3,894	10,299	11,715	N/A
Medicare follow-up, yrs	7.0 ± 3.5	7.2 ± 3.5	7.1 ± 3.6	<0.001	7.2 ± 3.5	7.2 ± 3.6	6.7 ± 3.6	<0.001
SBP, mm Hg	124.5 ± 14.5	122.5 ± 14.0	122.0 ± 14.1	<0.001	119.1 ± 15.7	116.3 ± 15.5	116.3 ± 15.7	<0.001
DBP, mm Hg	83.4 ± 9.8	82.0 ± 9.6	80.5 ± 9.1	<0.001	78.5 ± 9.9	77.4 ± 9.7	77.2 ± 9.5	0.017
Total cholesterol, mg/dl	221.8 ± 41.2	216.7 ± 39.4	209.7 ± 37.5	<0.001	213.7 ± 38.9	213.8 ± 40.3	209.6 ± 37.8	0.006
BMI, kg/m^2	28.6 ± 4.5	26.6 ± 3.1	25.0 ± 2.5	<0.001	25.3 ± 5.5	23.5 ± 3.8	22.4 ± 2.9	<0.001
METs, number	8.4 ± 1.2	10.3 ± 1.2	13.0 ± 1.8	<0.001	6.4 ± 0.9	8.0 ± 1.0	10.1 ± 1.5	<0.001
Diabetes	154 (5.3)	188 (2.9)	103 (1.7)	<0.001	18 (3.1)	26 (1.7)	23 (1.2)	0.007
Smoking	909 (31.0)	1,274 (19.0)	531 (9.0)	<0.001	101 (17.0)	155 (10.0)	101 (5.0)	<0.001
All-cause deaths	665 (23.0)	998 (15.0)	643 (11.0)	<0.001	97 (17.0)	169 (11.0)	119 (6.0)	<0.001
All-cause mortality rate per 1,000 person-yrs (95% CI)	35.7 (33.1–38.5)	23.3 (21.9–24.8)	16.5 (15.3–17.8)	N/A	24.9 (20.4–30.4)	16.4 (14.1–19.1)	10.2 (8.5–12.2)	N/A

Values are mean ± SD (25th, 50th, 75th percentiles) or n (%), unless otherwise noted. Age at CCLS examination indicates age at the time of initial cardiorespiratory fitness assessment. Average Medicare age denotes the patient's average age during Medicare follow-up. *p values obtained by the Kruskal-Wallis test.

BMI = body mass index; CCLS = Cooper Center Longitudinal Study; CI = confidence interval; CVD = cardiovascular disease; DBP = diastolic blood pressure; MET = metabolic equivalent; N/A = not applicable; SBP = systolic blood pressure.

total cholesterol, systolic blood pressure, and BMI. To characterize the effect of fitness on end-of-life health care costs, average and median health care costs stratified by fitness level were compared between participants who died and those who survived through Medicare follow-up. An indicator for survival was added to the multivariable-adjusted generalized linear and quantile regression models to complement the analysis of health care costs between participants who died during Medicare follow-up and those who survived.

In subsequent analyses, participants were categorized according to the presence or absence of traditional risk factor burdens using previously published algorithms (19). Using this method, we stratified participants into 3 mutually exclusive risk factor categories: no major risk factors; 1 major risk factor (smoking, diabetes, total cholesterol >240 mg/dl, systolic blood pressure >160 mm Hg, diastolic blood pressure >100 mm Hg); or ≥2 major risk factors. Estimated average annual health care costs for 80-year-old men and women were calculated by midlife fitness level and risk factor category using a generalized linear model. The average age of Medicare beneficiaries in the United States approaches 80 years, hence the use of age 80 years in this model (20).

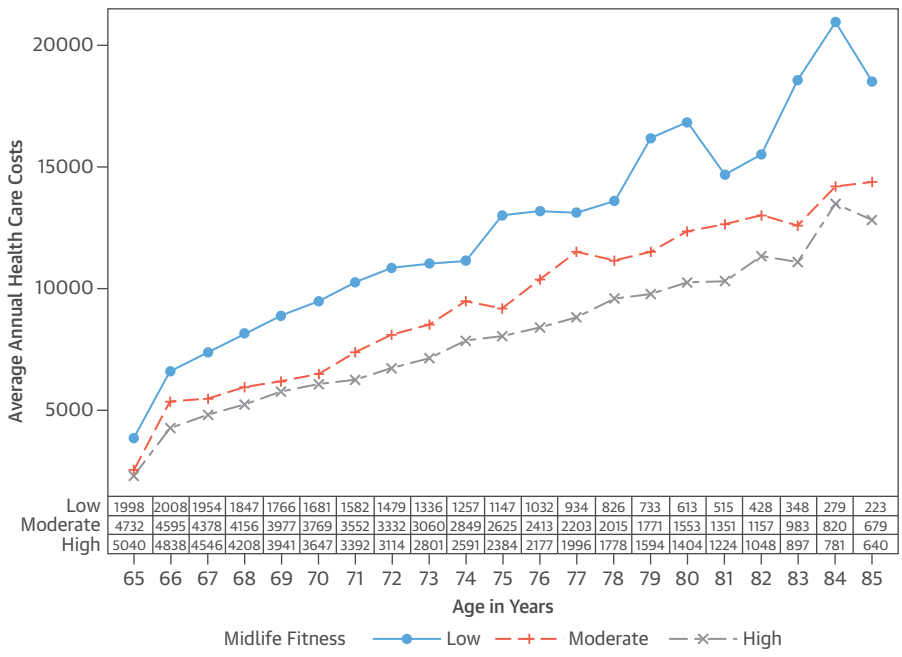
All analyses used SAS for Windows (release 9.2, SAS Institute Inc., Cary, North Carolina).

RESULTS

Participant characteristics for 15,524 men and 4,047 women are shown in **Table 1** (also see Online Table 2). The cohort had an average of 6.5 years of Medicare coverage, with a total of 126,388 person-years of follow-up. Participants had low levels of cardiovascular risk factors at study entry, and women had lower average METs than men, with a narrower range (mean 8.7 METs in women, SD = 1.9, versus mean 11.0 METs in men, SD = 2.3). Participants enrolled in the earlier decades of the CCLS made up a larger proportion of the low-fitness groups (Online Table 2). The age of enrollment was also younger in the low-fitness groups, although this difference was due to the application of historical fitness group MET cutpoints to the study cohort, and the age at enrollment was similar among fitness groups when quintile cutpoints specific to this cohort were applied (Online Table 3).

All-cause and CVD mortality rates were higher in lower fitness strata. Participants with high midlife fitness had significantly lower average annual health care costs during Medicare coverage (**Figure 1**). Similarly, health care use patterns were highest among

FIGURE 1 **Annual Mean Observed Costs at Each Year of Age by Midlife Fitness Level**



Average annual health care costs, adjusted for inflation and stratified by midlife fitness level, were plotted by each year of age. The number of observed participants for each year and fitness level is also reported.

participants with the lowest baseline fitness level, including higher inflation-adjusted average and median annual costs, average annual physician visits, hospitalization rates, and inpatient lengths of stay (Table 2). Total- and CVD-related health care costs were significantly lower in men and women with high levels of midlife fitness compared with those with lower midlife fitness. The cost gradient across fitness levels was steeper for CVD-related costs than for total costs, although the difference in dollars was greater for total costs. For example, there was a $5,242 (41%) difference in total average annual health care costs between low- and high-fit men ($12,811 vs. $7,569; $p < 0.001$) and a $1,875 (56%) difference for CVD-related health care costs ($3,333 vs. $1,458; $p < 0.001$) (Table 2).

The multivariable-adjusted association between average or median health care costs in later life and midlife fitness is shown in Table 3. In a generalized linear model adjusted for cardiovascular risk factors, average annual health care costs in later life decreased incrementally by each MET achieved in midlife in both men (6.8% decrease in costs per MET achieved; 95% confidence interval [CI]: 5.7% to 7.8%; $p < 0.001$) and women (6.7% decrease in costs per MET achieved; 95% CI: 4.1% to 9.3%; $p < 0.001$). Associations among health care costs and METs, diabetes, and smoking in midlife are presented in Online Table 4 for comparison.

Confirmatory associations between health care costs in later life and midlife fitness were found using quantile regression across the 50th, 75th, and 90th annual cost percentiles (Table 3). Parameter estimates from the generalized linear models tended to be greater than those of quantile regression for the 50th percentile of annual health care costs in men, reflecting the skewed nature of the health care cost distribution. A small percentage of patients with high health care costs accounted for the majority of total costs in the CCLS cohort. In 1999, for example, CCLS patients in the 90th percentile and higher for annual health care costs accounted for 58.4% of total health care costs. This distribution is consistent with national Medicare data. In 1999, patients in the 90th percentile and higher for annual Medicare costs accounted for 59.8% of total annual Medicare costs (21). In women, multivariable-adjusted quantile regression demonstrated a slightly smaller effect of fitness on the 90th cost percentile compared with the 50th cost percentile, which was possibly due to the lower hospitalization and mortality rate of women in the CCLS cohort compared with men.

To characterize the effect of midlife fitness on end-of-life costs, health care use and costs by midlife fitness categories were compared between CCLS participants who died during Medicare follow-up and who survived (Table 4). The 13.7% of participants who died during Medicare follow-up accounted for 41.8% of total health care costs in the CCLS cohort. Inverse associations between health care costs in later life and midlife fitness were present in both living participants and in those who died between 1999 and 2009 (Table 4). There was a 27% difference in median annual costs between the high and low fitness groups in living participants ($2,936 vs. $4,019; $p < 0.001$) and a 22% difference in decedents ($15,890 vs.

TABLE 2 Health Care Use in Later Life by Category of Midlife Fitness (N = 19,571)

	Men (n = 15,524)				Women (n = 4,047)			
Fitness Category	Low (n = 2,902)	Moderate (n = 6,536)	High n = 6,086	p Value*	Low (n = 578)	Moderate (n = 1,545)	High (n = 1,924)	p Value*
Average annual cost	$12,811 ± $32,838	$9,370 ± $19,278	$7,569 ± $21,547	<0.001	$10,029 ± $17,739	$8,248 ± $39,787	$6,065 ± $12,878	<0.001
Median annual costs (25th, 75th percentiles)	$5,568 (1,753, 14,807)	$4,510 (1,500, 10,761)	$3,475 (1,232, 8,368)	<0.001	$4,920 (2,051, 10,401)	$3,665 (1,474, 8,435)	$2,961 (1,221, 6,609)	<0.001
% with any claims	94.9	94.0	93.6	0.06	95.3	94.6	94.0	0.41
Average annual CVD costs	$3,333 ± $13,819	$2,093 ± $6,106	$1,458 ± $5,529	<0.001	$1,633 ± $4,655	$1,695 ± $25,947	$804 ± $3,769	<0.001
% with any CVD claims	84.1	79.7	76.3	<0.001	82.4	76.6	70.1	<0.001
Hospitalization rate, per 1,000 person-yrs, (95% CI)	329 (320-337)	245 (240-250)	197 (193-202)	N/A	257 (241-273)	209 (200-218)	153 (147-161)	N/A
Mean annual inpatient days	2.7 ± 7.4	1.7 ± 5.6	1.2 ± 4.3	<0.001	2.4 ± 6.9	1.5 ± 4.6	0.8 ± 3.1	<0.001
Mean annual physician office visits	6.4 ± 6.2	6.0 ± 5.9	5.5 ± 5.6	<0.001	7.2 ± 7.1	6.7 ± 6.3	6.1 ± 6.1	<0.001

Values are mean ± SD unless otherwise noted. *p Values obtained by the Kruskal-Wallis test.
Abbreviations as in Table 1.

$20,476; p < 0.001). As in Table 1, there was a smaller absolute, but greater relative difference in CVD costs in surviving participants and decedents. The effect of midlife fitness on mortality and deferral of costs due to increased survival was further characterized with a combined-sex, multivariable-adjusted generalized linear model augmented with a survival main effect and interaction with fitness. The main effect of fitness remained significant (6.3% decrease in costs per MET; 95% CI: 5.2% to 7.3%; p < 0.001), demonstrating that the association between health care costs in later life and midlife fitness was not entirely mediated by survival.

To further illustrate the effect of midlife cardiorespiratory fitness on health care costs later in life, we used generalized linear models to model average annual health care costs for 80-year-old men and women by METs achieved at age 50 years, stratified by CVD risk factor burden (Central Illustration). Health care costs were lower in those with lower levels of traditional risk factors. Inverse associations between health care costs in later life and midlife fitness were consistent across high, moderate, and low risk factor groups, with greater decreases in absolute costs in the high-risk groups.

TABLE 3 Incremental Decrease in Average Annual Health Care Costs in Later Life per MET Achieved in Midlife (N = 19,571)

Model	Analysis Type	Incremental % Decrease in Costs per MET Achieved	95% CI	p Value
Men (n = 15,524)				
Age-adjusted	GLM	9.0	8.0–10.0	<0.001
	50th quantile	7.5	6.4–8.7	<0.001
	75th quantile	9.3	8.2–10.4	<0.001
	90th quantile	10.0	8.7–11.3	<0.001
Multivariable-adjusted	GLM	6.8	5.7–7.8	<0.001
	50th quantile	3.8	2.4–5.1	<0.001
	75th quantile	5.5	4.2–6.9	<0.001
	90th quantile	6.6	5.1–8.1	<0.001
Women (n = 4,047)				
Age-adjusted	GLM	8.9	6.5–11.4	<0.001
	50th quantile	7.2	5.1–9.3	<0.001
	75th quantile	7.5	4.9–10.0	<0.001
	90th quantile	7.9	4.8–10.9	<0.001
Multivariable-adjusted	GLM	6.7	4.1–9.3	<0.001
	50th quantile	5.9	3.4–8.4	<0.001
	75th quantile	4.3	1.9–6.8	<0.001
	90th quantile	3.9	0.2–7.6	<0.04

Each row represents a separate generalized linear model or quantile regression analysis. The age-adjusted model adjusts for Medicare age and age at the time of fitness examination; the multivariable-adjusted model additionally adjusts for CVD risk factors, including smoking status (current vs. nonsmoker), diabetes (yes/no), total cholesterol, systolic blood pressure, and BMI.

GLM = generalized linear model; other abbreviations as in Table 1.

DISCUSSION

In the 19,571 participants studied here, higher levels of cardiorespiratory fitness at a mean age of 49 years were associated with lower total and CVD-related health care costs at an average of 22 years later. Robust inverse associations between health care costs in later life and midlife fitness were present for both men and women after adjustment for cardiovascular risk factors. Each MET achieved in midlife was associated with an incremental decease in health care costs in later life. There were greater decreases in absolute costs in participants with the highest

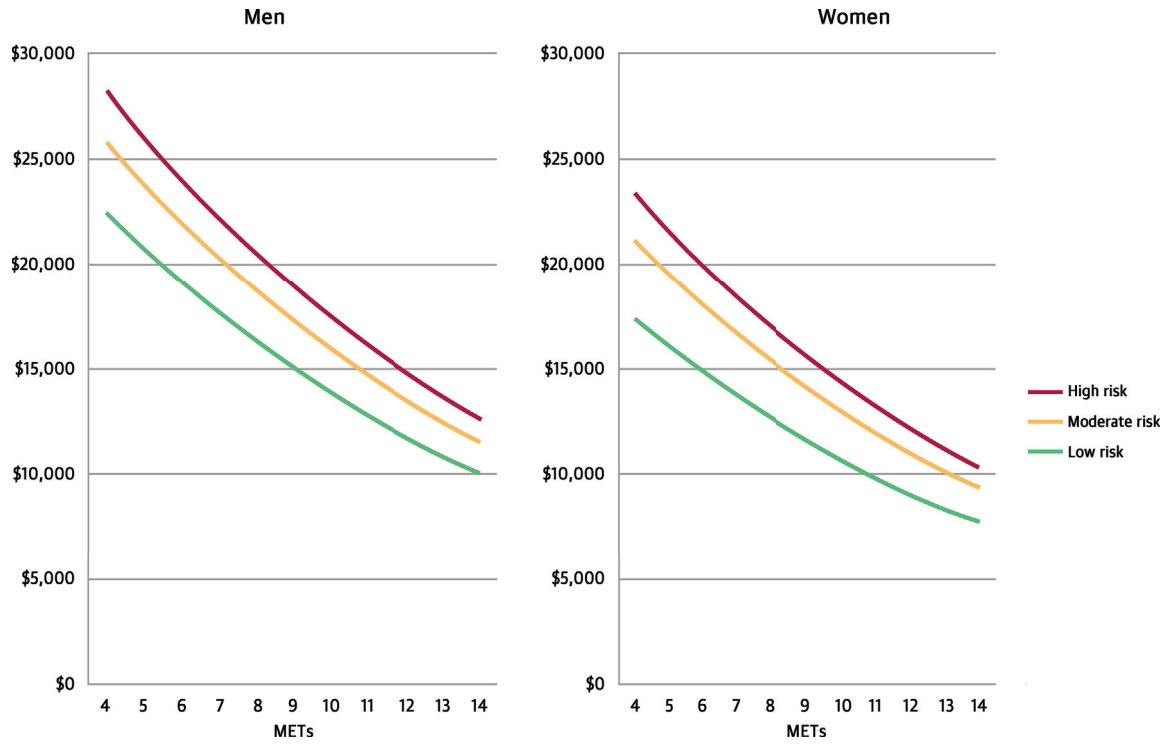
TABLE 4 Health Care Use of CCLS Participants Surviving Through Medicare Follow-Up Versus CCLS Participants Deceased During Medicare Follow-Up by Category of Midlife Fitness (N = 19,571)

	Survived Through Follow-Up (n = 16,880)				Deceased During Follow-Up (n = 2,691)			
Fitness Category	Low (n = 2,718)	Moderate (n = 6,914)	High (n = 7,248)	p Value*	Low (n = 762)	Moderate (n = 1,167)	High (n = 762)	p Value*
Average annual costs	$7,583 ± $28,355	$6,261 ± $21,292	$5,214 ± $8,339	<0.001	$29,351 ± $33,363	$26,304 ± $33,893	$26,173 ± $55,456	<0.001
Median annual costs (25th, 75th percentiles)	$4,019 (1,424, 9,048)	$3,456 (1,249, 7,680)	$2,936 (1,084, 6,545)	<0.001	$20,476 (9,335, 36,293)	$18,228 (9,975, 32,361)	$15,890 (8,059, 28,614)	<0.001
% with any claim	94.6	93.4	93.3	0.06	96.5	98.6	97.9	0.006
Average annual CVD costs	$1,876 ± $11,543	$1,516 ± $12,966	$973 ± $2,512	<0.001	$7,241 ± $15,747	$4,989 ± $9,676	$4,422 ± $14,499	<0.001
% with any CVD claims	82.0	77.3	73.2	<0.001	90.4	90.1	90.0	0.97
Hospitalization rate, per 1,000 person-yrs (95% CI)	211 (204–217)	177 (174–181)	149 (146–153)	N/A	807 (779–835)	640 (621–659)	581 (559–603)	N/A
Mean annual inpatient days	1.07 ± 3.25	0.70 ± 2.77	0.60 ± 2.78	<0.001	8.5 ±12.8	7.2 ±11.2	5.7 ± 8.6	<0.001
Mean annual physician office visit	6.0 ± 5.6	5.7 ± 5.4	5.3 ± 5.4	<0.001	8.4 ± 8.2	8.9 ± 8.0	8. ± 7.4	0.05

Values are mean ± SD unless otherwise noted. *p Values obtained by the Kruskal-Wallis test.

Abbreviations as in Table 1.

CENTRAL ILLUSTRATION **Cardiorespiratory Fitness and Health Care Costs: Estimated Average Annual Health Care Costs in an 80-Year-Old by METs Achieved at Age 50 Years, Stratified by Cardiovascular Risk Factor Burden**



Bachmann, J.M. et al. J Am Coll Cardiol. 2015; 66(17):1876–85.

Average annual health care costs were estimated using an age-adjusted generalized linear model stratified by risk factor status. Low risk indicates the absence of major risk factors (smoking, diabetes, total cholesterol >240 mg/dl, systolic blood pressure >160 mm Hg, diastolic blood pressure >100 mm Hg). Moderate risk indicates 1 major risk factor. High risk indicates ≥2 major risk factors. MET = metabolic equivalent.

burdens of cardiovascular risk factors. We observed inverse associations between health care use and fitness between both patients who died during Medicare follow-up and those who survived.

Cardiorespiratory fitness is favorably associated with CVD risk factors and is itself an independent risk factor for coronary heart disease (22,23). Previous work has established that cardiovascular risk factors, including BMI, are associated with increased health care costs in older age (8,9,24). This was the first study to evaluate the effect of cardiorespiratory fitness on health care costs over the long term. Our cohort was extensively characterized at midlife, allowing adjustment for cardiovascular risk factors.

To our knowledge, this is the first study to utilize Medicare standard analytical files to evaluate the association of fitness with health care costs. These data allowed for a full accounting of amounts paid by Medicare, amounts paid by third-party insurance, and the amounts for which patients were responsible. Although the Medicare standard analytical files are administrative claims, rather than adjudicated clinical data, they have been shown to be a reliable source of clinical outcomes and costs (24,25).

Previous work in managed care settings has suggested an association between physical activity and decreased health care costs (6,7,26–28). However, this previous work and most large, population-based studies have relied upon self-reported physical activity. The accuracy of self-reported physical activity and its relationship with fitness is controversial. Some studies suggest that self-reported activity has reasonable construct-related validity (29), whereas other studies have found differential accuracy by educational level and BMI (30–32). In our study, the number of METs achieved in midlife represented an objective measure of cardiorespiratory fitness.

Two previous studies have indicated that objectively measured cardiorespiratory fitness is inversely associated with health care costs in the near term

(5,33). However, the short-term nature of these studies could not exclude the possibility of reverse causation (i.e., that low levels of physical activity were the result of underlying illnesses). The 22-year interval between cardiorespiratory fitness ascertainment and Medicare follow-up represents an important strength of our study, making the probability of reverse causation remote. This long interval raises the possibility of differences in health care costs between birth cohorts, and earlier decades of the CCLS contributed more participants to the low fitness groups. However, one of the major mechanisms by which health care costs could differ between birth cohorts is due to secular trends in cardiovascular risk factors. Our analyses adjusted for these risk factors, as well as the age of enrollment and age during Medicare follow-up. Moreover, Berry et al. previously demonstrated that the effect of cardiovascular risk factors on mortality was consistent across multiple birth cohorts in a large pooled analysis (34).

Both others and we have observed strong, inverse associations between measured fitness and mortality (4,11,35). Due to the high burden of health care costs observed at the end of life, the inverse association between Medicare costs and a healthy lifestyle in middle age is attributed by some to effects on mortality and end-of-life costs (36). The fact that we observed similar associations between midlife fitness and health care use between patients who died during Medicare follow-up and those who survived suggests that potential cost savings due to higher levels of fitness are not limited to the period preceding death. Our previous observation that midlife fitness was associated with a decreased burden of chronic conditions and resultant compression of morbidity was consistent with these results (14). The relationship of fitness with mortality could result in deferral of costs beyond the Medicare follow-up period in some study participants with high fitness. However, similar inverse relationships between health care costs in later life and midlife fitness were seen when the multivariable-adjusted model was augmented with a survival indicator. Therefore, deferral of costs in participants with high fitness was unlikely to substantially alter our findings.

Our results suggest a potential financial benefit to participants and to health care systems that incorporate promotion of healthy lifestyles, including physical activity. The adoption of daily, habitual physical activity can result in a meaningful increase in cardiorespiratory fitness level (37). Fitness may also be increased through exercise training programs of various intensities (38). As such, cardiorespiratory fitness represents both an objective measure of physical activity and an important modifiable risk factor that is amenable to evidence-based interventions (39). Translating these results to health policy will require further understanding of the economic costs associated with incentivizing physical activity and the psychosocial dimensions of encouraging exercise, all of which represent inviting avenues for future study.

STUDY LIMITATIONS. First, we were not able to capture health care use data between study entry and the onset of Medicare eligibility. However, we observed a similar pattern of associations between health care use and midlife fitness with participants closer to Medicare eligibility at their baseline in previous work (14). Second, although our analyses adjusted extensively for cardiovascular risk factors, other unmeasured medical conditions, genetic factors, and health behaviors could affect health care costs. However, the long interval between fitness ascertainment and Medicare surveillance would help mitigate the effect of unmeasured confounding. Third, the CCLS was a homogeneous cohort with a lower burden of traditional risk factors compared with the general population. Although the prevalence of traditional risk factors in the general population is higher, the effect of these risk factors was similar in the CCLS cohort (35,40,41). Last, the healthy nature of our cohort might underestimate the effect of fitness on health care costs, because the strongest association was seen in high-risk participants.

CONCLUSIONS

High midlife cardiorespiratory fitness is associated with decreased health care costs and use in Medicare patients older than 65 years of age. Average annual health care costs in later life decrease incrementally with each MET achieved in midlife after adjustment for cardiovascular risk factors. These findings are consistent in both men and women and in participants who died during Medicare follow-up compared with those who survived. Strategies to improve physical activity, and hence, cardiorespiratory fitness, may help attenuate health care costs among the nation's aging population.

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PERSPECTIVES

COMPETENCY IN PATIENT CARE AND PROCEDURAL SKILLS: High levels of cardiorespiratory fitness in midlife are associated with lower mortality, use of health care resources, and health care costs later in life.

TRANSLATIONAL OUTLOOK: Further studies are needed to assess the psychosocial aspects and impact of specific incentives to implementing regular physical activity in populations defined on the basis of clinical, socioeconomic, ethnic, geographic, and other demographic variables.

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APPENDIX For supplemental tables, please see the online version of this article.