Journal of Physical Activity and Health 2006, 3, S6-S19

Physical Activity and Changes in Health Care Costs in Late Middle Age

Tatiana Andreyeva and Roland Sturm

Background: Physical activity has clear health benefits but there remains uncertainty about how it affects health care costs. *Objective*: To examine how physical activity is associated with changes in health expenditure for a national sample age 54 to 69 y, and estimate how this association varies across people with different chronic diseases and health behaviors. *Methods*: Data were from the Health and Retirement Study, a national longitudinal survey of late middle age Americans. *Results*: Correcting for baseline differences in active and inactive groups, physical activity was associated with reduced health care costs of about 7% over 2 y (or $483 annually). *Conclusions*: Regular physical activity in late middle age may lower health expenditure over time, and the effect is likely to be more pronounced for the obese, smokers, and individuals with some baseline health problems. While substantially large for the health care system, our estimates are much smaller than health-unadjusted comparisons or cross-sectional effects.

***Key Words**:* health behavior, medical expenditures

The health benefits of regular physical activity are well established, which suggests that having a more physically active population could lower health care costs. The magnitudes of such an effect remain unclear, and few direct estimates are available. The best known estimates to date rely on assessments of health effects attributing shares of average expenditure for specific diseases.[1-3] Other research compares active and inactive persons at one point in time (cross-sectionally), suggesting that physically inactive people have health care expenditures that are on average about one-third above medical costs of active individuals, or a difference of $330 in 1987 (which would correspond to $787 in 2004).[4] A cross-sectional approach is problematic because it cannot correct for selection bias, that is poor underlying health can simultaneously cause both high health care costs and physical inactivity. Prospective longitudinal data on health care costs can reduce selection bias, but longitudinal estimates are so far available only for members in a single health plan or for selected employers rather than for a national sample.[5-8]

For health plans trying to manage diseases, it is also important to know how physical activity may moderate future health care costs among individuals with pre-existing conditions like hypertension, heart disease, or health risk behaviors such as

Andreyeva is with the Pardee RAND Graduate School, Santa Monica, CA 90407-2138. Sturm is with the RAND Corporation, Santa Monica, CA 90407-2138.

obesity or smoking. Physical activity may very well have differential effects across these groups but no comparative data are available for specific health conditions other than for patients with arthritis and with depressive symptoms.[9, 10] Comparing the effects of physical activity across subpopulations would help health plans to more effectively target health promotion resources.

This study used longitudinal data from a nationally representative sample of individuals age 54 to 69. Health care costs were measured over 2 y following an assessment of regular physical activity (we show the annual average), and we adjusted for baseline socio-demographics, health status, health care costs, and health risk behaviors. We also stratified the analysis by baseline medical condition and health behavior to assess whether physical activity had differential effects for the subgroups of individuals with specific chronic diseases (e.g., diabetes) or health behaviors (e.g., smokers).

Data and Methods

The HRS is a national biennial longitudinal survey of individuals ages 51 to 61 at baseline (1992) and their spouses regardless of age, designed to study the issues of retirement, health insurance, saving, and economic well-being of the population approaching the retirement age. The survey over-sampled Hispanics, blacks, and Florida residents, and provided weighting variables to make it representative of the community-based population nationwide.[11] The initial 1992 panel included 9,824 age-eligible primary respondents at baseline. Follow-up surveys were conducted by telephone interviews in 1994, 1996, 1998, 2000, and 2002 with proxy interviews after death. Data on total health care costs were not collected in 1992 to 1994, and we therefore used the last four waves, which included 30,834 observations on 8,788 individuals.

The study collected information about demographics, family structure, health, cognition, functional limitations, health care utilization and expenditures, income, employment status and history, housing, insurance, and expectations of the survey participants. The most important advantages of the HRS data are its longitudinal nature and the focus on the late middle age group—a population at higher risk for developing chronic health problems and functional limitations than all adults. More information about the survey and its design is available on the HRS website (http://hrsonline.isr.umich.edu).

We used health care expenditure data from the HRS files developed by RAND (available to registered HRS users at http://hrsonline.isr.umich.edu/data/index.html). As the original HRS medical expenditure data were limited to bracket information on medical spending, and continuous values were derived in a complex imputation process, we compared the HRS data to the expenditure data from other national sources. We found that our HRS average expenditures were comparable with estimates for the same age group from the Medical Expenditure Panel Survey (MEPS), accounting for the fact that HRS used total health care costs, whereas MEPS excluded over-the-counter medications or alternative care sources.[12]

We imposed several sample restrictions. First, we excluded individuals with functional limitations based on self-reported difficulty with performing any of the five different tasks in the activities of daily living (ADL): bathing, eating, dressing, walking across a room, and getting in or out of bed (11% of the original sample).

The idea of this exclusion was to mitigate possible selection bias by excluding people whose physical activity is limited because of a pre-existing health condition. Individuals with ADL limitations were on average more than half less likely to engage in vigorous physical activity than the rest of the sample, and had substantially higher health care costs, supporting our assumption that selection bias would be a significant problem had we kept this group in the analysis. Second, we left out individuals when they did not have expenditure data between two consecutive periods (30% of the original sample). We required expenditure data at consecutive periods because it allowed us to identify a change in health care costs over time. This group was slightly less physically active and older than the rest of the sample. Some additional participants were lost to follow-up or due to missing data on covariates (around 5% of the original sample), yet this group was not significantly different from the sample on either physical activity or health expenditure measures. The final exclusion (0.6% of the original sample) was for data problems such as discrepancies in medical spending and utilization data (e.g., reported health care utilization but zero health care expenditures). After all exclusions, 7,338 individuals remained eligible for analysis, contributing 17,871 observations.

Measures

Dependent Variables

The main dependent variable was average annual health care costs, inflated to 2004 dollars using the medical care component of the consumer price index. We used total rather than out-of-pocket health care costs because in our age group the majority of individuals had insurance coverage through their employer or Medicare, and out-of-pocket medical costs would not give a complete picture of expenditures related to their health care. We assessed total health care costs over 2 y after measuring physical activity, health status, and other covariates. We included baseline health care costs as a covariate. Although expressed in absolute dollars, including baseline expenditures made the model equivalent to analyzing the *change in health care expenditures* as the dependent variable.

Explanatory Variables

The primary explanatory variable was a measure of regular vigorous physical activity that was based on a "yes-no" response to the question: "On average over the last 12 months have you participated in vigorous physical activity or exercise three times a week or more? By vigorous physical activity, we mean things like sports, heavy housework, or a job that involves physical labor." The survey asked initially more comprehensive questions about the types of physical activity, including light physical activity, vigorous physical activity, doing heavy housework, and the frequencies in each of these activity categories. Unfortunately, only the vigorous activity question was available in the survey years that collected data on total health care costs (1996 to 2002).

We adjusted for differences in baseline health using indicators for eight self-reported doctor-diagnosed chronic diseases, as assessed from responses to the question whether or not a doctor ever told the respondent that he/she had the conditions.

These ever-experienced chronic conditions were arthritis/rheumatism, diabetes, cardiovascular disease, hypertension, lung disease except asthma, cancer except skin cancer, nervous/psychiatric problems, and stroke. We also analyzed the model specifications with alternative measures of baseline health, such as an indicator of poor health, and a subset of selected health conditions to see how sensitive results were to partial adjustments for baseline differences.

We attempted to separate the effect of physical activity on changes in health care expenditure from the confounding effect of obesity by either including a weight group or stratifying by relative weight, distinguishing underweight (BMI < 18.5), normal weight (BMI: 18.5 to 24.9), overweight (BMI: 25.0 to 29.9), moderate obesity (BMI: 30.0 to 34.9), severe obesity (BMI: 35.0 to 39.9), and extreme obesity (BMI: ≥ 40.0). There are large differences across these groups in health care utilization and costs.[13]

Other explanatory variables were baseline health care expenditure, gender, age (age in years and the second order polynomial of age), race/ethnicity (black, Hispanic, other; white is the reference), insurance status (public, private; uninsured is the reference), marital status (married, divorced/separated, widowed; never married is the reference), education (college, some college, high school; less than high school is the reference), annual total household income on the log scale (inflated to 2004 dollars using the consumer price index), census region, and survey wave dummies. To account for the effects of behavioral risk factors on changes in health care costs, we used tobacco smoking status (current smoker and past smoker) and alcohol use (based on current dietary guidelines, heavy drinking was defined as more than on average 1 drink/day for women and all individuals ages 65 and above and greater than 2 drinks/day for men below age 65; moderate drinking was defined as an average of 1 drink/day or less for women and all individuals of ages below 65 and an average of 2 drinks or less per day for men ages 65 and below).[14-15] Table 1 reports descriptive statistics of the study participants by physical activity status.

The timing design of our model was such that we measured all explanatory variables in the period of physical activity assessment, while the main outcome was average annual health care costs 2 y after baseline. As a sensitivity analysis, we also analyzed average annual health care costs 4 and 6 y after baseline.

Methods

We pooled the HRS data across the four waves with available total medical expenditure to increase the sample size. All analyses accounted for the complex sampling design of the HRS using information on the survey weights, strata, and primary sampling units as implemented in survey data estimation commands in Stata 8.0 (Stata Corp., College Station, TX). The Huber/White nonparameteric correction was used to adjust standard errors for repeated observations on the same individuals.

The dependent variable (health care expenditure) was regressed using least squares regression on health care expenditure, physical activity, health status, and other covariates in the previous survey period. There was no advantage of using a two-part model in our data because the large majority in the sample (about 96%) used health care (multi-part models improve precision by separating users from nonusers).

Based on specification tests for interactions between physical activity, health

Table 1 Characteristics of Study Participants by Physical Activity Status

Characteristic		Study sample (N = 17,871) Sample size	Physically active[a]	Physically inactive
Physical activity	Participated in vigorous physical activity 3 or more times/week	9,407	53.0	47.0
Chronic health conditions	Arthritis	8,392	43.5	49.7**
	Back pain	3,202	23.7	30.3**
	Cancer	1,388	7.3	8.5*
	Diabetes	2,110	8.8	13.0**
	Heart disease	2,560	13.1	15.6**
	Hypertension	7,379	35.4	44.5**
	Lung disease	1,102	4.6	7.9**
	Psychiatric problems	1,667	7.1	11.8**
	Stroke	510	1.9	3.4**
Gender	Female	9,561	48.6	56.9**
Age (y)	Years		61.1	61.2
Race/ethnicity	White	13,679	85.6	81.7**
	Black	2,543	7.4	9.5**
	Hispanic	1,061	4.0	5.3**
	Other	588	3.0	3.5
Education	College	3,493	21.8	20.9
	Less than college	3,589	21.5	20.0
	High school	6,916	39.3	38.0
	Less than high school	3,873	17.4	21.0**
Insurance	Private	11,662	68.7	64.7**
	Public	5,252	26.6	31.2**
	Uninsured	2,962	16.3	15.1
Marital status	Married/partnership	13,462	78.2	71.9**
	Divorced	2,101	10.6	13.5**
	Widowed	1,734	8.3	10.6**
Smoking	Current smoking	3,358	16.6	20.9**
	Past smoking	7,566	44.7	41.0**
Alcohol consumption	Heavy drinking	1,214	7.6	7.2
	Moderate drinking	5,014	32.6	27.0**
Body mass index class	Underweight (BMI < 18.5)	152	0.6	1.1**
	Normal weight (BMI: 18.5-24.9)	5,593	36.5	28.2**
	Overweight (BMI: 25-29.9)	7,535	43.0	40.7*
	Moderate obesity (BMI: 30-34.9)	3,375	15.7	21.1**
	Severe obesity (BMI: 35-39.9)	880	3.3	6.2**
	Extreme obesity (BMI ≥ 40)	336	0.9	2.7**
Family income ($)	Per year in 2004 dollars		78,782	68,664**
Total health care costs ($)	Per year in 2004 dollars		4,557	6,462**

Note. [a] Participated in vigorous physical activity like sports, heavy housework, or a job that involves physical labor 3 times a week or more over the last 12 months.

Data are presented as percentages unless otherwise indicated. Means adjusted for the complex survey design. P-values are for comparison of means between physically active and inactive individuals.

*$P < 0.05$; **$P < 0.01$.

conditions, and socio-demographic covariates, we did not include any interaction terms. We used gender-specific linear regression to estimate differential effects of physical activity by gender, but all other analyses were based on estimation for women and men combined. We also conducted stratified analyses for individuals ages 65 or older and under 65, as well as race/ethnicity specific estimation, but these analyses were limited by small sample sizes of some groups (e.g., Hispanics, age 65 and above).

Another series of estimation analyses was based on the variation in pre-existing health conditions and health risks. First, we compared how changes in health care costs differed by physical activity status among people with a certain chronic condition. We considered all reported medical conditions regardless of whether links with physical activity have been established: arthritis, cancer, cardiovascular disease, diabetes, hypertension, lung disease, psychological problems, stroke, and back problems.

The next sub-sample analysis compared changes in health care expenditures related to physical activity among: 1) current smokers, current or past smokers, and people who never smoked, and 2) obese (as defined by BMI of 30 and above) and non-obese individuals. A separate analysis of heavy drinkers was limited by sample size. Finally, we checked the robustness of results to the exclusion of outliers in health care expenditures (top 1% of health expenditure data in a corresponding wave). While some extremely high cost observations (and there were some in excess of $500,000 per year) correctly reflected expenditures, others were the result of data entry errors. Unfortunately, these two situations were often indistinguishable.

Results

Regular Vigorous Physical Activity

Before we applied all exclusion criteria to our analytic sample (e.g., functionally limited people), about 48% of the 1996 to 2002 HRS sample reported being vigorously active. This is similar to the 43% among adults ages 55 to 64 that satisfied guidelines for *moderate* physical activity in the median state in the 2003 Behavioral Risk Factor Surveillance System (BRFSS), and much higher than the 19% who satisfied the vigorous activity guidelines among 55 to 64 year-olds in the 2003 BRFSS.[16] In the European analogue of HRS, the 2004 Survey of Health, Ageing and Retirement in Europe (SHARE), 38% respondents of the equivalent age group reported participation in similarly-defined vigorous physical activity (sports, heavy housework, or physical labor) more than once a week, although the estimates varied from 29% in Italy to 51% in Denmark.[17]

The main reason for such a high prevalence of regular vigorous physical activity in the HRS sample is that the 1996 to 2002 surveys included occupational physical activity in the measure. This seemed to almost double estimates of reported vigorous physical activity because in 1992 to 1994, when physical labor was not included in the vigorous activity question, only about 20% of all respondents indicated regular participation in "vigorous physical exercise or sports such as aerobics, running, swimming, or bicycling."

The prevalence of regular physical activity was significantly lower for individuals with any of the eight chronic conditions (Table 1), suggesting that adjustment for differences in baseline health would reduce selection or reverse causation bias of health status that affected both health care expenditure and physical activity (although we can never be sure that we have eliminated it).

Health Care Expenditures

Table 2 reports descriptive (unadjusted) and predicted (adjusted) average annual health care expenditures by physical activity status among individuals ages 54 to 69. Lack of regular physical activity was associated with higher health care costs both in a cross-sectional and longitudinal setting. Descriptively, the difference in health care costs related to the same year physical activity was 32.9% or $1,879 in 2004 dollars ($P < 0.01$), whereas a change in health care costs 2 y from the assessment of physical activity was about 29.6% or $1,784 ($P < 0.01$). These descriptive estimates included the effects of social and health differences between active and inactive groups.

After adjustment for baseline health care spending, socio-demographics, and potential behavioral confounders, but not for baseline health, the difference in prospective health care costs related to physical activity declined to 13.2%, or

Table 2 Health Care Costs in 2004 Dollars Among Individuals Ages 54 to 69 by Physical Activity Status

	Cross-sectional	Longitudinal (two years from assessment of physical activity)		
	Unadjusted means[1] (95% CI)	Unadjusted means[1] (95% CI)	Adjusted means baseline health not included[2] (95% CI)	Adjusted means baseline health included[2] (95% CI)
No regular physical activity	7,593	7,802	7,309	7,112
Regular physical activity	5,714	6,018	6,455	6,629
Dollar difference for physical inactivity	1,879** (1,216 to 2,542)	1,784** (1,077 to 2,490)	854* (145 to 1,562)	483 (-221 to 1,187)
% difference	32.9%	29.6%	13.2%	7.3%

Note. Regular physical activity is participation in vigorous physical activity like sports, heavy housework, or a job that involves physical labor 3 times a week or more over the last 12 months. CI = estimates of the confidence intervals. Data are corrected for the complex survey design.

[1]Estimates of health expenditure are for the period of 1998-2002; physical activity is for 1998-2002 (cross-sectional) and 1996-2000 (longitudinal). There are differences in the expenditure data due to missing values for some individuals across waves.

[2]Predicted average health care costs have been adjusted for baseline health care costs, age, gender, race/ethnicity, family income, education, insurance and marital status, census region, survey wave, body weight class, smoking, and drinking. Baseline health is assessed as a set of eight chronic conditions.

* $P < 0.05$; ** $P < 0.01$. P-values are for a comparison of means between physically active and inactive individuals.

$854 ($P < 0.05$). Our most comprehensive adjustment was to control for observed differences in baseline health—potential confounders of the ability to be physically active and contributors to selection bias. With adjustment for baseline health, the effects of physical activity declined to 7.3% or $483. While this magnitude was substantively important, the effect was no longer statistically significant.

Gender differences in the predicted changes of health care costs by physical activity are reported in Table 3. The presented results were drawn from models that adjusted for baseline health. The absolute dollar differences between active and inactive subpopulations were almost identical for men and women, although, due to lower average costs for women, the relative difference related to inactivity was larger for women (8.5%) than men (7.8%). The confidence intervals were wide, and there was no significant difference between men and women.

Table 3 Health Care Costs* in 2004 Dollars by Physical Activity Status: Gender Differences

	Males (*N* = 8,310)	Females (*N* = 9,561)
No regular physical activity	7,390	6,916
Regular physical activity	6,858	6,373
Dollar difference for physical inactivity	532 (-503 to 1,568)	543 (-446 to 1,533)
% difference	7.8%	8.5%

Note. Regular physical activity is participation in vigorous physical activity like sports, heavy housework, or a job that involves physical labor 3 times a week or more over the last 12 months.

CI = estimates of the confidence intervals. Data are corrected for the complex survey design.

*Predicted average health care costs have been adjusted for baseline health care costs, chronic health conditions, age, gender, race/ethnicity, family income, education, insurance and marital status, census region, survey wave, body weight class, smoking, and drinking.

The results from sub-sample analyses for health behaviors are reported in Table 4. Because sample sizes were smaller for the subgroup comparisons in Tables 3 and 4 compared to Table 2, confidence intervals became even wider, and most of the differences were not statistically significant. The point estimate of changes in health care costs related to physical activity was particularly large for obese individuals who had on average $745 or about 10% lower future health care costs if they regularly engaged in vigorous physical activity. In absolute magnitudes, this was much larger than the health care cost difference by physical activity in the non-obese population ($473). Similar to the obese group, we found larger than average effects in the population of current smokers ($523), as well as in the combined sample of current and previous regular smokers ($648). Those savings were more than twice the effect of physical activity among never smokers ($250).

Stratifying by pre-existing health condition, we found higher future health care expenditures related to baseline physical inactivity across most chronic conditions examined (Table 5). Estimated differences were particularly large for back pain

Table 4 Health Care Costs* in 2004 Dollars by Physical Activity Status: Differences by Health Risk

	Obese (*N* = 4,591)	Non-obese (*N* = 13,280)	Current smokers (*N* = 3,358)	Past/ current smokers (*N* = 10,924)	Never smoked (*N* = 6,947)
No regular physical activity	8,368	6,732	7,786	7,975	5,743
Regular physical activity	7,623	6,259	7,264	7,327	5,493
Dollar difference for physical inactivity	745 (-876 to 2,365)	473 (-288 to 1,234)	523 (-1,150 to 2,195)	648 (-324 to 1,619)	250 (-758 to 1,259)
% difference	9.8%	7.6%	7.2%	8.8%	4.5%

Note. Regular physical activity is participation in vigorous physical activity like sports, heavy housework, or a job that involves physical labor 3 times a week or more over the last 12 months. CI = estimates of the confidence intervals. Data are corrected for the complex survey design.

*Predicted average health care costs have been adjusted for baseline health care costs, chronic health conditions, age, gender, race/ethnicity, family income, education, insurance and marital status, census region, survey wave, body weight class, smoking, and drinking.

Table 5 Health Care Costs* in 2004 Dollars by Physical Activity Status: Differences by Pre-Existing Health Condition

	Arthritis (*N* = 8,392)	Back pain (*N* = 3,202)	Diabetes (*N* = 2,110)	Heart disease (*N* = 2,560)	Hypertension (*N* = 7,379)
No regular physical activity	8,303	9,681	11,437	13,256	8,436
Regular physical activity	7,866	8,122	12,014	10,959	8,655
Dollar difference for physical inactivity	437 (-663 to 1,537)	1,559* (-236 to 3,353)	-577 (-4,038 to 2,885)	2,297* (-442 to 5,035)	-219 (-1,452 to 1,014)
% difference	5.6%	19.2%	-4.8%	20.9%	-2.5%

Note. Regular physical activity is participation in vigorous physical activity like sports, heavy housework, or a job that involves physical labor 3 times a week or more over the last 12 months. CI = estimates of the confidence intervals. Data are corrected for the complex survey design.

*Predicted average health care costs have been adjusted for baseline health care costs, chronic health conditions, age, gender, race/ethnicity, family income, education, insurance and marital status, census region, survey wave, body weight class, smoking, and drinking.

and heart disease, and smaller than average effects for diabetes, hypertension, and arthritis. The largest difference between 2-y health care expenditures of physically active and inactive individuals was predicted for people with doctor-diagnosed cardiovascular disease, on average $2,297 or 21% ($P < 0.10$). The effect of people with back pain was on average $1,559 or 19% ($P < 0.10$). We were concerned that such large effect sizes reflected differences in the severity of the underlying condition rather than unbiased effects of physical activity. The sample sizes for people with stroke, lung disease, cancer, and psychiatric problems were too small for a meaningful analysis, and therefore we did not report their results.

The effect of physical activity on annual health care costs 4 y after baseline was similar in magnitude to the changes over 2 y. Descriptively, the difference in health care costs according to baseline physical activity was 29% ($P < 0.01$) 4 y from baseline, and 16% ($P < 0.10$) 6 y after the assessment of physical activity. Multivariate regression analysis predicted a difference in 4-y health care costs of 16% ($P < 0.05$) without adjustment for baseline health, and 10% in the model that included eight chronic diseases as controls for health status. The magnitude of the physical activity effects for 6-y health care costs was smaller than changes for the 2-y and 4-y period (10% without health adjustment and 5% with health controls, insignificant in any model). One explanation for these results is a more limited sample with the expenditure data in the later periods of the survey (about 60% of observations from the primary sample had expenditure data over 4 y and less than 30% were available to estimate health care costs 6 y from baseline). This also precluded reliable estimation of 4- and 6-y health expenditure data for many sub-sample analyses.

Table 6 presents estimates from sensitivity analyses. We explored the sensitivity of estimates with alternative measures of baseline health using an indicator for self-reported poor/fair health status and a subset of chronic conditions, such as heart disease and diabetes. The model with poor health status predicted a difference of $418 (6.3%) in health care costs of physically active and inactive people. When we used baseline diabetes and heart disease as proxies of health status, we found a significant change in health care costs related to physical activity of an average $728 or 11%. This was only slightly lower than the effects of physical activity predicted by models without adjustment for baseline health. Finally, we tested the robustness of our estimates to the exclusion of outliers. The exclusion of bottom 1% and top 1% health care costs, as well as only top 1%, left the magnitude of the effects unchanged at about 7 to 8%.

Table 6 Health Care Costs* in 2004 Dollars by Physical Activity Status: Sensitivity Analysis

	Self-reported poor health as control for baseline health (*N* = 17,868)	Heart disease and diabetes as control for baseline health (*N* = 17,871)	1% top excluded (*N* = 17,731)	1% top and 1% bottom excluded (*N* = 17,065)
No regular physical activity	7,077	7,242	6,879	6,978
Regular physical activity	6,659	6,514	6,369	6,519
Dollar difference for physical inactivity	418 (-263 to 1,098)	728[2] (24 to 1,432)	510 (-135 to 1,155)	459 (-201 to 1,119)
% difference	6.3%	11.2%	8.0%	7.1%

Note. Regular physical activity is participation in vigorous physical activity like sports, heavy housework, or a job that involves physical labor 3 times a week or more over the last 12 months. CI = estimates of the confidence intervals. Data are corrected for the complex survey design.

*Predicted average health care costs have been adjusted for baseline health care costs, chronic health conditions, age, gender, race/ethnicity, family income, education, insurance and marital status, census region, survey wave, body weight class, smoking, and drinking.

$P < 0.05$. *P*-values are for a comparison of means between physically active and inactive individuals.

Discussion

This study analyzed prospectively how physical activity was associated with changes in health care expenditures in a nationally representative sample of adults age 54 to 69 y. This age group is at high risk of increased health care expenditures because of the onset of chronic medical problems that could be delayed or prevented with physical activity. We found that among adults ages 54 to 69 without functional limitations lack of regular physical activity was associated with an average 7% increase in total health care costs over 2 y, or $483 in 2004 dollars, although a 95% confidence interval included the possibility of no effect. The absolute magnitude of the effect was similar for men and women.

Changes in health care costs related to physical activity varied substantially across people with different health risks or chronic conditions. This information remains hidden in the average effects of physical activity, but would be important for health plans targeting health promotion resources. Stratifying by risk behavior, we found that physical activity was particularly beneficial to lower health care costs of smokers and obese individuals. Regular physical activity might help reduce some of the excess health care costs in the obese population, although even physically active obese individuals still had on average 13% (almost $900) higher medical costs than non-obese physically inactive individuals. Results for specific chronic conditions showed very large positive effects of physical activity on people with back pain or heart disease, although we were concerned that the large estimates reflected some unadjusted severity of baseline conditions.

When replicating the approach of prior cross-sectional analysis, we found much larger absolute differences in health care costs by physical activity for this age group: $1,879 vs. estimates published for the full age range of $787 in 2004 dollars ($330 in 1987 dollars).[4] This is not surprising, as late middle age adults are at particularly high risk for developing chronic health problems, and experience increases in health care costs over time. Higher cross-sectional effects associated with physical activity in our sample may also reflect health benefits associated with physical activity that have been accumulated over a longer lifespan.

Observational cross-sectional data are more likely to reflect the effects of reverse causality from health status to physical activity. Individuals hospitalized for prolonged periods have extremely high health care costs, yet by definition they are also physically inactive during that period. Because physical activity patterns can change rapidly, cross-sectional estimates are much more vulnerable to selection bias than corresponding estimates of the effects of obesity, which tends to reflect a more long-term individual characteristic related to genetics, diet, and physical activity. Biases from poor health are also more likely to operate the opposite way, i.e., underestimate the effects of obesity in cross-sectional data, in that individuals that had been diagnosed with diabetes, hypertension, or heart disease in the past may start to lose weight as part of the treatment.

When only partially controlling for baseline health, as some previous prospective studies did, we found larger effects. For example, a study of one group of health plan enrollees ages 40 or older suggested that *each* active day per week is associated with 4.7% lower median health care charges over 18 months from an assessment of physical activity, or 13 to 15% using the average number of active days.[5] When we used a similar approach, we obtained 22% (data not presented), probably a reflection of our older sample. However, the partial adjustment left much of the selection bias between compared groups and could not be interpreted as a good estimate of the short-term effects of physical activity on health care costs. At the same time, it was not an estimate of the long-term effects either because past inactivity may have contributed to some of the controlled health conditions.

Adjusting estimates for differences in baseline health between physically active and inactive subpopulations changed the magnitude of physical activity effects dramatically, to less than 1/4 of what unadjusted longitudinal comparisons, or almost 1/5 of descriptive cross-sectional comparisons. This may indicate the extent of selection bias. It remains an open question how well we measured baseline health, and how much residual biases were still retained in our estimates. We were certainly closer to estimating the causal effect of how physical activity changes health care costs over 2 y than studies leaving out baseline differences in health. We believe our estimates in the 7 to 8% range, or almost $500 per year, are substantively large and provide a more credible basis for assessing the potential effects of physical activity interventions than assuming that physical activity could reduce short-term health care costs by 30%. Lifecycle effects may very well be much larger than our short-term estimates because they would include the extent to which physical inactivity in the past had contributed to development of health conditions observed at baseline. Lifecycle effects are, however, hard to estimate without longitudinal data on individuals over several decades.

This paper also highlights a common problem with studying health care costs in a general population. There are many factors other than physical activity that affect health care costs and, even if these factors are uncorrelated with physical activity, the additional variation reduces the precision of statistical estimates, especially for dependent variables such as highly skewed health care costs. Although our point estimates may be suggestive, the limited precision also means that they should not be overinterpreted. A much larger than usual sample size is necessary to get reasonable precision in health care expenditure data, which is highly skewed and noisy.[18] Very few studies including ours had sufficient sample sizes to reliably measure small effect sizes. This has resulted in many (unreported) null findings and, due to publication bias that favors statistically significant results, publications exaggerating true effects. We need to guard against this problem because exaggerated expectations about physical activity interventions will only result in disappointments that are detrimental to the long-term promotion of physical activity. Our estimates, even though smaller than earlier estimates and statistically insignificant, are substantively important to health plans. But to more precisely measure small effects, very large sample sizes are needed and the availability of such data will be a limitation for the foreseeable future.

Among other important study limitations are the crudeness of the physical activity measure, which did not permit to characterize intensity, duration of activity, or energy expenditure, and evaluated a 12-month period before the interview. That regular brisk walking, apparently the most common form of physical activity in our age group, did not qualify under the survey definition of vigorous activity means that we may have underestimated the effects of physical activity on changes in health care expenditure among late middle age adults. The short-run effects (2 y in the main part, up to 6 y in sensitivity analyses) also did not capture the total lifecycle effects of physical activity. Finally, regardless of how extensively we tried to control for baseline differences between active and inactive people, our measures of baseline health did not capture all differences in the severity of the baseline health conditions and the person's ability to engage in physical activity. The longitudinal design reduced some types of selection biases, but did not guarantee that any of the estimates reflected the causal relationship that decision-makers are interested in.

Nevertheless, this study provides new information about the role of physical activity for changes in health care expenditures. From a policy perspective, the population we studied—people nearing retirement age and those recently retired—merit special attention for implications of their transition into Medicare and Social Security programs. Physical inactivity may impose a noticeable burden on the health care system, and this burden may be particularly large for some population subgroups, like smokers and obese individuals.

It is important to get credible point estimates, yet publication biases may encourage inflated estimates of the effects of physical activity just because they are statistically significant. While smaller estimated effects may not have the same immediate policy appeal as promises of dramatic cost savings, broken promises do not further the cause of physical activity interventions in the long run.

References

1. Colditz GA. Economic costs of obesity and inactivity. *Med Sci Sports Exerc*. 1999;31(11suppl):S663-7.
2. Keeler EB, Manning WG, Newhouse JP, Sloss EM, Wasserman J. The external costs of a sedentary lifestyle. *Am J Public Health*. 1989;79(8):975-81.
3. Katzmarzyk PT, Gledhill N, Shephard RJ. The economic burden of physical inactivity in Canada. *CMAJ*. 2000;163(11):1435-40.
4. Pratt M, Macera CA, Wang G. Higher direct medical costs associated with physical inactivity. *Phys Med*. 2000;28(10):63-70.
5. Pronk NP, Goodman MJ, O'Connor PJ, Martinson BC. Relationship between modifiable health risks and short-term health care charges. *JAMA*. 1999;282(23):2235-9.
6. Martinson BC, Crain AL, Pronk NP, O'Connor PJ, Maciosek MV. Changes in physical activity and short-term changes in health care charges: a prospective cohort study of older adults. *Prev Med*. 2003;37:319-26.
7. Goetzel R, Anderson D, Whitmer R, Ozminkowski R, Dunn R, Wasserman J. Relationship between modifiable health risks and health care expenditures: an analysis of the multi-employer HERO health risk and cost database. *J Occup Environ Med*. 1998;40(10):843-54.
8. Wang F, McDonald T, Champagne LJ, Edington DW. Relationship of body mass index and physical activity to health care costs among employees. *J Occup Environ Med*. 2004;46(5):428-36.
9. Wang G, Brown DR. Impact of physical activity on medical expenditures among adults downhearted and blue. *Am J Health Behav*. 2004;28(3):208-17.
10. Wang G, Helmick CG, Macera C, Zhang P, Pratt M. Inactivity-associated medical costs among US adults with arthritis. *Arthritis Rheum*. 2001;45(5):439-45.
11. Heeringa SG, Connor JH. Technical description of the health and retirement survey sample design. University of Michigan, Ann Arbor, 1995. Available at http://hrsonline.isr.umich.edu/docs/sample/hrs/HRSSAMP.pdf (accessed Feb 22, 2005).
12. MEPS, Center for Cost and Financing Studies, Agency for Healthcare Research and Quality: Medical Expenditure Panel Survey, 1996-2000. Available at http://www.meps.ahrq.gov (last accessed on February 22, 2005).

13. Andreyeva T, Sturm R, Ringel JS. Moderate and severe obesity have large differences in health care costs. *Obes Res*. 2004 Dec;12(12):1936-43.
14. CDC National Center for Chronic Disease Prevention and Health Promotion. Alcohol and Public Health. http://www.cdc.gov/alcohol/faqs.htm (last accessed February 22, 2005).
15. NIAAA. Helping patients with alcohol problems: A health practitioner's guide http://www.niaaa.nih.gov/publications/Practitioner/HelpingPatients.htm#step1A (last accessed February 19, 2005).
16. National Center for Chronic Disease Prevention and Health Promotion. Behavioral Risk Factor Surveillance Survey, 2003. Available at http://apps.nccd.cdc.gov/brfss/display.asp?cat=PA&yr=2003&qkey=4418&state=US (last accessed on September 13, 2005).
17. Survey of Health, Ageing and Retirement in Europe 50+ Europe, Manmheim Research Institute for the Economics of Aging, 2004.
18. Sturm R, Unützer J, Katon W. Effectiveness research and implications for study design: sample size and statistical power. *Gen Hosp Psychiatry.* 1999;21(4):274-83.