Association Between Cardiorespiratory Fitness and Health Care Costs: The Veterans Exercise Testing Study

Jonathan Myers, PhD; Rachelle Doom, MD; Robert King, MS; Holly Fonda, MS; Khin Chan, MD; Peter Kokkinos, PhD; and David H. Rehkopf, MPH, ScD

Abstract

Objective: To determine the association between cardiorespiratory fitness (CRF) and annual health care costs in Veterans.

Patients and Methods: The sample included 9942 subjects (mean age, 59±11 years) undergoing a maximal exercise test for clinical reasons between January 2005 and December 2012. Cardiorespiratory fitness, expressed as a percentage of age-predicted peak metabolic equivalents (METs) achieved, was categorized in quartiles. Total and annualized health care costs, derived from the Veterans Administration Allocated Resource Center, were compared using multiple regression, controlling for demographic and clinical characteristics.

Results: A gradient for reduced health care costs was observed as CRF increased, with subjects in the least-fit quartile having approximately $14,662 ($P<.001$) higher overall costs per patient per year compared with those in the fittest quartile, after controlling for potential confounding variables. Each 1-MET higher increment in fitness was associated with a $1592 annual reduction in health care costs (5.6% lower cost per MET), and each higher quartile of fitness was associated with a $4163 annual cost reduction per patient. The effect of CRF was more pronounced among subjects without cardiovascular disease (CVD), suggesting that the results were not driven by the possibility that less-fit individuals had greater CVD. Cost savings attributable to higher fitness were greatest in overweight and obese subjects, with lower savings observed among those individuals with a body mass index less than 25 kg/m^2. In a model including historical, clinical, and exercise test responses, heart failure was the strongest predictor of health care costs, followed by CRF ($P<.01$).

Conclusion: Low CRF is associated with higher health care costs. Efforts to improve CRF may not only improve health but also result in lower health care costs.

 ■ Mayo Clin Proc. 2018;93(1):48-55

From Veterans Affairs Palo Alto Health Care System, Palo Alto, CA (J.M., R.D., R.K., H.F., K.C.); Division of Cardiovascular Medicine, Stanford University, Stanford, CA (J.M.); Veterans Affairs Medical Center, Washington, DC (P.K.); and Division of Clinical Medicine & Population Health, Stanford University, Stanford, CA (D.H.R.).

Chronic illnesses are increasing in the United States, in part because of increasing trends in unhealthy lifestyle behaviors including lack of physical activity.[1,2] In the current era of rising health care costs, many health care systems have directed a greater emphasis toward promoting health behaviors that reduce the incidence of disability and disease.[3,4] The Affordable Care Act of 2010 includes federally mandated preventive services for adults that incorporate counseling on health and wellness, including physical activity. The latter reflects the widely recognized observation that more physically active individuals have fewer health problems and lower overall health costs, and modulating fitness, physical activity patterns, or both may have a profound effect on health care utilization.[1,2,5,6] Indeed, numerous recent studies have reported that individuals who are comparatively sedentary have higher overall health care costs, which has been attributed to factors including greater illness, hospitalization, and disability.[3,5-9]

A great deal of epidemiologic evidence has also been published in recent years demonstrating a strong inverse association between level of fitness and adverse health outcomes.[1,2,10-18] Relative to highly fit or moderately fit individuals, low-fit subjects are particularly susceptible not only to higher mortality but also to higher rates of cardiovascular events, type 2 diabetes, stroke, hypertension, particular forms of cancer, and other conditions.[1,2,10-18] In a growing number of studies, fitness has been reported to be a stronger predictor of risk for mortality and cardiovascular events than traditional risk factors including hyperlipidemia, hypertension, and smoking.[1,10,12,13,17] These observations have led many national and international health organizations to advocate strategies to improve fitness by promoting physical activity.[12,17,19] Although a great deal of research in recent years has been devoted to the economic consequences of physical inactivity,[3,6-9] surprisingly few data are available regarding the association between objective measures of fitness and health care costs.

Physical activity patterns are often considered a surrogate for fitness,[18,20] in part because direct measures of fitness require an exercise test and are frequently not available. However, quantifying physical activity patterns in epidemiologic studies typically relies on self-report, and self-reported physical activity can be unreliable.[21,22] There is a need for studies on the association between health care costs and fitness using objective measures. The Veterans Health Administration in the US Department of Veterans Affairs Health Care System has been a leader in the development of electronic medical records, which not only enables direct quantification of health expenditures but also detailed observations of history, alterations in health status, and other outcomes.[23] These qualities, along with a unique relational exercise test reporting program that automatically generates a report for distribution within the Veterans Administration (VA) clinical database,[24] and direct measures of fitness determined by a maximal exercise test provided a singular opportunity to assess the association between fitness and health care costs. The demonstration of such an association would provide an objective, economic rationale for employers, health care professionals, and professional organizations to promote physical activity.

PATIENTS AND METHODS

Study Sample

The population included 9942 consecutive patients who were referred for an exercise treadmill test for clinical reasons at the Palo Alto VA Health Care System and the VA Medical Center in Washington, DC, between January 1, 2005, and December 31, 2012. Most tests were performed as part of a routine evaluation, clearance to participate in exercise, or assessment of suspected coronary artery disease. The following subjects were excluded: (1) those unable to complete the test for orthopedic, neurologic, or similar reasons; (2) those with an implanted pacemaker; (3) subjects who were unstable or required emergent intervention; and (4) those with an exercise capacity less than 2 metabolic equivalents (METs). In addition, 5 subjects in the study population were missing data on age and thus were not included.

Exercise Testing

A thorough clinical history, list of medications, and cardiac risk factors were recorded prospectively at the time of testing using computerized forms.[24] Patients underwent symptom-limited treadmill testing using an individualized ramp treadmill protocol as previously described.[25] Heart rate targets were not used as an end point or to judge the adequacy of the test. Estimated METs were calculated from treadmill speed and grade.[26] Exercise capacity was expressed as an age-predicted value calculated from normal standards based on veterans referred for exercise testing.[27] Quartiles of percent-predicted exercise capacity were used to categorize fitness as less than 60%, 60% to less than 80%, 80% to less than 100%, and 100% or greater of the age-predicted values achieved. Clinical and exercise test data were entered into a unique collection and reporting program that automatically generates a report for distribution within the VA clinical database.[24] This program relies on a set of carefully defined clinical and exercise variables that are also stored in a relational database. We used this database to provide the clinical and exercise data for analysis and as the parent database used to query the broader VA database for health care costs.

Calculation of Costs

The Decision Support System is a set of programs that uses relational databases to provide data on the costs, patterns of care, patient outcomes, and workload details of specific patient care encounters within the VA Health Care System. Central to this system is the Veterans Health Information Systems and Technology Architecture with which the VA records clinical data and documents health care encounters. This system includes modules that record data from laboratory, pharmacy, radiology, surgery, and other departments, information from the abstract of the hospital discharge, and records of outpatient

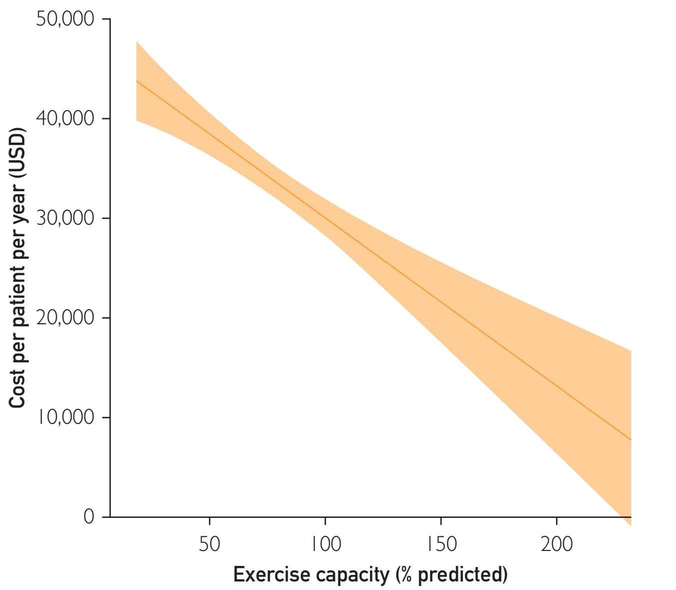

FIGURE 1. The association between costs per patient per year (USD) and exercise capacity (% predicted). USD = US dollars.

visits, including codes for the type of clinic visited, procedures, and diagnoses. The Decision Support System cost data, including both direct and indirect costs, are extracted from the VA payroll and general ledger. The cost of each intermediate product, such as a chest radiograph or a unit of blood, is also included. Relative value units (RVUs) are assigned to each product on the basis of an estimate of the relative costs of the local resources. The department cost per RVU is calculated and multiplied by the RVUs assigned to the intermediate product to determine its cost. The data from each patient encounter include the number of intermediate products used, their cost, and the total cost of that encounter. Costs are given in units roughly equivalent to dollars but require adjustment for local differences in cost component values. The list of patients who had undergone treadmill tests during the study period was submitted to the Austin VA Automation Center. The output generated by the center was merged with our treadmill database. Total costs for each patient were estimated during the 8-year time period of data collection after the treadmill test based on a time-weighted average of the costs during the period in which a given patient was followed. Notably, our cost estimates are higher than other cost analyses linked to Medicare; this is because many subjects referred for an exercise test had existing disease and comorbid conditions, and the fact that the VA system includes cost details that other systems do not.

Statistical Analyses

Patient characteristics are presented as the percentage of the total or mean ± SD. Cost data are expressed in absolute values in US dollars as total for the 8-year observation period, and average cost per patient per year. Comparisons of costs between quartiles of fitness were performed using linear regression models. For our primary analyses, we fit 3 different regression models to show minimally and maximally adjusted models to examine whether the results were consistent. Model 1 adjusted only for age and age-squared, so this can be considered to be unadjusted for hypothesized confounding variables. Model 2 then adjusted for the factors we a priori believed may be confounding the association between exercise capacity and costs. Finally, model 3 also controlled for prevalent cardiovascular disease (CVD). A multiple regression procedure was performed among clinical and exercise variables to determine predictors of health care costs. Sensitivity analyses (not shown) demonstrated that results were not sensitive to excluding different proportions of high-cost patients (top 10%, top 5%, top 1%); thus, the models were fit on the full population (although Figures 1 and 2 exclude the top 1% for clarity of presentation). All analyses were performed using the R software environment, version 3.3.3.

RESULTS

Subject Characteristics

Clinical and demographic characteristics of the study sample are presented in Table 1, stratified by levels of age-predicted exercise capacity. The mean age of the sample was similar across categories, ranging from 57 to 60 years; 97% to 98% were males. The mean body mass index (BMI) was similar across categories as well, although there were different levels of obesity across categories, with the lowest levels of obesity in those with the highest level of fitness. There was a high prevalence of cardiovascular risk factors across all levels of fitness, including 10% to 13% currently smoking, 23% to 36% history of hypertension, and 44% to 51% with type 2 diabetes. Thus, although there were somewhat better risk

Mayo Clin Proc. ■ January 2018;93(1):48-55 ■ https://doi.org/10.1016/j.mayocp.2017.09.019
www.mayoclinicproceedings.org

profiles among those with the highest level of fitness, these differences were generally not of a large magnitude.

Figure 1 shows the unadjusted association between cost per patient per year fit with a flexible nonlinear model, illustrating that this relationship generally exists across the full distribution of exercise capacity. Figure 2 presents this same relationship, but by category of spending. Mean health care costs per patient per year in the least-fit group were approximately \$41,100 per year, as compared with approximately \$26,300 per year in the highest fitness group ($P<.001$ for trend). Each 1-MET higher increment in fitness was associated with a \$1592 reduction in annual health care costs (5.6% lower costs per MET achieved). Multiple regression indicated that among clinical, demographic, and exercise variables, significant predictors of costs, in rank order, were history of heart failure, fitness level, hypertension, and smoking.

Table 2 presents the regression-based estimates of the association between categories of exercise capacity and total costs per patient per year, with the lowest level of fitness as the comparison group. The results were consistent across all the 3 models regardless of which potential confounders were controlled for. We observed that for those at or beyond their age-predicted exercise capacity ($\geq$100%), costs were more than \$14,000 per year less than for those achieving less than 60% of their age-predicted capacity ($P<.001$). Compared with the least-fit group, there were also lower costs for those between 80% and 100% and 60% and 80% of age-predicted exercise capacity.

We also fit a model controlling for age, age-squared, hypertension, chronic heart failure, stroke, family history of coronary artery disease, diabetes, smoking, and drugs in a population without CVD to ensure that our results were not being driven by the fact that less-fit individuals may have CVD along with higher health care costs. The magnitude of association was even greater in the population without CVD, where individuals in the 100% or greater exercise capacity group had \$18,409 lower health care costs per year compared with individuals with less than 60% age-predicted exercise capacity ($P<.001$). The results were similar after excluding subjects who died within 1 year of follow-up.

Finally, we ran models in the full population after controlling for BMI in addition to the covariates controlled for in model 3, and the results were similar. Individuals in the 100% or greater exercise capacity group had \$13,810 lower health care costs per year compared with individuals in the less than 60% age-predicted exercise capacity group ($P<.001$). Although the overall population relationship thus did not change when controlling for BMI, we also examined the associations between exercise capacity and costs at different levels of BMI. We ran 3 separate regression models in the populations with BMI less than 25, 25 to 29.9, and 30 or greater. The results from models stratified by BMI are presented in Table 3. Although we did not find strong evidence of effect measure modification by BMI, cost savings were greatest in relation to exercise capacity among individuals with BMI between 25 and 29.9 and with BMI of 30 or greater.

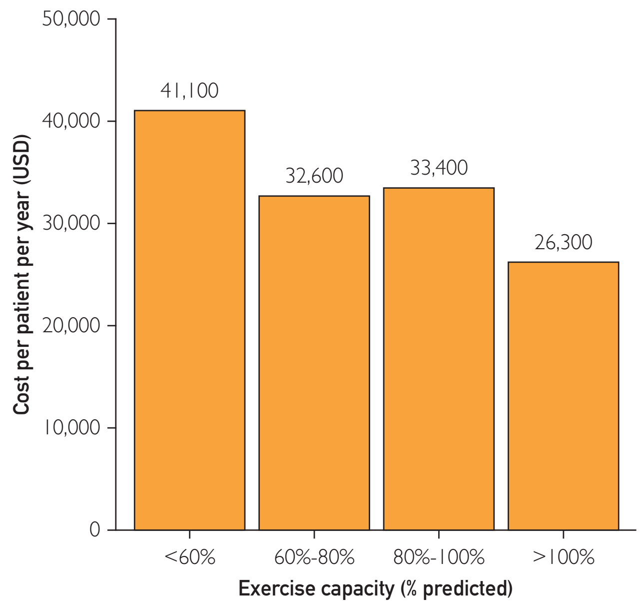

FIGURE 2. Mean annual costs (USD) by category of exercise capacity. USD = US dollars.

DISCUSSION

The current results demonstrate that level of fitness is inversely related to overall health care costs among veterans referred for exercise testing for clinical reasons. Costs were lower per MET achieved, and were not altered appreciably after excluding patients without CVD or who died within 1 year of follow-up. Among clinical, demographic, and other exercise data, reduced exercise capacity was a significant predictor of annualized

TABLE 1. Characteristics of the Sample by Categories of Age-Predicted Exercise Capacity (mean ± SD or %)

Characteristic	<60% (N=2004)	60%-<80% (N=3117)	80%-<100% (N=2684)	≥100% (N= 2137)
Demographic				
Age (y)	58±10	57±12	58±11	60±11
Sex (% males)	98	97	97	97
Clinical history and anthropometry				
Body mass index (kg/m^2)	29±5.9	29±5.3	29±5.0	28±4.6
Obesity (body mass index ≥30 kg/m^2) (%)	37	41	35	33
CVD (%)	51	51	42	26
Type 2 diabetes (%)	51	45	44	50
Heart failure (%)	3	1	1	1
Hypertension (%)	30	23	24	36
Currently smoking (%)	13	14	13	10
Medications (%)				
Statins	39	42	37	25
Beta blockers	39	38	33	22
ACE-I	29	26	23	22
Exercise test responses				
Resting heart rate (beats/min)	77±15	76±14	75±13	75±21
Resting systolic blood pressure (mm Hg)	135±26	133±20	131±19	129±17
Resting diastolic blood pressure (mm Hg)	80±12	80±11	81±11	81±11
Maximal heart rate (beats/min)	124±22	134±21	141±20	152±20
Maximal systolic blood pressure (mm Hg)	169±29	176±27	178±24	181±24
Maximal diastolic blood pressure (mm Hg)	84±15	84±14	85±23	85±32
Exercise capacity (METs)	4.4±1.2	6.6±1.4	8.3±1.6	10.8±2.4

ACE-I = angiotensin-converting enzyme inhibitor; CVD = cardiovascular disease; MET = metabolic equivalent.

costs, surpassed only by history of heart failure. The effects of fitness on health care costs were particularly evident among overweight and obese subjects. These results extend the many recent studies showing lower mortality among individuals with higher versus lower fitness[1,10-17] by demonstrating an inverse association between objective measures of fitness and directly determined annual health care costs. The present observations also support the recent case for "fitness as a vital sign"[12] and the concept that programs designed to increase worksite physical activity participation have a positive economic impact.[1,3-9] In addition, these results provide further impetus for health care providers and health organizations to recommend moderate physical activity to their patients to improve fitness.[1,4,12,17,28]

In recent years, many efforts have been directed toward the influence of *physical activity patterns* on health care costs. Most of these studies have centered on short-term (eg, <1-year) health promotion programs, and often have been employer-sponsored,

TABLE 2. Regression-Based Association of Total Cost Per Patient Per Year and Age-Predicted Exercise Capacity (Estimates in USD)[a,b]

		Model 1		Model 2		Model 3	
Exercise capacity	N	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
≥100%	2137	−14,847[c]	−19,778 to −9915	−14,836[c]	−19,794 to −9877	−14,730[c]	−19,747 to −9712
80%-<100%	2684	−7723[d]	−12,400 to −3047	−6574[d]	−11,262 to −1886	−6542[d]	−11,236 to −1848
60%-<80%	3117	−8548[c]	−13,089 to −4007	−7379[d]	−11,917 to −2842	−7381[d]	−11,919 to −2843
<60%	2004	Comparison group		Comparison group		Comparison group	

[a]CAD = coronary artery disease; CVD = cardiovascular disease; USD = US dollars.

[b]Model 1 controls for age and age-squared. Model 2 also controls for hypertension, chronic heart failure, stroke, family history of CAD, diabetes, smoking, and drugs. Model 3 also controls for prevalent CVD.

[c]*P*<.001.

[d]*P*<.01.

TABLE 3. Regression-Based Association of Total Cost Per Patient Per Year by Age-Predicted Exercise Capacity and Normal, Overweight, and Obese Categories (Estimates in USD)[a,b]

		BMI<25 kg/m^2 (N=1381)		BMI=25-29.9 kg/m^2 (N=5126)		BMI≥30 kg/m^2 (N=3484)	
Exercise capacity	N	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
≥100%	2137	−596	−13,244 to 12,053	−17,784[c]	−23,827 to −11,743	−19,509[d]	−34,486 to −4532
80%-<100%	2684	2261	−9412 to 13,665	−9324[e]	−15,282 to −3366	−7184	−17,615 to 3247
60%-<80%	3117	3209	−7930 to 14,348	−10,655[c]	−16,560 to −4750	−8351	−17,687 to 984
<60%	2,004	Comparison group		Comparison group		Comparison group	

[a]BMI = body mass index; CAD = coronary artery disease; CVD = cardiovascular disease; USD = US dollars.
[b]All models controlled for age, age-squared, hypertension, chronic heart failure, stroke, family history of CAD, diabetes, smoking, drugs, and prevalent CVD.
[c]$P<.001$.
[d]$P<.05$.
[e]$P<.01$.

which raises the potential for participation bias (eg, those who choose to participate are healthier than those who do not). Health care costs from these studies have typically been linked to Medicare claims data and thus the samples have been limited to comparatively older subjects. In addition, many of the estimates of population-level cost savings associated with higher physical activity patterns are based on hypothetical models and have therefore required assumptions for values on costs of services.[6,29,30] Moreover, private and Medicare costs and services are often poorly integrated, may vary considerably, and may not accurately reflect true health care costs.[31,32] Regardless of the source of cost data, these studies are consistent in demonstrating that health care expenditures are considerably lower among more active individuals.[3,4,6-9,33] The current study extends these findings on patterns of physical activity by relating direct health expenditures within a single, integrated health care system to objective measures of fitness.

There are a limited number of previous studies that have been performed relating health expenditures to exercise capacity. Mitchell et al[34] reported an inverse relation between fitness level (expressed in quartiles) and the number of office visits and hospitalizations over a 1-year period. Subjects who exhibited improved fitness on a second examination had a decreased number of hospital stays compared with those who remained classified as unfit. Although direct costs were not available in the Mitchell et al[34] study, the comparison between the fittest subjects and the least-fit amounted to a 53% reduction in costs based on overnight hospital stays, which is roughly similar to the overall reduction in direct costs between the most-fit and least-fit quartiles in the present study (Table 2). Weiss et al[35] quantified inpatient and outpatient costs after a maximal exercise test among veteran subjects, and reported that among clinical, demographic, and exercise test variables, exercise capacity was the strongest predictor of health care costs during the year subsequent to the exercise test. Costs were incrementally lower by an average of 5.4% per MET achieved. Most recently, Bachman et al[36] studied 19,571 individuals who underwent a baseline fitness assessment at a mean age of 49 years and who received Medicare coverage between 1999 and 2009. They observed that annual health care costs were significantly lower for participants with high midlife fitness compared with low midlife fitness ($7559 vs $12,811 in men, $P<.001$, and $6065 vs $10,029 in women, $P<.001$). The reductions in annual health care costs per MET achieved were 6.8% and 6.7% in men and women, respectively.

The gradient for the reduction in health care costs between fitness categories in the present study parallel those of Bachman et al.[36] Likewise, the reductions in annual costs per MET in the current study are similar to those of the Bachman et al[36] and Weiss et al[35] studies (≈5%-7%). The current results also extend those of Weiss et al[34] among Veterans in several respects. In the earlier study, costs were available for only 1 year (for patients tested between 1998 and 2000); the current study provides a broader evaluation of health-related expenses over 8 years. Thus, the present findings are less likely to be influenced by a given patient's inordinate costs or catastrophic event. The longer follow-up period permitted the removal of subjects who died within 1 year after testing, reducing the potential for reverse causality, as well as the potential influence of late-life illness on costs. In addition, the follow-up period facilitated the annualizing of costs, in which cost data were standardized to represent single years. The VA informatics have also evolved considerably over the last decade, allowing for better data accuracy and more complete follow-up. For example, the VA Information Resource Center, a resource designed to develop, optimize, and disseminate research-relevant information related to VA databases and information systems,[37] was not previously available.

The potential to lower health care costs provides an additional impetus for health care providers to promote physical activity in order to improve fitness. In addition to reduced rates of cardiovascular and all-cause mortality, higher levels of fitness are associated with reductions in the incidence of numerous chronic conditions.[1,2,10-17] Health care costs have risen in the United States and other Western countries disproportionately as a percentage of gross domestic product for more than 20 years, a trend that several economic analyses have concluded is unsustainable.[38,39] Given the growing proportion of Western populations that are sedentary[1,2,11,12,17] and the epidemic rise in obesity, diabetes, and other conditions in part related to sedentary lifestyles,[2,40] efforts by health care providers to increase physical activity therefore have the potential to have a marked impact on lowering health care costs by increasing fitness. Even modest improvements in fitness have important societal benefits that include improved quality of life, higher productivity, and reduced disability.[1,4,12,16,17] A significant societal cost not typically considered in the economic studies is that associated with reduced physical function, and fitness is an important determinant of loss of function.[41] The potential to reduce health care costs by improving fitness through physical activity is therefore an important public health message.

Study Limitations

Matching cost and treadmill data were available only for an 8-year period; as more cost data become available, a broader and longer-term assessment may provide greater insights into the association between health care costs and exercise capacity. We evaluated *overall* health costs during the period in which data were available; a larger data set would be required to stratify by type of costs (eg, inpatient/outpatient). Serial exercise tests would be valuable to determine the influence of *changes* in fitness on health care costs, but only a single evaluation was available. Fitness is a complex attribute that is influenced by many factors in addition to physical activity patterns, and it is not possible to account for all of them. For example, fitter subjects may have engaged in other healthy behaviors such as a better diet, regular physician visits, or better medication adherence. Cost models were derived from VA resources, and these may differ for other health care systems. Because we had limited power, our BMI-stratified results had wide CIs that overlap. We thus do not have data consistent with effect modification, but our data are suggestive that future work should examine whether fitness benefits for cost differ by the level of BMI. Finally, the sample comprised 98% males, and therefore the results may not apply to women.

CONCLUSION

The current results demonstrate that low cardiorespiratory fitness is associated with a significant financial burden on the health care system. In addition to its effect on health outcomes, improving fitness through regular physical activity should be encouraged for its potential to lower health care costs.

Abbreviations and Acronyms: **BMI** = body mass index; **CVD** = cardiovascular disease; **MET** = metabolic equivalent; **RVU** = relative value unit; **VA** = Veterans Administration

Potential Competing Interests: The authors report no competing interests.

Correspondence: Address to Jonathan Myers, PhD, VA Palo Alto Health Care System, Cardiology 111C, 3801 Miranda Ave, Palo Alto, CA 94304 (drj993@aol.com).

REFERENCES

1. Myers J, McAuley P, Lavie CJ, Despres JP, Arena R, Kokkinos P. Physical activity and cardiorespiratory fitness as major markers of cardiovascular risk: their independent and interwoven importance to health status. *Prog Cardiovasc Dis*. 2015;57(4):306-314.
2. Booth FW, Roberts CK, Laye MJ. Lack of exercise is a major cause of chronic diseases. *Compr Physiol*. 2012;2(2):1143-1211.

3. Ding D, Lawson KD, Kolbe-Alexander TL, et al; Lancet Physical Activity Series 2 Executive Committee. The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *Lancet*. 2016;388(10051):1311-1324.
4. Cahalin LP, Myers J, Kaminsky L, et al. Current trends in reducing cardiovascular risk factors in the United States: focus on worksite health and wellness. *Prog Cardiovasc Dis*. 2014; 56(5):476-483.
5. Barr VJ, Robinson S, Marin-Link B, et al. The expanded Chronic Care Model: an integration of concepts and strategies from population health promotion and the Chronic Care Model. *Hosp Q*. 2003;7(1):73-82.
6. Carlson SA, Fulton JE, Pratt M, Yang Z, Adams EK. Inadequate physical activity and health care expenditures in the United States. *Prog Cardiovasc Dis*. 2015;57(4):315-323.
7. Burton WN, Chen CY, Li X, Schultz AB, Abrahamsson H. The association of self-reported employee physical activity with metabolic syndrome, health care costs, absenteeism, and presenteeism. *J Occup Environ Med*. 2014;56(9):919-926.
8. Anderson LH, Martinson BC, Crain AL, et al. Health care changes associated with physical inactivity, overweight, and obesity. *Prev Chronic Dis*. 2005;2(4):A09.
9. Rosenberg D, Cook A, Gell N, Lozano P, Grothaus L, Arterburn D. Relationships between sitting time and health indicators, costs, and utilization in older adults. *Prev Med Rep*. 2015;2:247-249.
10. Kodama S, Saito K, Tanaka S, et al. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis. *JAMA*. 2009;301(19):2024-2035.
11. Després JP. Physical activity, sedentary behaviours, and cardiovascular health: when will cardiorespiratory fitness become a vital sign? *Can J Cardiol*. 2016;32(4):505-513.
12. Ross R, Blair SN, Arena R, et al; American Heart Association Physical Activity Committee of the Council on Lifestyle and Cardiometabolic Health; Council on Clinical Cardiology; Council on Epidemiology and Prevention; Council on Cardiovascular and Stroke Nursing; Council on Functional Genomics and Translational Biology; Stroke Council. Importance of assessing cardiorespiratory fitness in clinical practice: a case for fitness as a clinical vital sign. An American Heart Association Scientific Statement from the Committee on Physical Activity and the Council on Lifestyle and cardiometabolic Health. *Circulation*. 2016;134(24):e653-e699.
13. Kokkinos PF, Faselis C, Myers J, et al. Cardiorespiratory fitness and incidence of major adverse cardiovascular events in US veterans: a cohort study. *Mayo Clin Proc*. 2017;92(1):39-48.
14. Nauman J, Nes BM, Lavie CJ. Prediction of cardiovascular mortality by estimated cardiorespiratory fitness independent of traditional risk factors: the HUNT study. *Mayo Clin Proc*. 2017;92(2):218-227.
15. Jimenez-Pavon D, Artero EG, Lee DC, et al. Cardiorespiratory fitness and risk of sudden cardiac death in men and women in the United States. *Mayo Clin Proc*. 2016;91(7):849-857.
16. Kokkinos P, Myers J. Physical activity: clinical outcomes and applications. *Circulation*. 2010;122(16):1637-1648.
17. Kaminsky LA, Arena R, Beckie TM, et al; American Heart Association Advocacy Coordinating Committee, Council on Clinical Cardiology, and Council on Nutrition, Physical Activity and Metabolism. The importance of cardiorespiratory fitness in the United States: the need for a national registry. A Policy Statement from the American Heart Association. *Circulation*. 2013;127(5):652-662.
18. Defina LF, Haskell WL, Willis BL, et al. Physical activity versus cardiorespiratory fitness: two (partly) distinct components of cardiovascular health? *Prog Cardiovasc Dis*. 2015;57(4):324-329.
19. EU Working Group "Sport and Health". EU Physical Activity Guidelines. 2008. Available at: http://ec.europa.eu/assets/eac/sport/library/policy_documents/eu-physical-activity-guidelines-2008_en.pdf. Accessed November 1, 2017.
20. Haskell WL, Lee IM, Pate RR, et al; American College of Sports Medicine; American Heart Association. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*. 2007;116(9):1081-1093.
21. Helmerhorst HJ, Brage S, Warren J, Besson H, Ekelund U. A systematic review of reliability and objective criterion-related validity of physical activity questionnaires. *Int J Behav Nutr Phys Act*. 2012;9:103.
22. Ainsworth B, Cahalin L, Buman M, Ross R. The current state of physical activity assessment tools. *Prog Cardiovasc Dis*. 2015;57(4):387-395.
23. Page WF, Mahan CM, Kang HK. Vital status ascertainment through the files of the Department of Veterans Affairs and the Social Security Administration. *Ann Epidemiol*. 1996;6(2):102-109.
24. Shue P, Froelicher VF. EXTRA: an expert system for exercise test reporting. *J Non-Invasive Testing*. 1998;II-4:21-27.
25. Myers J, Buchanan N, Walsh D, et al. Comparison of the ramp versus standard exercise protocols. *J Am Coll Cardiol*. 1991;17(6):1334-1342.
26. Glass S, Dwyer GB. *ACSM's Metabolic Equations Handbook*. Philadelphia: Lippincott, Williams & Wilkins; 2007.
27. Morris CK, Myers J, Froelicher VF, Kawaguchi T, Ueshima K, Hideg A. Nomogram based on metabolic equivalents and age for assessing aerobic capacity in men. *J Am Coll Cardiol*. 1993;22(1):175-182.
28. Berra K, Rippe J, Manson JE. Making physical activity counseling a priority in clinical practice: the time for action is now. *JAMA*. 2015;314(24):2617-2618.
29. Leigh JP, Hubert HB, Romano PS. Lifestyle risk factors predict healthcare costs in an aging cohort. *Am J Prev Med*. 2005; 29(5):379-387.
30. Jones TF, Eatton CB. Cost-benefit analysis of walking to prevent coronary heart disease. *Arch Fam Med*. 1994;3(8):705-710.
31. Romley JA, Axeen S, Lakdawalla DN, Chernew ME, Bhattacharya J, Goldman DP. The relationship between commercial health care prices and Medicare spending and utilization. *Health Serv Res*. 2015;50(3):883-896.
32. Archer D, Marmor T. Medicare and commercial health insurance: the fundamental difference. *Health Affairs Blog*. February 15, 2012.
33. Fonarow GC, Calitz C, Arena R, et al; American Heart Association. Workplace wellness recognition for optimizing workplace health: a presidential advisory from the American Heart Association. *Circulation*. 2015;131(20):e480-e497.
34. Mitchell TL, Gibbons LW, Devers SM, Earnest CP. Effects of cardiorespiratory fitness on healthcare utilization. *Med Sci Sports Exerc*. 2004;36(12):2088-2092.
35. Weiss JP, Froelicher VF, Myers JN, Heidenreich PA. Health care costs and exercise capacity. *Chest*. 2004;126(2):608-613.
36. Bachman JM, DeFina LF, Franzini L, et al. Cardiorespiratory fitness in middle age and health care costs in later life. *J Am Coll Cardiol*. 2015;66(17):1876-1885.
37. What is driving U.S. health care spending? America's unsustainable health care cost growth. A report from the Robert Wood Johnson Foundation, 2012. Available at: https://www.rwjf.org/content/dam/farm/reports/issue_briefs/2012/rwjf401339. Accessed October 29, 2017.
38. Organization for Economic Cooperation and Development (OECD). Healthcare costs unsustainable in advanced economies without reform. Available at: http://www.oecd.org/health/healthcarecostsunsustainableinadvancedeconomieswithoutreform.htm. Accessed March 14, 2017.
39. Social Security Advisory Board. The unsustainable cost of health care. 2009. Available at: http://ssab.gov/portals/0/documents/TheUnsustainableCostofHealthCare_graphics.pdf. Accessed March 15, 2017.
40. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. *Appl Physiol Nutr Metab*. 2010;35(6):725-740.
41. Forman D, Arena R, Boxer R, et al; American Heart Association Council on Clinical Cardiology; Council on Cardiovascular and Stroke Nursing; Council on Quality of Care and Outcomes Research; and Stroke Council. Prioritizing functional capacity as a principal endpoint for therapies oriented to older adults with cardiovascular disease: a scientific statement for healthcare professionals from the American Heart Association. *Circulation*. 2017;136(16):e894-e918.