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Burden of Inadequate Levels of Physical Activity in the United States

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Burden of Inadequate Levels of Physical Activity

in the United States

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Abstract

Burden of Inadequate Levels of Physical Activity in the United States

By Susan A. Carlson

Despite the health benefits of physical activity, less than half of U.S. adults meet current aerobic physical activity guidelines and almost one-third of adults are physically inactive. Levels of physical activity inadequate to meet guidelines (i.e., inactive and insufficiently active) can be a substantial public health burden in the U.S.

The first article examined the association between inadequate physical activity and health care expenditures. Compared to being physically active, the mean difference (after adjusting for covariates and body mass index category) in annual health care expenditures was $1248 (percent difference: 26.6%) for those inactive and $661 (percent difference: 14.4%) for those insufficiently active. Overall, 11.5% of aggregate health care expenditures were associated with inadequate physical activity. When adults who reported any difficulty walking due to a health problem were excluded, the mean difference for those inactive was $871 (percent difference: 20.7%) and $504 (percent difference: 11.7%) for those insufficiently active. After this exclusion, 8.9% of health care expenditures were associated with inadequate physical activity.

The second article estimated the percentage of depression- and anxiety-specific health care expenditures associated with inadequate physical activity using both attributable fraction (AF) and regression based (RB) approaches. The percentage of depression- and anxiety-specific health care expenditures associated with inadequate physical activity was significantly higher (21.2%) when using the RB approach than with the AF approach (11.1%). Percentage estimates were higher when examining depression and anxiety separately with the RB approach (depression: 21.9%, anxiety: 17.2%) compared to the AF approach (depression: 13.2%, anxiety: 7.5%); however, differences were not significant.

The third article estimated the percentage of premature deaths attributable to inadequate physical activity. For adults age 40-69 and 70 or older, inactive (hazard ratio (HR) for 40-69: 1.24; 70+: 1.19) and insufficiently active adults (HR for 40-69: 1.11; 70+: 1.12) had an increased risk of mortality compared to active adults. Among adults age 25-39, there was no association between levels of physical activity and mortality. Among adults 40-69, 10.1% of premature deaths in the U.S. were attributed to inadequate physical activity. Among adults 70 or older, 9.0% of deaths were attributed to inadequate physical activity.

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Chapter 1: Motivation and Key Research Questions

Motivation

Regular physical activity is associated with important health benefits including reduced risk for premature death, cardiovascular disease, ischemic stroke, type 2 diabetes, colon and breast cancer, osteoporosis, fall-related injuries, and depression; prevention of weight gain; improved cardiorespiratory and muscular fitness; and better cognitive function (for older adults).[1] The *2008 Physical Activity Guidelines for Americans (2008 Guidelines)* recommend for substantial health benefits, adults should participate weekly in at least 150 minutes of moderate-intensity aerobic activity, at least 75 minutes of vigorous-intensity aerobic activity, or an equivalent combination.[2] For additional and more extensive health benefits, adults require a weekly volume greater than 300 minutes of moderate-intensity physical activity, 150 minutes of vigorous-intensity physical activity or an equivalent combination of the two.

Despite the health benefits of physical activity, less than half of U.S. adults meet the minimal national physical activity guideline for aerobic physical activity and almost one-third of adults are physically inactive. These levels have remained relatively stable over the past decade.[3] Given the high prevalence of inadequate levels of physical activity and the health risks associated with it, inadequate levels of physical activity can be a substantial public health burden in the U.S. The public health burdens relevant to physical activity include premature mortality, economic cost of medical care, inferior physical and mental function, and deficient physical and emotional well-being.[4,5]

The burden of current health-related behavior and the potential savings of behavior change can help policy makers justify health program decisions and can form the basis of economic, health care, and social reform.[5,6] Specifically, information about the burden of inadequate levels of physical activity in the U.S. is important for setting research, policy, and program priorities; for use in cost effectiveness analyses; and for public health planning and resource allocation purposes.

Key Research Questions

This series of studies will quantify the burden levels of physical activity inadequate to meet current guidelines have in the U.S. in terms of economic costs and premature mortality. The three topics and key research questions are:

1. **Inadequate Physical Activity and Health Care Expenditures in the United States**
    - Are there measurable effects of physical activity (defined using current guidelines criteria) on health care expenditures that are independent of overweight or obesity?
2. **Physical activity and Depression- and Anxiety-Specific Health Care Expenditures**
    - What percentage of depression- and anxiety-specific health care expenditures in the U.S. are attributable to inadequate levels of physical activity?
3. **Inadequate Physical Activity and Mortality in the United States**
    - What percentage of premature deaths in the U.S. are attributable to inadequate levels of physical activity?

References

1. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report, 2008.* Washington, DC: U.S. Department of Health and Human Services;2008.

2. US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans.* Washington, DC: U.S. Department of Health and Human Services;2008.

3. Carlson SA, Fulton JE, Schoenborn CA, Loustalot F. Trend and prevalence estimates based on the 2008 Physical Activity Guidelines for Americans. *Am J Prev Med.* Oct 2010;39(4):305-313.

4. Powell KE, Blair SN. The public health burdens of sedentary living habits: theoretical but realistic estimates. *Med Sci Sports Exerc.* Jul 1994;26(7):851-856.

5. Caspersen CJ, Powell KE, Merriitt RK. Measurement of health status and well being. In: Bouchard C, Shephard RJ, Stephens T, eds. *Physical activity, fitness, and health: International proceeding and consensus statement*. Champaign, IL: Human Kinetics; 1994.

6. Allender S, Foster C, Scarborough P, Rayner M. The burden of physical activity-related ill health in the UK. *J Epidemiol Commun H.* Apr 2007;61(4):344-348.

Chapter 2: Background, Rationale, and Study Objectives

This chapter provides a background section for each of the three research topics. Each section includes a summary of the literature and an outline of the current gaps in the literature specific to the research topic. Finally, each section concludes with a statement of the study's objectives.

Inadequate Physical Activity and Health Care Expenditures in the United States

A number of studies have examined the influence physical activity has on health care expenditures.[1-15] Many of these studies have estimated the costs associated with physical inactivity indirectly by applying population attributable fractions estimated from one or more sources to aggregate cost estimates from another source.[1-6] These estimates can be biased because estimates of risk, prevalence, and aggregate cost data are obtained from different sources and confounding or effect modification may not be properly taken into account as part of the population attributable estimation procedure.[16,17] Furthermore, these studies are limited as they do not allow for the direct examination of the association between physical activity and health care expenditures nor do they allow researchers to examine the roles that other relevant variables, such as adiposity level, play in this association.

Studies that have directly linked physical activity collected via questionnaires to individual health care expenditure data have found that those who are physically inactive have higher health care expenditures than those who are physically active.[7-15] However, these studies have at least 3 limitations. First, the majority of studies have been limited to select populations (e.g., enrollees or retirees in select health plans and a cohort of Australian women aged 50-55) therefore potentially limiting the generalizability of these studies.[8-14] Second, some studies have estimated mean expenditures by physical activity level and have not adequately controlled for potentially confounding characteristic using more advanced econometric methods.[7,10,15] Third, studies have assessed and defined levels of physical activity in different ways and only one study used measures of physical activity that are directly related to levels recommended in current guidelines for substantial health benefits.[10,18]

There are 2 studies whose findings can be roughly equated to levels of physical activity as defined using current guidelines criteria. In a study of Australian women 50-55 years, the percent difference in costs for women who were sedentary versus moderately-active (a level consistent with current guidelines) was 26.3%.[10] In a second study of enrollees 40 years or older in a Minnesota health plan, each additional ‘active’ day per week was associated with a 4.7% decrease in cost. If we consider 5 days of activity, this is about a 23.5% reduction compared with those who reported no days of physical activity.[11] However, given the specific populations studied, these findings may not be generalizable to the U.S. population and therefore should not be used to estimate the percentage of health care expenditures associated with inadequate levels of physical activity in the U.S.

Unlike physical activity, which is associated with health benefits, there are health risks associated with being overweight or obese including increased morbidity related to hypertension, type 2 diabetes, coronary heart disease, stroke, gallbladder disease, osteoarthritis, sleep apnea, respiratory problems, and some types of cancer (endometrial, breast, prostate, and colon).[19] Studies have consistently shown that obese persons have higher health care expenditures compared to normal weight persons.[8,10-12,14,15,20-25]

The relationship between physical activity, adiposity, and health is a complicated one. Sufficient physical activity can contribute to the reduction of adiposity through the prevention of weight gain and thereby influence health indirectly through weight.[1,2] Physical activity may also improve the health of an individual directly through effects independent of adiposity; thereby, making physical activity beneficial to all, regardless of adiposity level.[18,26-28] Because many of the health risks associated with obesity (e.g., hypertension, type 2 diabetes, coronary heart disease, stroke, colon cancer) can be reduced by physical activity through mechanisms independent of weight, the question is whether the magnitude of the influence of physical activity on health is the same regardless of an individual's adiposity level and to what extent physical activity can counterbalance the health risks associated with obesity.[10,26,29]

Previous studies that have examined whether adiposity level moderates the relationship between physical activity and health care expenditures have mixed results.[8,10,12,14] For example, one study suggested the influence of physical activity on health care expenditures was most pronounced among obese persons while another study reported the influence did not differ significantly by adiposity level.[8,14] Because these studies have been limited to select populations (e.g., enrollees or retirees in select health plans and a cohort of Australian women aged 50-55) the generalizability of these studies is also limited. Due to the inconsistent findings and the limited populations studied, these studies have not provided a definitive answer as to whether the association between physical activity and health care expenditures is independent of adiposity level.

There are two main research gaps the first study in this series will address. First, no study of the U.S. population has examined the association between physical activity and health care expenditures when physical activity is defined using current guidelines.[18] Second, the question of whether the association between physical activity and health care expenditures is modified by adiposity level has yet to be fully addressed in the literature.

The objective of the first study is threefold. The first aim is to examine the influence physical activity (as defined by current guidelines criteria) has on health care expenditures in the U.S. The second aim is to examine whether overweight and obesity modifies the association between physical activity level and health care expenditures. The third aim is to estimate the percentage of total health care expenditures associated with inadequate levels of physical activity in the U.S.

Physical activity and Depression- and Anxiety-Specific Health Care Expenditures

Mental health conditions impose an emotional and financial burden on individuals and their families. Beyond the medical resources spent on care, treatment, and rehabilitation, poor mental health is also associated with higher indirect costs due to reduced or lost productivity.[30] Depression and anxiety are the two most commonly reported mental health conditions. Among U.S. adults, depression has an annual prevalence of 9.0%[31] and estimates of the annual prevalence of anxiety range from 10.6% to 18.1%.[32,33]

Physical activity has been shown to lower the risk of both depression and anxiety. Population-based prospective cohort studies provide substantial evidence that regular physical activity protects against the onset of depressive symptoms.[27] Studies have shown, compared to inactive adults, the odds of having depressive symptoms were 15 to 25% lower among physically active adults.[27] When using a clinical diagnosis to measure depression, the odds of developing depression was 30% lower for adults who were physically active compared to those inactive.[27]

Evidence for the association between physical activity and anxiety is limited; however, some evidence suggests that regular physical activity protects against the onset of anxiety disorders and symptoms.[27] One previous U.S. study found that regular physical activity (defined as reporting ‘regularly’ when asked how often they get physical activity) reduced the odds of a generalized anxiety disorder by about 24% when compared to not regularly active.[34]

Studies have also shown that physical activity can play an important role in the treatment of depression and anxiety by reducing symptoms of the condition among adults with depression or anxiety.[35-37] Studies have found that exercise compares favorably to pharmacotherapy as a treatment for mild to moderate depression and has also been shown to improve depressive symptoms when used together with pharmacotherapy.[35] Reductions in anxiety from exercise training have been found comparable to other treatments for panic and generalized anxiety disorders, such as pharmacotherapy, relaxation therapy, and cognitive therapy.[37] A previous meta-analysis concluded that exercise training can serve as an alternative therapy for patients with social anxiety disorder, generalized anxiety disorder, and obsessive–compulsive disorder.[37] Given the evidence supporting physical activity as a treatment of depression and anxiety disorders,[35-37] it is plausible that participation in physical activity can decrease treatment cost among adults with depression and/or anxiety. This has not been previously examined in the literature.

It is likely that inadequate levels of physical activity are associated with a substantial percentage of depression- and anxiety-specific health care expenditures, given physical activity's role in the development and treatment of depression and anxiety.[27,34-37] Previous studies found that physical activity is associated with increased overall health care expenditures among adults with symptoms of depression or mental disorders.[38,39] No previous study, however, has estimated what percentage of depression or anxiety-specific expenditures are associated with levels of physical activity inadequate to meet current guidelines.[18]

There is one previous study that estimated 12% of depression- and anxiety-specific health care expenditures were associated with irregular and inactive levels of physical activity among adults enrolled in a major health plan in Minnesota.[3] This study has some limitations. First, the prevalence of the physical activity levels for the state of Minnesota were used (25% inactive, 49% irregularly active) as part of the estimation procedure. The epidemiological formula used in the estimation procedure calls for the prevalence of physical activity levels among those with the condition and using the prevalence for the overall population may result in an underestimation.[17] Second, the relative risk that was used was based on a report that estimated sedentary people were 1.3 times as likely to experience depression compared to active people.[40] Based on this estimate, authors used a relative risk of 1.3 for inactive and 1.1 for the irregular active level for a combined depression and anxiety outcome. Given the limitations in the prevalence and risk estimates used in the calculation and the specificity of the population, it would not be appropriate to assume these findings accurately portray what percentage of depression- and anxiety-specific health care expenditures are associated with inadequate levels of physical activity in the U.S.

Two approaches can be applied to estimate the economic burden of inadequate physical activity associated with depression- and anxiety-specific spending. The attributable fraction approach uses an equation to combine risk and prevalence estimates to calculate the percentage of depression and anxiety associated with inadequate levels of physical activity.[41,42] The attributable fraction approach then applies this percentage to estimates of aggregate condition-specific health care expenditures to estimate the amount of depression and anxiety-specific health care expenditures associated with inadequate levels of physical activity.[42] The major limitation of the attributable fraction approach is that only physical activity's influence on the presence of depression and anxiety is accounted for and this approach does not account for whether the cost among those with depression and anxiety differs by physical activity level.

A regression based approach is another approach that can be applied to estimate the economic burden related to inadequate levels of physical activity. The regression based approach requires individual level data on physical activity and health care expenditures. This approach then uses regression analysis to estimate models of health care expenditures. Using these models, the regression based approach compares health care expenditures among people of different physical activity levels and then estimates the percentage of health care expenditures associated with inadequate levels of physical activity. This approach captures the influence of physical activity on whether an individual has depression or anxiety and the cost to treat the depression or anxiety.[42] If there is a positive association between inadequate levels of physical activity and the cost to treat depression or anxiety then a regression based approach will produce higher estimates than an attributable fraction approach of the percentage of health care expenditures associated with inadequate levels of physical activity. The magnitude of the difference will depend on the strength of the association between inadequate levels of physical activity and the cost to treat depression or anxiety.

The second study of this series will address two gaps in the literature. First, no study has estimated the percentage of depression- and anxiety-specific health care expenditures associated with inadequate levels of physical activity (as defined using current guidelines). Assessing the percentage of the depression- and anxiety-specific expenditures attributable to inadequate levels of physical activity is important for setting research and policy priorities overall and specifically for programs addressing these conditions. Second, it is not clear how estimates of depression- and anxiety-specific health care expenditures associated with inadequate levels of physical activity compare when an attributable fraction approach versus a regression based approach are applied. Attributable fraction and regression based approaches are often applied by different disciplines and understanding how the two relate can be important when examining and comparing policy analyses related to cost and cost control

The objective of the second study is to examine how leisure-time aerobic physical activity relates to the presence and amount of health care expenditures specific to depression, anxiety, and the two conditions combined. This study will apply and compare 2 approaches, the attributable fraction and regression based approach, to estimate the percentage of depression- and anxiety-specific health care expenditures associated with inadequate levels of physical activity in the U.S.

Inadequate Physical Activity and Mortality in the United States

Regular participation in physical activity prevents the development of premature death. Studies have found that compared to those inactive, there is a 20-30% lower risk of dying for active individuals during follow-up periods.[27] Current guidelines recommend for substantial health benefits adults participate weekly in at least 150 minutes of moderate-intensity aerobic activity, at least 75 minutes of vigorous-intensity aerobic activity, or an equivalent combination.[18] Population levels of physical activity inadequate to meet current guidelines can place a burden on the U.S. population for premature mortality.

The population attributable fraction (PAF) provides an estimate of the proportion of premature deaths that could be averted if inactive or insufficiently active individuals were physically active at levels consistent with current guidelines.[17] The PAF provides policy makers with useful quantitative estimates of the public health burden of inadequate levels of physical activity and the potential effect of programs aimed at increasing physical activity in the U.S.[43] This information can be important for setting research and program priorities, and for public health planning and resource allocation purposes.

Studies have estimated the PAF for physical inactivity using an equation that combines risk estimates from one source with prevalence estimates from another source.[41,44-47] Combining risk estimates across different sources can bias results for three reasons. The first reason is the biological and socio-demographic characteristics vary between sample populations and therefore it may not be appropriate to apply the risks calculated from one population directly to another population.[48] A second reason is physical activity can be measured and defined in different ways across studies. Often, the physical activity measure used to generate prevalence estimates is based on one measure of physical inactivity and these are matched loosely with risk estimates from a single study or a combination of studies in the literature that used different measures of physical inactivity.[44-47] Depending on how well the measures match, this can cause a bias in either direction. A third reason is that to estimate the PAF, adjusted measures of risk are often used. While it is important to use risk estimates that have controlled for potentially confounding factors, when using adjusted risk estimates the prevalence of physical activity among the cases is needed; however, because this estimate is often not available prevalence estimates among the entire population (with[46] or without an adjustment factor[44,47]) are used. This can also bias estimates in either direction.

Estimating the PAF from a survival analysis conducted in a single population can overcome these biases. And if the source population is nationally representative, the PAF will accurately estimate the burden of inadequate levels of physical activity in the U.S. To date, no study has estimated the PAF for inadequate levels of physical activity (using criteria based on current guidelines)[18] from a survival analysis of a nationally-representative sample. One prospective study estimated that 10.9% of deaths were attributed to being physically inactive versus not using data from the National Health and Nutrition Examination Survey linked with mortality data.[49] However, this study did not use criteria based on current guidelines to categorize physical activity levels.[18] When estimating the public health burden of inadequate levels of physical activity, it is important to examine physical activity levels consistent with current guidelines and health objectives in the U.S.[18,50]

In addition, no study has estimated the PAF when individuals are categorized into three physical activity levels (i.e., active, insufficiently active, and inactive). Categorizing individuals into three levels allows for the examination of the burden of inactivity as well as levels of activity above inactive but at levels insufficient to meet current guidelines.

The ability to separately examine the contribution these different levels of inadequate physical activity (i.e., inactive and insufficiently active) have on the percentage of premature deaths can be important for public health planning and resource allocation purposes. Programs targeting adults who are insufficiently active versus inactive may be different and knowing the burden associated with each level can be valuable for public health planning and resource allocation.

Finally, there is one issue related to the risk calculation used to estimate the PAF that has not been fully addressed in the literature. Currently the evidence of the association between physical activity and mortality comes from studies that have focused on middle aged subjects.[27] The few studies that have examined the influence that age across the adult lifespan has on the association between physical activity and mortality have suggested that the association gets stronger with increasing age.[51-53] It is desirable for this differential risk by age to be included as part of the estimation process of the attributable burden and therefore it is necessary to have age-specific models that can be used to calculate age-specific PAFs.[44] One European study with forty-two years of follow-up found the PAFs for physical inactivity were relatively consistent across age groups ranging from 7.3 for those age 20 to 44 to 9.1 for those 65 and over.[53] However, this study used a crude measure of physical activity (any versus none) and it is unclear how the PAFs would vary by age group if a measure of physical activity that matches current guidelines was used.

This study will address two gaps in the literature. First, the most accurate estimates of the PAF for the overall U.S. population requires a nationally-representative, prospective study of physical activity and mortality. To date, no study provides estimates of the PAF for inadequate levels of physical activity in the U.S. (defined using current guideline criteria) calculated directly from such a sample. Second, the question of how the association between physical activity and mortality and thus estimates of the PAF vary by age group has not been fully addressed in the literature.

The objective of the third study is two-fold. The first aim is to examine the influence physical activity level (defined using current guidelines criteria) has on mortality in a sample that is nationally representative of the U.S. population and to examine this association by age group. The second aim is to use results from the survival analysis to directly estimate the percentage of deaths attributable to inadequate levels of physical activity (i.e., inactive and insufficiently active) in the U.S.

References

1. Allender S, Foster C, Scarborough P, Rayner M. The burden of physical activity-related ill health in the UK. *J Epidemiol Commun H.* Apr 2007;61(4):344-348.

2. Colditz GA. Economic costs of obesity and inactivity. *Med Sci Sports Exerc.* Nov 1999;31(11 Suppl):S663-667.

3. Garrett NA, Brasure M, Schmitz KH, Schultz MM, Huber MR. Physical inactivity: direct cost to a health plan. *Am J Prev Med.* Nov 2004;27(4):304-309.

4. Katzmarzyk P, Janssen I. The economic costs associated with physical inactivity and obesity in Canada: an update. *Can J Appl Physiol.* 2004;29(1):90-115.

5. Katzmarzyk PT, Gledhill N, Shephard RJ. The economic burden of physical inactivity in Canada. *CMAJ.* Nov 28 2000;163(11):1435-1440.

6. Popkin BM, Kim S, Rusev ER, Du S, Zizza C. Measuring the full economic costs of diet, physical activity and obesity-related chronic diseases. *Obes Rev.* Aug 2006;7(3):271-293.

7. Pratt M, Macera CA, Wang G. Higher direct medical costs associated with physical inactivity. *Phys Sportsmed.* Oct 2000;28(10):63-70.

8. Anderson LH, Martinson BC, Crain AL, et al. Health care charges associated with physical inactivity, overweight, and obesity. *Prev Chronic Dis.* Oct 2005;2(4):A09.

9. Bland PC, An L, Foldes SS, Garrett N, Alesci NL. Modifiable health behaviors and short-term medical costs among health plan members. *Am J Health Promot.* Mar-Apr 2009;23(4):265-273.

10. Brown WJ, Hockey R, Dobson AJ. Physical activity, Body Mass Index and health care costs in mid-age Australian women. *Aust N Z J Public Health.* Apr 2008;32(2):150-155.

11. Pronk NP, Goodman MJ, O'Connor PJ, Martinson BC. Relationship between modifiable health risks and short-term health care charges. *Jama-J Am Med Assoc.* Dec 15 1999;282(23):2235-2239.

12. Wang F, McDonald T, Reffitt B, Edington DW. BMI, physical activity, and health care utilization/costs among Medicare retirees. *Obes Res.* Aug 2005;13(8):1450-1457.

13. Yang G, Niu K, Fujita K, et al. Impact of physical activity and performance on medical care costs among the Japanese elderly. *Geriatr Gerontol Int.* Apr 2011;11(2):157-165.

14. 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.* May 2004;46(5):428-436.

15. Wang G, Pratt M, Macera CA, Zheng ZJ, Heath G. Physical activity, cardiovascular disease, and medical expenditures in U.S. adults. *Ann Behav Med.* Oct 2004;28(2):88-94.

16. Flegal KM, Graubard BI, Williamson DF. Methods of calculating deaths attributable to obesity. *Am J Epidemiol.* Aug 15 2004;160(4):331-338.

17. Rockhill B, Newman B, Weinberg C. Use and misuse of population attributable fractions. *Am J Public Health.* Jan 1998;88(1):15-19.

18. US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans.* Washington, DC: U.S. Department of Health and Human Services;2008.

19. National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. 1998; http://www.nhlbi.nih.gov/guidelines/obesity/ob_gdlns.pdf.

20. Bell JF, Zimmerman FJ, Arterburn DE, Maciejewski ML. Health-care expenditures of overweight and obese males and females in the medical expenditures panel survey by age cohort. *Obesity (Silver Spring).* Jan 2011;19(1):228-232.

21. Finkelstein EA, Fiebelkorn IC, Wang G. National medical spending attributable to overweight and obesity: how much, and who's paying? *Health Aff (Millwood).* Jan-Jun 2003;Suppl Web Exclusives:W3-219-226.

22. Finkelstein EA, Trogdon JG, Cohen JW, Dietz W. Annual medical spending attributable to obesity: payer-and service-specific estimates. *Health Aff (Millwood).* Sep-Oct 2009;28(5):w822-831.

23. Thorpe KE, Florence CS, Howard DH, Joski P. The impact of obesity on rising medical spending. *Health Aff (Millwood).* Jul-Dec 2004;Suppl Web Exclusives:W4-480-486.

24. Wee CC, Phillips RS, Legedza AT, et al. Health care expenditures associated with overweight and obesity among US adults: importance of age and race. *Am J Public Health.* Jan 2005;95(1):159-165.

25. Yang Z, Hall AG. The financial burden of overweight and obesity among elderly Americans: the dynamics of weight, longevity, and health care cost. *Health Serv Res.* Jun 2008;43(3):849-868.

26. Fogelholm M. Physical activity, fitness and fatness: relations to mortality, morbidity and disease risk factors. A systematic review. *Obes Rev.* Mar 2010;11(3):202-221.

27. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report, 2008.* Washington, DC: U.S. Department of Health and Human Services;2008.

28. Lee DC, Artero EG, Sui X, Blair SN. Mortality trends in the general population: the importance of cardiorespiratory fitness. *J Psychopharmacol.* Nov 2010;24(4 Suppl):27-35.

29. Lee DC, Sui X, Blair SN. Does physical activity ameliorate the health hazards of obesity? *Br J Sports Med.* Jan 2009;43(1):49-51.

30. US Department of Health and Human Services. *Mental Health: A Report of the Surgeon General.* Rockville, MD1999.

31. Centers for Disease Control and Prevention. Current depression among adults---United States, 2006 and 2008. *MMWR Morb Mortal Wkly Rep.* 2010;59(38):1229-1235.

32. Kessler RC, Chiu WT, Demler O, Walters EE. Prevalence, severity, and comorbidity of 12-month DSM-IV disorders in the National Comorbidity Survey Replication. *Archives of general psychiatry.* Jun 2005;62(6):617-627.

33. Somers JM, Goldner EM, Waraich P, Hsu L. Prevalence and incidence studies of anxiety disorders: A systematic review of the literature. *Can J Psychiat.* Feb 2006;51(2):100-113.

34. Goodwin RD. Association between physical activity and mental disorders among adults in the United States. *Prev Med.* Jun 2003;36(6):698-703.

35. Carek PJ, Laibstain SE, Carek SM. Exercise for the treatment of depression and anxiety. *International journal of psychiatry in medicine.* 2011;41(1):15-28.

36. Strohle A. Physical activity, exercise, depression and anxiety disorders. *Journal of neural transmission.* Jun 2009;116(6):777-784.

37. Herring MP, Lindheimer JB, O'Connor PJ. The Effects of Exercise Training on Anxiety. *American Journal of Lifestyle Medicine.* 2013;Published online before print.

38. Brown DR, Wang G, Safran MA. A Preliminary analysis of medical expenditures among active and sedentary US adults with mental disorders. *American journal of health behavior.* May-Jun 2005;29(3):195-205.

39. Wang G, Brown DR. Impact of physical activity on medical expenditures among adults downhearted and blue. *American journal of health behavior.* May-Jun 2004;28(3):208-217.

40. DiMatteo M, Lepper HS, Croghan TW. Depression is a risk factor for noncompliance with medical treatment: Meta-analysis of the effects of anxiety and depression on patient adherence. *Archives of Internal Medicine.* 2000;160(14):2101-2107.

41. Rockhill B, Newman B, Weinberg C. Use and misuse of population attributable fractions. *American Journal of Public Health.* 1998;88(1):15-19.

42. Honeycutt AA, Segel JE, Hoerger TJ, Finkelstein EA. Comparing cost-of-illness estimates from alternative approaches: an application to diabetes. *Health Serv Res.* Feb 2009;44(1):303-320.

43. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet.* Jul 21 2012;380(9838):219-229.

44. Bull FC, Armstrong TP, Dixon T, Ham S, Neiman A, Pratt M. Physical inactivity. In: Ezzati M, Lopez AD, Rodgers A, Murray CJ, eds. *Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors*. Geneva: World Health Organization; 2004.

45. Danaei G, Ding EL, Mozaffarian D, et al. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. *PLoS Med.* Apr 28 2009;6(4):e1000058.

46. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet.* Jul 21 2012;380(9838):219-229.

47. Powell KE, Blair SN. The public health burdens of sedentary living habits: theoretical but realistic estimates. *Med Sci Sports Exerc.* Jul 1994;26(7):851-856.

48. Flegal KM, Williamson DF, Pamuk ER, Rosenberg HM. Estimating deaths attributable to obesity in the United States. *American journal of public health.* Sep 2004;94(9):1486-1489.

49. Yang Q, Cogswell ME, Flanders WD, et al. Trends in cardiovascular health metrics and associations with all-cause and CVD mortality among US adults. *JAMA.* Mar 28 2012;307(12):1273-1283.

50. U.S. Department of Health and Human Services. Healthy People 2020. 2012; http://www.healthypeople.gov/2020/topicsobjectives2020/default.aspx. Accessed December 1, 2012.

51. Andersen LB, Schnohr P, Schroll M, Hein HO. All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. *Arch Intern Med.* Jun 12 2000;160(11):1621-1628.

52. Schoenborn CA, Stommel M. Adherence to the 2008 adult physical activity guidelines and mortality risk. *Am J Prev Med.* May 2011;40(5):514-521.

53. Gulsvik AK, Thelle DS, Samuelsen SO, Myrstad M, Mowe M, Wyller T. Ageing, physical activity, and mortality - a 42-year follow-up study. *International journal of epidemiology.* 2012;41:521-530.

Chapter 3: Guiding Theoretical Frameworks

This chapter provides a description of the guiding theoretical framework for each of the three studies. For the first two studies that examine the association between physical activity and health care expenditures (overall and depression- and anxiety-specific), I have drawn on Grossman's Human Capital model as a guide.[1] For the third study that examines the association between physical activity and premature mortality, I have drawn on the Determinants of Health model as a guide.[2]

Inadequate Physical Activity and Health Care Expenditures in the United States

The focal relationship examined in this study is physical activity and its influence on health care expenditures. To guide the framework for this analysis, I have drawn on an implication from Grossman's Human Capital model.[1] In Grossman's model, individuals maximize an inter-temporal utility function of commodities and health, where health exhibits both consumption value and investment value, subject to time and budget constraints. Individuals are endowed with an initial health stock which depreciates each period due to not only the ageing process but also to unhealthy behaviors (e.g., poor diet, smoking, and alcohol use). Individuals can make health investments each period through combining inputs such as medical care and health promoting behaviors, which allow them to choose their optimal health stock.

An implication arising from Grossman's model is that medical care inputs and time participating in health promoting behaviors are substitutes, since each activity contributes to achieving the desired end of health.[3] Physical activity has been well established as a health promoting behavior.[4] The health benefits of physical activity are numerous and include reduced risk of cardiovascular disease, ischemic stroke, type 2 diabetes, colon and breast cancer, osteoporosis, fall-related injuries, and depression; prevention of weight gain; improved cardiorespiratory and muscular fitness; and better cognitive function (for older adults).[4] In my first study, I examined the focal relationship between participation in physical activity in a previous period to subsequent medical care inputs measured as overall health care expenditures. The purpose of this study was to determine if these two components are inversely associated as the theoretical framework implies.

Since decisions are shaped by preferences, which differ across people, I included in the model individual characteristics. Individual characteristics that are likely to influence both participation in physical activity and overall health care expenditures were selected. Individual characteristics included were: sex, age, race/ethnicity, education level, marital status, region of residence, income level, and health insurance coverage.[5-7] I also included in the analysis an indicator of cigarette smoking. The presence of this unhealthy behavior may mediate the focal relationship given its association with physical activity and health care expenditures.[6,8] Therefore, I modeled health care expenditures as a function of the previous time period's physical activity and relevant individual characteristics:

Overall health care expenditures = f (physical activity, age, sex, race/ethnicity, marital status, region, education, income, health insurance coverage, smoking status)

My first study also examined if adiposity level as measured by body mass index (BMI) category (i.e., normal weight, overweight, or obese) is a moderator of the relationship between physical activity and health care expenditures. Higher levels of adiposity will negatively influence an individual's health.[9] This will result in the depreciation of an individual's health stock; therefore, the question is whether physical activity will offer the same marginal returns given this depreciation of health stock or if those with the most depreciated health stock (i.e., obese persons) will experience greater marginal returns. If the marginal returns for the physical activity investment differ by adiposity level, this will imply that the magnitude of the association between physical activity and health care expenditures will also differ by adiposity level.[10,11]

The first study examined the role that BMI category plays in the association between physical activity and health care expenditures by including in the function an interaction term between BMI category and physical activity level. This interaction term allowed the influence of physical activity to vary by BMI category and thereby accounts for potential differences in marginal returns by BMI category.

Physical activity and Depression- and Anxiety-Specific Health Care Expenditures

For my second study, the focal relationship examined was the association between physical activity and depression- and anxiety-specific health care expenditures. I used the same framework to guide this analysis as was used for the first study.

Similar to the first study, I focused on physical activity as the health promoting behavior. Physical activity has been shown to lower the risk of both depression and anxiety.[4] Studies have also shown that physical activity can play an important role in the treatment of depression and anxiety by reducing symptoms of the condition among adults with depression or anxiety.[12-14] Given physical activity's beneficial influence on the risk and treatment of depression and anxiety, participation in physical activity can promote positive mental health. For this study, medical care inputs were specific to mental health and were measured as depression- and anxiety-specific health care expenditures. The purpose of the second study was to determine if participation in physical activity (i.e., the health promoting behavior) and depression- and anxiety-specific health care expenditures (i.e., the medical care input) are inversely associated as the theoretical framework implies.[3]

To capture differences in individual preferences, I included in the model demographic characteristics that are likely to influence participation in physical activity, health care expenditures, and the reporting of depression and/or anxiety. Individual characteristics included were sex, age, race/ethnicity, education level, marital status, region of residence, income level, and health insurance coverage.[5-7,15,16] I also included in the analysis two indicators of unhealthy behaviors, cigarette smoking and body mass index (BMI) category, as these behavioral indicators may mediate the focal relationship. Therefore, I modeled depression- and anxiety-specific health care expenditures as a function of the previous time period's physical activity and relevant individual characteristics:

Depression- and anxiety-specific health care expenditures = f (physical activity, age, sex, race/ethnicity, marital status, region, education, income, health insurance coverage, smoking status, BMI category)

Inadequate Physical Activity and Mortality in the United States

The Determinants of Health model was used to guide the framework for the third study.[2] The Determinants of Health model contains multiple levels that influence an individual's health. Levels of influence include: individual characteristics, lifestyle factors, social and community influences, living and working conditions, and finally general social, socioeconomic, cultural, and environmental conditions.[2]

For the third study, the focal relationship that I examined was physical activity and its influence on premature mortality. When applying my guiding theoretical framework, I defined health at the extreme, i.e., premature death. I focused on the first two-levels of the Determinants of Health model as predictors within my model. The first level of the model includes characteristics that cannot be changed about the individual. Given the focal relationship, individual characteristics that are strongly associated with physical activity were selected for inclusion. Characteristics included: sex, age, race/ethnicity, and education level.[6] The second level of the model includes lifestyle factors. Within the second level is the primary independent variable of the focal relationship (i.e., physical activity). Additional indicators of lifestyle factors that were selected for inclusion were those that may mediate the focal relationship and include: hypertension, BMI category, and smoking status. Therefore, I modeled premature death as a function of physical activity at baseline, relevant individual characteristics at baseline, and indicators of potentially confounding lifestyle factors at baseline:

$$\textit{premature death} = f\,(\textit{physical activity}_B,\ \textit{sex},\ \textit{age}_B,\ \textit{race/ethnicity},\ \textit{education level}_B,\ \textit{hypertension}_B,\ \textit{BMI category}_B,\ \textit{smoking status}_B)$$

References

1. Grossman M. On the Concept of Health Capital and the Demand for Health. *Journal of Political Economy.* 1972;80(2):223-255.

2. Dahlgren G, Whitehead M. *Policies and strategies to promote social equity in health.* Stockholm: Institute for Future Studies;1991.

3. Jacobs P, Rapoport J. *The economics of health and medical care.* 5th ed. Gaithersburg, Md.: Aspen Publishers; 2002.

4. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report, 2008.* Washington, DC: U.S. Department of Health and Human Services;2008.

5. Carlson SA, Fulton JE, Schoenborn CA, Loustalot F. Trend and prevalence estimates based on the 2008 Physical Activity Guidelines for Americans. *Am J Prev Med.* Oct 2010;39(4):305-313.

6. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. *Med Sci Sports Exerc.* Dec 2002;34(12):1996-2001.

7. Agency for Healthcare Research and Quality. Total Health Services-Mean and Median Expenses per Person With Expense and Distribution of Expenses by Source of Payment: United States, 2008. 2008; http://www.meps.ahrq.gov/mepsweb.

8. US Department of Health and Human Services. *The Health Consequences of Smoking: 50 Years of Progress. A Report of the Surgeon General.* Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and

Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health;2014.

9. National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. 1998; http://www.nhlbi.nih.gov/guidelines/obesity/ob_gdlns.pdf.

10. Lee DC, Sui X, Blair SN. Does physical activity ameliorate the health hazards of obesity? *Br J Sports Med.* Jan 2009;43(1):49-51.

11. Brown WJ, Hockey R, Dobson AJ. Physical activity, Body Mass Index and health care costs in mid-age Australian women. *Aust N Z J Public Health.* Apr 2008;32(2):150-155.

12. Carek PJ, Laibstain SE, Carek SM. Exercise for the treatment of depression and anxiety. *International journal of psychiatry in medicine.* 2011;41(1):15-28.

13. Strohle A. Physical activity, exercise, depression and anxiety disorders. *Journal of neural transmission.* Jun 2009;116(6):777-784.

14. Herring MP, Lindheimer JB, O'Connor PJ. The Effects of Exercise Training on Anxiety. *American Journal of Lifestyle Medicine.* 2013;Published online before print.

15. Centers for Disease Control and Prevention. Current depression among adults---United States, 2006 and 2008. *MMWR Morb Mortal Wkly Rep.* 2010;59(38):1229-1235.

16. Kessler RC, Chiu WT, Demler O, Walters EE. Prevalence, severity, and comorbidity of 12-month DSM-IV disorders in the National Comorbidity Survey Replication. *Archives of general psychiatry.* Jun 2005;62(6):617-627.

Chapter 4: Inadequate Physical Activity and Health Care Expenditures in the United States

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Abstract

Objective. Estimate direct health care expenditures associated with levels of aerobic physical activity inadequate to meet current guidelines.

Methods. Merged adults' leisure-time aerobic physical activity data from the National Health Interview Survey (2004-2009) with health care expenditure data from the Medical Expenditure Panel Survey (2006-2010). Calculated annual mean differences in health care expenditures comparing inactive (i.e., no leisure-time physical activity) and insufficiently active adults (i.e., some physical activity but not enough to meet guidelines) with active adults (i.e., ≥ 150 minutes/week moderate-intensity equivalent activity) using a four-part econometric model.

Results. Compared to being physically active, the mean difference (after adjusting for covariates and body mass index) in annual health care expenditures was $1248 for inactive adults and $661 for insufficiently active adults. Overall, 11.5% of aggregate health care expenditures were associated with inadequate physical activity. When adults who reported any difficulty walking due to a health problem were excluded, the mean difference for inactive adults was $871 and the mean difference for insufficiently active adults was $504. After this exclusion, 8.9% of aggregate health care expenditures were associated with inadequate levels of physical activity.

Conclusion. Inadequate physical activity is associated with a significant percentage of health care expenditures in the United States.

Introduction

Regular physical activity is associated with important health benefits, including reduced risk for premature death, cardiovascular disease, ischemic stroke, type 2 diabetes, colon and breast cancers, fall-related injuries, and depression.[1] Current guidelines for aerobic physical activity recommend that, for substantial health benefits, adults should participate weekly in at least 150 minutes of moderate-intensity aerobic activity, at least 75 minutes of vigorous-intensity aerobic activity, or an equivalent combination.[2] Despite the health benefits, fewer than half of U.S. adults meet the minimal guidelines for aerobic activity and almost one-third of adults are physically inactive.[3]

Studies show an individual's physical activity level affects health care costs, but these studies have limitations in their measurements and approaches.[4-18] Many studies estimate health care costs for physical inactivity using population-attributable fraction approaches that combine risk, prevalence, and aggregate cost estimates from unlinked sources.[4-9] Costs calculated from unlinked sources can be biased if the characteristics of the source populations differ or if measures of physical inactivity differ across sources. Studies using individual physical activity data linked to health care expenditure data overcome many of these limitations.[10-18] However, existing studies using linked data also have limitations, such as selected study populations,[11-17] lack of adequate control for confounding characteristics,[10,13,18] and measures of physical activity that do not match current guidelines.[10-12,14-18] No study estimates the percentage of health care expenditures in the United States associated with inadequate levels of aerobic physical activity defined using current guidelines criteria.

Studies have consistently shown that obese persons have higher health care expenditures than normal weight persons.[11,13,19-21] Physical activity may influence health care expenditures indirectly through the prevention of weight gain;[1] however, physical activity may also reduce health care expenditures directly through effects independent of weight.[1,13] Therefore, it is important to examine the role that being overweight or obese plays in the association between physical activity and health care expenditures. This association has not been examined in a large, nationally representative sample of U.S. adults.

Using linked data, this study examines the association of leisure-time aerobic physical activity (defined using current guidelines) and health care expenditures in a nationally representative sample of U.S. adults. In addition, this study estimates the percentage of overall health care expenditures in the non-institutionalized U.S. population associated with levels of physical activity inadequate to meet current guidelines.

Methods

Data

Data from the National Health Interview Survey (NHIS) (2004-2009) and the Medical Expenditure Panel Survey (MEPS) (2006-2010) were merged at the individual level. The

NHIS is a multistage probability sample survey of U.S. households conducted annually. Data on physical activity are collected during the sample adult interview. The MEPS uses the same sampling frame as the NHIS. Respondents from the previous 2 years of NHIS are included in each MEPS year. MEPS response rates for our study years range from 56.9% (2007) to 59.3% (2008). Additional information about the design of the NHIS and the MEPS are described elsewhere.[22,23]

Measures

Physical activity level. In the NHIS, adults were asked how often and, if applicable, the duration during leisure-time they participated for at least 10 minutes at a time, in 1) vigorous-intensity activities (i.e., heavy sweating or large increases in breathing or heart rate) and 2) light- or moderate-intensity activities (i.e., light sweating or slight to moderate increases in breathing or heart rate). Based on current guidelines,[1] 1 minute of vigorous-intensity activity was counted as 2 minutes of moderate-intensity activity to calculate minutes of moderate-intensity equivalent activity. Respondents were classified into three physical activity levels using current guidelines: 1) active, if they reported at least 150 minutes/week of moderate-intensity equivalent physical activity; 2) insufficiently active, if they reported some physical activity but not enough to meet guidelines; 3) inactive, if they reported no leisure-time physical activity.[2] Adults who reported being unable to do physical activity were excluded (n = 906).

Body mass index category. Body mass index (BMI) was calculated using self-reported weight and height collected during the NHIS interview and was categorized as normal weight (18.5 kg/m^2 - <25 kg/m^2), overweight (25 kg/m^2 - <30 kg/m^2), and obese (≥30 kg/m^2).[24] We excluded underweight (BMI < 18.5 kg/m^2) adults because of small sample size (n = 647).

Health care expenditures. A continuous variable of yearly total direct health care expenditures from all payers was calculated. The Personal Health Care Expenditure Price Index was used to adjust all expenditures to 2011 dollars.[25]

Statistical Analysis

To capture the skewed nature of health care expenditure data, a Rand four-part regression model was used.[20,26] Two logit models predicted the probability of having a non-zero health care expenditure and, among those with a positive health care expenditure, having a positive in-patient expenditure. Two generalized linear models with a log link and gamma distribution predicted total health care expenditures separately for adults with a positive health care expenditure but no in-patient expenditure and for adults with a positive in-patient expenditure. We used modified Park tests to determine the appropriate distribution specification for the generalized linear models.[27,28] Predictions from the four-part model were combined to generate predicted health care expenditures for each individual. To examine overall model fit, we regressed prediction errors from each four-part model on the distribution of predicted expenditures in deciles and on each independent variable. We found no systematic differences between reported expenditures and model predictions.

We first compared inactive adults to active adults by calculating the mean and percent difference in health care expenditures. To calculate the mean difference in health care expenditures, we subtracted the mean of predicted health care expenditures for inactive adults with the inactive variable set to 0 (i.e., "as if" the individual was active) from the mean of predicted health care expenditures for inactive adults with the inactive variable set to 1 (i.e., "as is").[20,29] The percent difference was estimated by dividing the mean difference between health care expenditures for inactive adults compared to active adults by the mean predicted health care expenditure for inactive adults "as if" the individual was active. The percentage of aggregate health care expenditures for inactive adults was calculated by dividing the sum of differences in health care expenditures for inactive compared to active adults by the total predicted expenditures for all adults.[20,29] This process was repeated for insufficiently active adults.

Three models were estimated. Model 1 included physical activity level and covariates (i.e., sex, age group, race/ethnicity, census region, marital status, education, poverty level, health insurance status, smoking status, and MEPS year). Model 2 added BMI category. Model 3 added an interaction term between physical activity level and BMI category.

Though we had excluded those who reported being unable to do physical activity, we wanted to address the concern that inactive or insufficiently active adults might have health problems that would keep them from participating in physical activity and increase their expenditures. So, we conducted a sensitivity analysis that excluded additional subgroups such as adults who reported at the time of the NHIS interview (i.e., baseline) ever having had a heart attack or stroke; needing help with getting in/out of bed or chairs, using the toilet, or getting around the home; or having difficulty walking because of a health problem. In addition, we excluded adults who died during the MEPS survey year or who were greater than or equal to 80 years of age.

We applied statistical weights and used balanced repeated replication to produce estimates representative of the civilian, non-institutionalized U.S. population and to account for the complex sample design. In the NHIS, only one sampled adult per household is asked questions about physical activity and we adjusted MEPS person-year weights to account for this sampling.[30]

Results

The analytic sample included 41 992 adults age 20 years or older and excluded those who were pregnant during the MEPS year, were underweight, or who reported being unable to do physical activity. From 2006-2010, the average total annual health care expenditures per year were $1.02 trillion for this sample weighted to the U.S. population. The majority of the sample was white non-Hispanic, married, had some college education or was a college graduate, and had some private insurance coverage for the year (Table 4.1).

Over one-third of adults were inactive, 19.9% were insufficiently active, and 45.1% were physically active (Table 4.1). Physical activity varied significantly (adjusted Wald *P*-

value < 0.01) by sex, age, race/ethnicity, education level, marital status, census region, poverty level, insurance status, smoking status, BMI category, and MEPS year.

After adjusting for the main covariates (Model 1, Table 4.2), the mean annual expenditure difference per capita for inactive adults compared to active adults was $1372 (percent increase: 30.0%) and for insufficiently active compared to active adults was $788 (17.6%). After including BMI category as a covariate (Model 2, Table 4.2), the mean annual expenditure and percent difference for inactive adults ($1248, 26.6%) and insufficiently active adults ($661, 14.4%) decreased slightly but remained significant. After including an interaction term in for physical activity by BMI category (Model 3, Table 4.2), overall estimates were similar to results for Model 1 and 2.

The percentage of aggregate health care expenditures associated with inadequate levels of physical activity (i.e., inactive and insufficiently active) was 12.9% and remained significant after adjusting for BMI (11.5%, Table 4.2). After adjusting for BMI (Model 2), an estimated $118 billion (95% CI: $76 billion, $160 billion) of health care expenditures per year were associated with inadequate levels of physical activity.

To examine whether there was an interaction between physical activity and BMI, estimates of mean expenditure difference (compared to active) and percent difference were compared for each BMI category using two models. Model 2 included covariates, physical activity, and BMI category. Model 3 added an interaction term between physical activity and BMI category. No significant differences were found between estimates from Models 2 and 3 by BMI category (Table 4.3). Estimates from both models showed the mean expenditure difference for inactive and insufficiently active adults compared with active adults was higher among obese adults versus normal weight and overweight adults; however, these comparisons were only significant for Model 2. The percent difference in expenditures was similar (i.e., no significant differences noted) across BMI categories using each model, and percent differences estimated for each BMI category were similar to overall estimates.

Sensitivity Analysis

Mean differences in expenditures for inactive and insufficiently active adults (compared to active) remained significant after excluding adults who reported at baseline ever having a heart attack or stroke; needing help getting in/out of bed or chairs, using the toilet, or getting around the home; difficulty walking because of a health problem; who died during the MEPS year; or who were aged 80 or over (Figure 1).

The largest overall change was observed when adults who reported any difficulty walking because of a health problem were excluded; therefore, all estimates were recalculated after this exclusion (Table 4.4). This exclusion resulted in removing 4.2% of the population. About 44.8% of adults who reported difficulty walking were aged 70 years or older, 51.9% had public insurance only for the year, 63.6% were inactive, and 17.9% were active. After removing those who reported difficulty walking, the total annual health care expenditure was $883 billion or 86.6% of spending for the full population.

Among adults reporting no difficulty walking, the percentage of health care expenditures associated with inadequate levels of physical activity was significant at an estimated 10.1% and remained significant after adjusting for BMI (8.9%, Table 4.4), resulting in about $78 billion (95% CI: $42 billion, $115 billion) of health care expenditures per year being associated with inadequate levels of physical activity.

Discussion

During 2006-2010, an estimated 11.5% of aggregate health care expenditures were associated with inadequate levels of aerobic physical activity, independent of BMI. Conservatively, if those who reported any difficulty walking were excluded, 8.9% of aggregate health care expenditures were associated with inadequate levels of physical activity. The considerable financial burden associated with inadequate levels of physical activity in the U.S. could potentially be reduced by increasing adults' physical activity to levels consistent with guidelines and *Healthy People 2020* objectives.[2,31] Efforts to change physical inactivity are especially important given the high prevalence and associated high per capita costs.

Our study found that adequate levels of aerobic physical activity were associated with reduced costs regardless of obesity status. The absolute difference in mean expenditures for inactive and insufficiently active adults (compared to active) was greater among obese than normal weight and overweight adults; however, the relative differences (i.e., percent difference) in health care expenditures were similar, regardless of obesity status.

It is difficult to compare our findings with other studies linking physical activity and health care expenditures because of the numerous measures and methods that have been used.[10-18] There are two studies whose findings can be roughly equated to our defined physical activity levels, and findings from these studies were similar to ours. In a study of Australian women age 50 to 55 years, the percent difference in costs for sedentary versus moderately-active (a level consistent with current guidelines) women was 26.3%.[13] In a second study of enrollees age 40 years or older in a Minnesota health plan, each additional "active" day per week was associated with a 4.7% decrease in cost. Thus, 5 days of activity would represent about a 23.5% reduction compared with no days of physical activity.[14]

Reverse causality is a concern for this study. It could be argued that some persons who are not physically active have higher health care expenditures because previous health events limit their ability to be active while also increasing health care expenditures. We addressed this issue with two elements of the study design. First, there is a 1 to 2 year lag between the physical activity assessment and the time when health care expenditure data are collected; therefore, any new health events captured in the health care expenditure measure would not directly influence an individual's physical activity level. Second, adults who reported being unable to do physical activity were excluded from the analytic sample.

We also conducted multiple sensitivity analyses that excluded certain individuals from our study population. When individuals who reported previous health events, limitations, and difficulty walking, or who died during the MEPS year were excluded, estimates of mean differences in health care expenditures for inactive adults decreased compared to active adults, although they were still significant. There are two plausible explanations for this decrease: 1) individuals were inactive because of poor health, confounding our association, and when we adjusted for markers of poor health the association decreased; or 2) our sensitivity analyses controlled for ways physical activity might influence health care expenditures, and the association decreased as some of the influences were removed. For example, when we excluded adults who reported difficulty walking because of a health problem, we removed the influence physical activity may have had on these individuals experiencing the health problem and their ability to maintain function after the health problem. If someone had been active prior to the event and had become inactive, to include the individual would overestimate the costs of inactivity; however, if the individual had been inactive prior to the health event and remained inactive, excluding that person would result in an underestimate. Given our data, we were unable to determine which of these explanations was more likely. However, through our multiple sensitivity analyses we have shown that our findings are robust to different sample specifications. We also have provided estimates for the more conservative model that excludes those reporting difficulty walking.

Several limitations of our study are noted. We used observational data, which may have biased the observed associations by introducing confounding factors. We attempted to reduce such bias by controlling for several factors; however, we were not able to control for all potential confounding factors. For example, active adults may have had positive health behaviors related to diet, sleep, or participation in preventive care. Second, MEPS data rely on one household informant to report health care expenditures for all household members with a sample of expenditures further verified and supplemented with data from medical providers.[23] Some studies have shown that expenditures may be underreported, though they concluded that behavioral analyses are largely unaffected by this issue because underreporting is similar across demographic groups.[32,33] Third, NHIS physical activity data are derived from self-reported information, and studies have indicated that reporting bias can result in high estimates of physical activity.[34] However, individuals overestimating their physical activity would likely lead to a more conservative estimate of the association between physical activity and health care expenditures. Finally, the physical activity measure is based only on leisure-time activity and this may have resulted in an underestimate of physical activity levels when individuals' work hours and occupations are considered.

This study has several important strengths. First, data from the NHIS and MEPS include a large, nationally representative sample, allowing for broad generalizability of findings to non-institutionalized U.S. adults. In addition, the NHIS and the MEPS contained relevant variables that allowed us to include many covariates and to conduct multiple sensitivity analyses. Finally, our physical activity measures categorized individuals into levels consistent with current physical activity guidelines.[2]

Conclusions

Inadequate physical activity is associated with a significant financial burden. Our estimates are likely conservative because we calculated only the direct health care expenditures associated with inadequate physical activity and did not estimate indirect costs, which include lost productivity from premature death and disability associated with illness. Future studies that consider indirect costs may improve estimates of the economic burden of inadequate physical activity in the U.S. Nevertheless, we found that inadequate levels of physical activity are associated with a significant percentage of health care expenditures. Increasing adults' physical activity levels to meet current guidelines may be one way to reduce health care expenditures in the U.S.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

References

1. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report, 2008.* Washington, DC: U.S. Department of Health and Human Services;2008.

2. US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans.* Washington, DC: U.S. Department of Health and Human Services;2008.

3. Carlson SA, Fulton JE, Schoenborn CA, Loustalot F. Trend and prevalence estimates based on the 2008 Physical Activity Guidelines for Americans. *Am J Prev Med.* Oct 2010;39(4):305-313.

4. Allender S, Foster C, Scarborough P, Rayner M. The burden of physical activity-related ill health in the UK. *J Epidemiol Commun H.* Apr 2007;61(4):344-348.

5. Colditz GA. Economic costs of obesity and inactivity. *Med Sci Sports Exerc.* Nov 1999;31(11 Suppl):S663-667.

6. Garrett NA, Brasure M, Schmitz KH, Schultz MM, Huber MR. Physical inactivity: direct cost to a health plan. *Am J Prev Med.* Nov 2004;27(4):304-309.

7. Katzmarzyk P, Janssen I. The economic costs associated with physical inactivity and obesity in Canada: an update. *Can J Appl Physiol.* 2004;29(1):90-115.

8. Katzmarzyk PT, Gledhill N, Shephard RJ. The economic burden of physical inactivity in Canada. *CMAJ.* Nov 28 2000;163(11):1435-1440.

9. Popkin BM, Kim S, Rusev ER, Du S, Zizza C. Measuring the full economic costs of diet, physical activity and obesity-related chronic diseases. *Obes Rev.* Aug 2006;7(3):271-293.

10. Pratt M, Macera CA, Wang G. Higher direct medical costs associated with physical inactivity. *Phys Sportsmed.* Oct 2000;28(10):63-70.

11. Anderson LH, Martinson BC, Crain AL, et al. Health care charges associated with physical inactivity, overweight, and obesity. *Prev Chronic Dis.* Oct 2005;2(4):A09.

12. Bland PC, An L, Foldes SS, Garrett N, Alesci NL. Modifiable health behaviors and short-term medical costs among health plan members. *Am J Health Promot.* Mar-Apr 2009;23(4):265-273.

13. Brown WJ, Hockey R, Dobson AJ. Physical activity, Body Mass Index and health care costs in mid-age Australian women. *Aust N Z J Public Health.* Apr 2008;32(2):150-155.

14. Pronk NP, Goodman MJ, O'Connor PJ, Martinson BC. Relationship between modifiable health risks and short-term health care charges. *Jama-J Am Med Assoc.* Dec 15 1999;282(23):2235-2239.

15. Wang F, McDonald T, Reffitt B, Edington DW. BMI, physical activity, and health care utilization/costs among Medicare retirees. *Obes Res.* Aug 2005;13(8):1450-1457.

16. Yang G, Niu K, Fujita K, et al. Impact of physical activity and performance on medical care costs among the Japanese elderly. *Geriatr Gerontol Int.* Apr 2011;11(2):157-165.

17. 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.* May 2004;46(5):428-436.

18. Wang G, Pratt M, Macera CA, Zheng ZJ, Heath G. Physical activity, cardiovascular disease, and medical expenditures in U.S. adults. *Ann Behav Med.* Oct 2004;28(2):88-94.

19. Bell JF, Zimmerman FJ, Arterburn DE, Maciejewski ML. Health-care expenditures of overweight and obese males and females in the medical expenditures panel survey by age cohort. *Obesity (Silver Spring).* Jan 2011;19(1):228-232.

20. Finkelstein EA, Fiebelkorn IC, Wang G. National medical spending attributable to overweight and obesity: how much, and who's paying? *Health Aff (Millwood).* Jan-Jun 2003;Suppl Web Exclusives:W3-219-226.

21. Finkelstein EA, Trogdon JG, Cohen JW, Dietz W. Annual medical spending attributable to obesity: payer-and service-specific estimates. *Health Aff (Millwood).* Sep-Oct 2009;28(5):w822-831.

22. National Center for Health Statistics (NCHS). National Health Interview Survey (NHIS). 2013; http://www.cdc.gov/nchs/nhis.htm. Accessed November 3, 2013.

23. Agency for Healthcare Research and Quality (AHRQ). Medical Expenditure Panel Survey (MEPS). 2013; http://www.meps.ahrq.gov/mepsweb/. Accessed November 3, 2013.

24. National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. 1998; http://www.nhlbi.nih.gov/guidelines/obesity/ob_gdlns.pdf.

25. Agency for Healthcare Research and Quality. Using appropriate price indices for analyses of health care expenditues or income across multiple years. 2013;

http://meps.ahrq.gov/mepsweb/about_meps/Price_Index.shtml. Accessed June 19, 2013.

26. Duan N, Manning WG, Morris CN, Newhouse JP. *A comparison of alternative models for the demand for medical care.* Santa Monica, CA: RAND Corporation;1982.

27. Manning WG, Mullahy J. Estimating log models: to transform or not to transform? *Journal of Health Economics.* 2001;20:461-494.

28. Buntin MB, Zaslavsky AM. Too much ado about two-part models and transformation? Comparing methods of modeling Medicare expenditures. *Journal of Health Economics.* May 2004;23(3):525-542.

29. Adams EK, Melvin CL, Raskind-Hood C, Joski PJ, Galactionova E. Infant delivery costs related to maternal smoking: an update. *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco.* Aug 2011;13(8):627-637.

30. Cohen SB. *An estimation methodology to permit longitudinal cohort analyses based on the National Health Interview Survey and Medical Expenditure Panel Survey.* Rockville, MD: Agency for Healthcare Research and Quality (AHRQ);2010.

31. U.S. Department of Health and Human Services. Healthy People 2020. 2012; http://www.healthypeople.gov/2020/topicsobjectives2020/default.aspx. Accessed December 1, 2012.

32. Zuvekas SH, Olin GL. Validating household reports of health care use in the medical expenditure panel survey. *Health Serv Res.* Oct 2009;44(5 Pt 1):1679-1700.

33. Zuvekas SH, Olin GL. Accuracy of Medicare expenditures in the medical expenditure panel survey. *Inquiry.* Spring 2009;46(1):92-108.

34. Sallis JF, Saelens BE. Assessment of physical activity by self-report: status, limitations, and future directions. *Res Q Exerc Sport.* Jun 2000;71(2 Suppl):S1-14.

Table 4.1. Distribution of Select Characteristics and Prevalence of Physical Activity Level by Select Characteristics, U.S. Adults, NHIS and MEPS 2006-2010[a]

	Overall		Prevalence of Physical Activity Level					
	Sample Size (%)[c]		Inactive (N=16 715)		Insufficiently Active (N=8318)		Active (N=16 959)	
Characteristic[b]			%	(SE)	%	(SE)	%	(SE)
Overall	41 992	(100)	34.9	(0.7)	19.9	(0.4)	45.1	(0.6)
Sex								
Male	18 855	(50.2)	33.8	(0.8)	18.1	(0.6)	48.1	(0.8)
Women	23 137	(49.8)	36.1	(0.9)	21.7	(0.5)	42.2	(0.7)
Age (years)								
20-29	5753	(17.3)	29.2	(1.2)	17.1	(0.9)	53.7	(1.3)
30-39	7886	(18.1)	30.2	(1.1)	19.6	(0.7)	50.2	(1.1)
40-49	8369	(20.0)	33.3	(1.0)	20.1	(0.7)	46.6	(1.0)
50-59	7829	(19.2)	35.1	(1.1)	21.3	(0.8)	43.6	(1.0)
60-69	5751	(13.1)	38.0	(1.3)	21.6	(1.0)	40.4	(1.2)
70-79	3766	(7.5)	44.1	(1.6)	20.0	(1.1)	35.9	(1.5)
≥80	2638	(4.9)	56.7	(1.9)	19.5	(1.4)	23.8	(1.6)
Race/ethnicity								
White, non-Hispanic	23 146	(68.9)	30.7	(0.8)	20.3	(0.5)	48.9	(0.7)
Black, non-Hispanic	7941	(11.3)	44.9	(1.4)	18.9	(0.9)	36.2	(1.0)
Hispanic	7919	(13.4)	47.9	(1.2)	18.2	(0.8)	34.0	(1.2)
Other, non-Hispanic	2986	(6.4)	35.7	(1.6)	20.6	(1.4)	43.6	(1.8)
Education level								
Less than HS graduate	8652	(14.4)	57.2	(1.3)	17.5	(0.9)	25.3	(1.0)
High school graduate	11 312	(27.1)	44.0	(1.1)	19.8	(0.7)	36.2	(1.0)
Some college	11 834	(29.5)	30.1	(0.9)	21.5	(0.6)	48.4	(0.9)
College graduate	10 194	(28.9)	20.3	(0.8)	19.6	(0.7)	60.2	(0.9)
Marital status								
Married	19 516	(55.8)	33.2	(0.9)	21.0	(0.5)	45.8	(0.7)
Widowed	4290	(6.8)	53.1	(1.5)	20.7	(1.1)	26.2	(1.3)

Divorced/separated	8385	(14.2)	38.3	(1.0)	19.5	(0.8)	42.2	(1.0)
Never married	9801	(23.1)	31.6	(1.1)	17.4	(0.7)	51.0	(1.1)
Census region								
Northeast	6362	(18.6)	35.4	(1.5)	20.2	(0.9)	44.3	(1.5)
Midwest	9133	(21.8)	28.9	(1.5)	24.1	(1.0)	47.0	(1.1)
South	16 278	(36.5)	40.8	(1.4)	17.8	(0.8)	41.4	(1.0)
West	10 219	(23.1)	31.0	(1.3)	19.0	(0.7)	50.0	(1.2)
Poverty status (income as percentage of federal poverty level (FPL))								
< 100% FPL	7225	(10.7)	50.0	(1.2)	17.7	(0.8)	32.2	(1.1)
100%-199% FPL	9230	(17.1)	46.5	(1.0)	19.2	(0.6)	34.3	(0.9)
200%-400% FPL	12 431	(30.6)	36.8	(1.0)	20.6	(0.6)	42.6	(0.9)
> 400% FPL	13 106	(41.6)	24.9	(0.8)	20.2	(0.6)	54.8	(0.8)
Insurance status (coverage for the year)								
Any private coverage	25 876	(69.6)	28.9	(0.8)	20.6	(0.5)	50.5	(0.7)
Public insurance only	9080	(15.0)	52.5	(1.2)	19.6	(0.8)	27.9	(1.1)
Uninsured for full year	7036	(15.5)	45.0	(1.3)	17.2	(0.8)	37.7	(1.0)
Smoking								
Current	8863	(20.7)	41.8	(1.4)	17.9	(0.8)	40.2	(1.2)
Former	8992	(21.8)	30.9	(0.9)	21.7	(0.8)	47.4	(1.0)
Never	24 137	(57.4)	34.0	(0.8)	20.0	(0.5)	46.1	(0.6)
BMI category[d]								
Normal weight	14 591	(36.6)	31.6	(0.8)	18.0	(0.6)	50.5	(0.8)
Overweight	15 112	(36.2)	34.6	(1.0)	19.1	(0.7)	46.3	(0.9)
Obese	12 289	(27.3)	40.0	(1.0)	23.6	(0.7)	36.4	(0.8)
MEPS year								
2006	8815	(19.5)	36.8	(1.1)	18.7	(0.6)	44.5	(0.9)
2007	7957	(19.8)	35.8	(1.0)	19.9	(0.6)	44.3	(0.9)
2008	8116	(19.9)	35.4	(1.1)	19.6	(0.8)	45.1	(1.0)

2009	8822	(20.3)	34.9	(1.0)	19.9	(0.7)	45.2	(0.9)
2010	8282	(20.5)	31.9	(1.1)	21.5	(0.6)	46.6	(0.9)

[a] There were 48 083 adults age 20 years or older with NHIS and MEPS records. 3157 adults were excluded for missing covariate, BMI, or physical activity data. Certain adults were excluded from the analysis: 1381 who were pregnant during the MEPS year, 906 who reported being unable to do physical activity, and 647 who were classified as underweight.

[b] Covariate data from the MEPS dataset included: sex, age, race/ethnicity, marital status, census region, poverty level, and insurance status. Covariate data from the NHIS interview included: education level, BMI, and smoking status.

[c] Estimates of % are weighted.

[d] BMI category is defined as normal weight (BMI < 25 kg/m^2), overweight (BMI 25 - $<$ 30 kg/m^2), and obese (BMI ≥ 30 kg/m^2).

Table 4.2. Expenditure Differences, Percent Differences, and Percentage of Aggregate Health Care Expenditures of Inactive and Insufficiently Active Versus Active Physical Activity Levels, U.S. Adults, NHIS and MEPS 2006-2010[a]

Model and Physical Activity Level	Health Care Expenditure Difference per Capita (Compared to Active)		Percent Difference per Capita (Compared to Active)		Percentage of Aggregate Health Care Expenditures	
	Mean ($)[b]	(95% CI)	%	(95% CI)	%	(95% CI)
Model 1: Physical activity and covariates[c]						
Inactive	1372	(898, 1846)	30.0	(18.4, 41.6)	9.7	(6.4, 13.0)
Insufficiently active	788	(378, 1197)	17.6	(8.1, 27.1)	3.2	(1.6, 4.8)
Inactive and insufficiently active	[e]	[e]	[e]	[e]	12.9	(8.9, 16.9)
Model 2: Physical activity, BMI category, and covariates[c]						
Inactive	1248	(770, 1727)	26.6	(15.3, 37.9)	8.9	(5.5, 12.2)
Insufficiently active	661	(261, 1061)	14.4	(5.4, 23.4)	2.7	(1.1, 4.3)
Inactive and insufficiently active	[e]	[e]	[e]	[e]	11.5	(7.5, 15.6)
Model 3: Physical activity, BMI category, physical activity by BMI category interaction term, and covariates[c,d]						
Inactive	1278	(787, 1769)	27.3	(15.7, 39.0)	9.1	(5.7, 12.5)
Insufficiently active	671	(248, 1094)	14.6	(5.1, 24.2)	2.7	(1.0, 4.4)
Inactive and insufficiently active	[e]	[e]	[e]	[e]	11.8	(7.5, 16.0)

[a] Excludes adults who were pregnant during the MEPS year, those underweight, and those who reported being unable to do physical activity.
[b] Expenditures adjusted to 2011 dollars using the Personal Health Care Expenditure Price Index.
[c] Covariates include sex, age group, race/ethnicity, census region, marital status, education, poverty level, health insurance status, smoking status, and MEPS year.

[d] Model 3 included terms for the main effect of physical activity level and BMI category, as well as an interaction term of physical activity level by BMI category.
[e] Estimates of mean differences and percent differences are based on models including inactive and insufficiently active as distinct categories therefore these estimates are not provided for the combined group.

Table 4.3. Expenditure Differences and Percent Differences of Inactive and Insufficiently Active Versus Active Physical Activity Levels, by Model and BMI Category, U.S. Adults, NHIS and MEPS 2006-2010[a]

BMI Category by Physical Activity Level	Model 2: Physical Activity, BMI Category, and Covariates[b]				Model 3: Physical Activity, BMI Category, Physical Activity by BMI Category Interaction Term, and Covariates[b,c]			
	Health Care Expenditure Difference per Capita (Compared to Active)		Percent Difference per Capita (Compared to Active)		Health Care Expenditure Difference per Capita (Compared to Active)		Percent Difference per Capita (Compared to Active)	
	Mean ($)[d]	(95% CI)	%	(95% CI)	Mean ($)[d]	(95% CI)	%	(95% CI)
Normal weight								
Inactive	1055	(635, 1474)	26.4	(15.1, 37.7)	1167	(510, 1824)	29.8	(11.3, 48.2)
Insufficiently active	535	(210, 859)	14.2	(5.4, 23.0)	591	(-133, 1315)	16.0	(-4.0, 35.9)
Overweight								
Inactive	1220	(741, 1698)	27.1	(15.5, 38.8)	1080	(324, 1836)	23.6	(5.4, 41.9)
Insufficiently active	673	(262, 1084)	14.7	(5.3, 24.0)	607	(-71, 1285)	13.0	(-2.1, 28.2)
Obese								
Inactive	1486	(917, 2056)	26.3	(15.2, 37.5)	1622	(727, 2516)	29.0	(10.4, 47.6)
Insufficiently active	776	(305, 1247)	14.2	(5.2, 23.2)	821	(-214, 1856)	15.2	(-5.2, 35.6)

[a] Excludes adults who were pregnant during the MEPS year, those underweight, and those who reported being unable to do physical activity.
[b] Covariates include sex, age group, race/ethnicity, census region, marital status, education, poverty level, health insurance status, smoking status, and MEPS year.
[c] Model 3 included terms for the main effect of physical activity level and BMI category, as well as an interaction term of physical activity level by BMI category.
[d] Expenditures adjusted to 2011 dollars using the Personal Health Care Expenditure Price Index.

Table 4.4. Expenditure Differences, Percent Differences, and Percentage of Aggregate Health Care Expenditures of Inactive and Insufficiently Active Versus Active Physical Activity Levels, U.S. Adults, Excluding Those Who Reported Difficulty Walking, NHIS and MEPS 2006-2010[a]

	Health Care Expenditure Differences per Capita (Compared to Active)		Percent Differences per Capita (Compared to Active)		Percentage of Aggregate Health Care Expenditures	
Model and Physical Activity Level	**Mean ($)[b]**	**(95% CI)**	**%**	**(95% CI)**	**%**	**(95% CI)**
Model 1: Physical activity and covariates[c]						
Inactive	969	(539, 1399)	23.5	(12.1, 34.9)	7.3	(4.1, 10.6)
Insufficiently active	619	(206, 1033)	14.8	(4.6, 24.9)	2.8	(0.9, 4.6)
Inactive and insufficiently active	[d]	[d]	[d]	[d]	10.1	(6.1, 14.2)
Model 2: Physical activity, BMI category, and covariates[c]						
Inactive	871	(434, 1308)	20.7	(9.5, 31.9)	6.6	(3.3, 9.9)
Insufficiently active	504	(100, 907)	11.7	(2.1, 21.4)	2.3	(0.5, 4.1)
Inactive and insufficiently active	[d]	[d]	[d]	[d]	8.9	(4.8, 13.0)

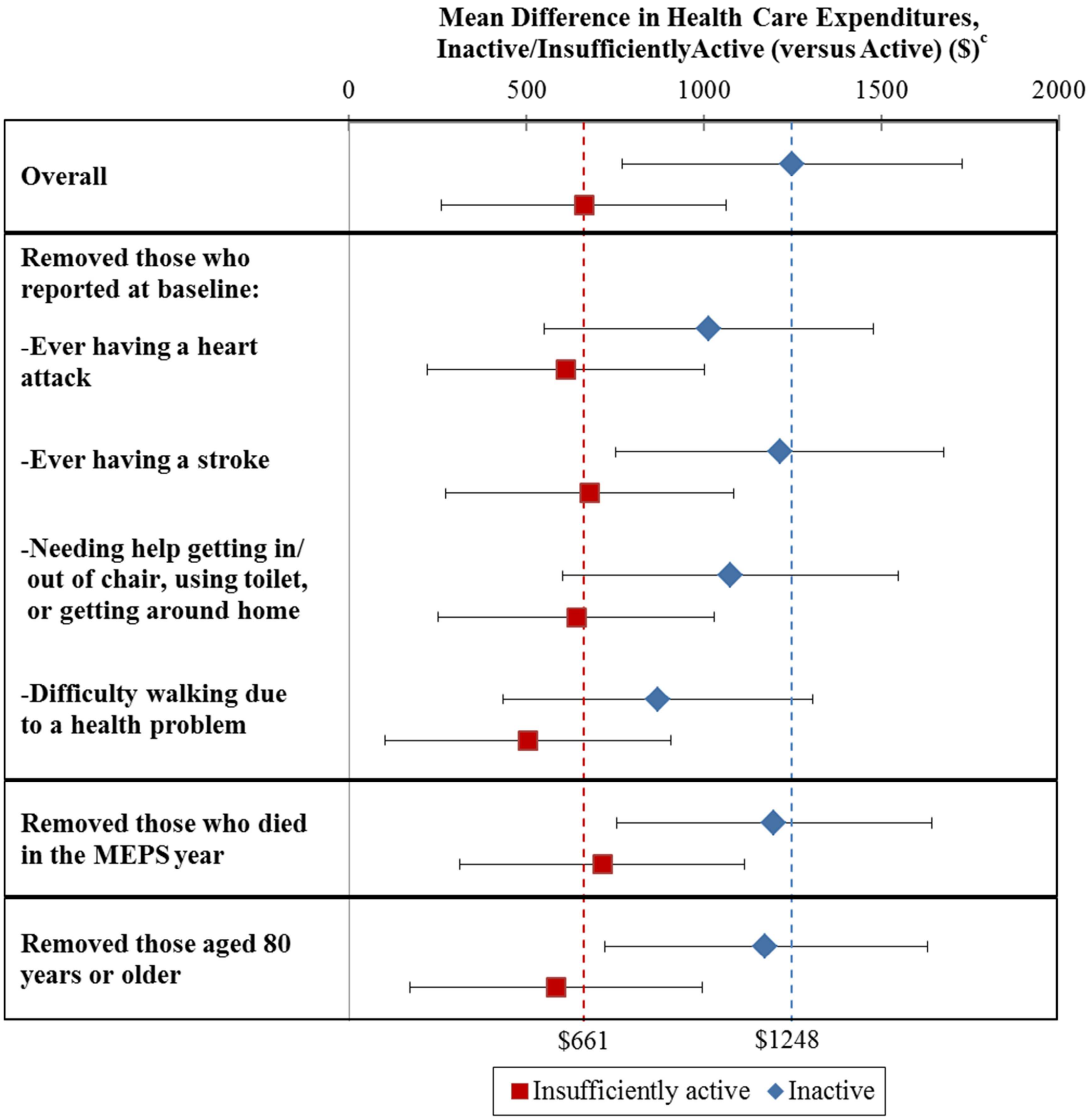
[a] Excludes adults who were pregnant during the MEPS year, those underweight, and those who reported being unable to do physical activity. In addition, excludes 2525 adults (4.2%) who reported difficulty walking (without the use of equipment) because of a health problem.

[b] Expenditures adjusted to 2011 dollars using the Personal Health Care Expenditure Price Index.

[c] Covariates include sex, age group, race/ethnicity, census region, marital status, education, poverty level, health insurance status, smoking status, and MEPS year.

[d] Estimates of mean difference and percent difference are based on models including inactive and insufficiently active as distinct categories therefore these estimates are not provided for the combined group.

Figure 1. Mean Expenditure Differences per Capita of Inactive and Insufficiently Active Versus Active Physical Activity Levels, after Selected Exclusions, U.S. Adults, NHIS and MEPS 2006-2010[a,b]



[a] Excludes adults who were pregnant during the MEPS year, those underweight, and those who reported being unable to do physical activity. The number of adults excluded for each subanalysis was: 1506 reported ever having a heart attack at baseline; 1234 reported ever having a stroke at baseline; 403 who reported at baseline needing help getting in/out of bed or chairs, using toilet, or getting around the home; 2525 who reported at baseline difficulty walking (without the use of equipment) because of a health problem; 409 who died during MEPS survey year; or 2638 ≥ 80 years of age.

[b] Model covariates included: sex, age group, race/ethnicity, census region, marital status, education, poverty level, health insurance status, smoking status, BMI category, and MEPS year. Upper and lower error bars represent upper and lower bounds of the 95% CI. Red and blue vertical lines represent overall estimates.

[c] Expenditures adjusted to 2011 dollars using the Personal Health Care Expenditure Price Index.

Chapter 5: Physical activity and Depression- and Anxiety-Specific Health Care Expenditures

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Abstract

Objective. Estimate the percentage of depression- and anxiety-specific health care expenditures associated with levels of aerobic physical activity inadequate to meet current guidelines using two approaches.

Methods. Merged adults' leisure-time aerobic physical activity data from the National Health Interview Survey (2003-2009) with health care expenditure data from the Medical Expenditure Panel Survey (2005-2010). To estimate the percentage of condition-specific health care expenditures associated with inadequate physical activity, the attributable fraction (AF) approach applied epidemiologic formulas and the regression based (RB) approach used 2-part econometric models. Inadequate physical activity was defined as participating in less than 150 minutes per week of moderate-intensity equivalent activity.

Results. Annually 9.4% of adults reported depression and 8.5% reported anxiety. With the RB approach, the estimated percentage of depression- and anxiety-specific health care expenditures associated with inadequate physical activity was significantly higher (21.2%) than with the AF approach (11.1%). Percentage estimates were higher when examining depression and anxiety separately with the RB approach (depression: 21.9%, anxiety: 17.2%) compared to the AF approach (depression: 13.2%, anxiety: 7.5%); however, differences were not significant.

Conclusion. Inadequate physical activity is associated with a significant percentage of depression- and anxiety-specific health care expenditures regardless of the approach used.

Introduction

Mental health conditions impose an emotional and financial burden on individuals and their families. Beyond the medical resources spent on care, treatment, and rehabilitation, poor mental health is also associated with higher indirect costs due to reduced or lost productivity.[1] Depression and anxiety are the two most commonly reported mental health conditions. Among U.S. adults, depression has an annual prevalence of 9.0% [2] and estimates of the annual prevalence of anxiety range from 10.6% to 18.1%.[3,4]

Physical activity has been shown to lower the risk of depression and anxiety. Population-based prospective cohort studies provide substantial evidence that regular physical activity protects against the onset of depressive symptoms.[5] Studies have shown, compared to inactive adults, the odds of having depressive symptoms were 15 to 25% lower among those physically active.[5] Evidence for the association between physical activity and anxiety is limited; however, evidence suggests regular physical activity protects against the onset of anxiety disorders and symptoms.[5] In addition, physical activity can play an important role in the treatment of depression and anxiety by reducing symptoms of depression and anxiety among those with the condition.[6,7]

Given the role that physical activity plays in the development and treatment of depression and anxiety, it is likely that inadequate levels of physical activity are associated with a substantial percentage of depression- and anxiety-specific health care expenditures. Previous studies have found that physical activity is associated with increased overall health care expenditures among adults with symptoms of depression or mental disorders.[8,9] No study, however, has estimated the percentage of depression- and anxiety-specific expenditures associated with physical activity levels inadequate to meet current guidelines.

To estimate the economic burden of inadequate levels of physical activity on depression- and anxiety-specific health care expenditures, two analytic approaches could be applied. The attributable fraction (AF) approach combines relative risk and prevalence to estimate the percentage of a condition associated with inadequate levels of physical activity.[10] The major limitation of the AF approach is it is predicated on physical activity's influence on the presence of depression or anxiety, treated or not. The AF approach does not account for the influence of physical activity on health care expenditures among those with depression or anxiety.

A regression based (RB) approach uses a multivariate regression model to compare depression- and anxiety-specific health care expenditures among people of different physical activity levels. The percentage of health care expenditures associated with inadequate levels of physical activity is based on predictions from the estimated model.[10] If there is a positive association between inadequate physical activity and the cost to treat depression or anxiety then a RB approach will produce higher estimates than the AF approach. However, the RB approach can be challenging to implement as is it requires physical activity information from individuals linked to depression- and anxiety-specific health care expenditures.

National estimates for the percentage of depression- and anxiety-specific health care expenditures associated with inadequate levels of physical activity do not currently exist. Assessing the percentage of the depression- and anxiety-specific expenditures attributable to inadequate levels of physical activity is important for setting research and policy priorities overall and specifically for programs addressing these conditions. Using AF and RB approaches, this study will estimate the percentage of depression- and anxiety-specific health care expenditures associated with inadequate levels of physical activity.

Methods

Data

Data from the National Health Interview Survey (NHIS) (2003–2009) and the Medical Expenditure Panel Survey (MEPS) (2005–2010) were merged. The NHIS is a multi-stage probability sample survey of U.S. households conducted annually. Data on leisure-time aerobic physical activity are collected during the sample adult interview. The MEPS uses the same sampling frame as the NHIS. Respondents from the previous 2 years of NHIS are included in each MEPS year. MEPS response rates ranged from 56.9% (2007) to 59.3% (2008). Additional information about the sample design of the NHIS and the MEPS are described elsewhere.[11,12]

There were 58 322 adults 20 years or older with NHIS sample adult records and MEPS records and 3854 adults were excluded for missing physical activity or covariate data. Three individuals were excluded due to high depression-specific expenditures (>$40 k) that resulted in models systematically over predicting depression-specific expenditures. Adults who were pregnant during the MEPS year (1712) and adults who reported being unable to do physical activity (1112) were excluded (final sample size: 51 641).

Measures

Physical activity level. In the NHIS, adults were asked how often and, if applicable, the duration during leisure-time they participated for at least 10 minutes at a time, in 1) vigorous-intensity activities (i.e., heavy sweating or large increases in breathing or heart rate) and 2) light- or moderate-intensity activities (i.e., light sweating or slight to moderate increases in breathing or heart rate). Current guidelines recommend adults obtain ≥ 150 minutes of moderate-intensity equivalent aerobic physical activity per week to obtain substantial health benefits.[13] Based on current guidelines,[13] 1 minute of vigorous-intensity activity was counted as 2 minutes of moderate-intensity activity to calculate minutes of moderate-intensity equivalent activity. Respondents were classified into three physical activity levels: 1) active, if they reported at least 150 minutes/week of moderate-intensity equivalent physical activity; 2) insufficiently active, if they reported some physical activity but not enough to meet guidelines; 3) inactive, if they reported no leisure-time physical activity.[13]

Presence of depression and anxiety. In the MEPS, information on the presence of health conditions was asked of the household respondent. Respondents were asked: "Now we are going to focus on health problems that have actually bothered anyone in the family since [*start date*] and between [*end date*]. Health problems include physical conditions, accidents, or injuries that affect any part of the body as well as mental or emotional health conditions, such as feeling sad, blue, or anxious about something".[11] The usual recall period was 5 to 6 months. Responses were recorded verbatim then coded into ICD-9 codes and subsequently Clinical Classification Software (CCS) categories.[14] To identify depression, the ICD-9 code 311 (i.e., depressive disorder, not elsewhere classified) was used. To identify anxiety, the CCS category 651 (i.e., anxiety disorder) was used. Dichotomous indicators for the presence of 1) depression, 2) anxiety, and 3) depression and/or anxiety were created.

Condition-specific health care expenditures. If a condition resulted in a medical event, including in-patient, out-patient, office-based, home health, prescription drugs, or emergency room visits, the cost for the event was linked to the associated condition. A continuous variable of total condition-specific health care expenditures per year was created for depression, anxiety, and combined depression and/or anxiety related events. When an event was associated with multiple conditions, total expenditures for the event was equally divided by the number of conditions for which the event was associated.[10] The Personal Health Care Expenditure (PHCE) Price Index was used to adjust expenditures to 2011 dollars.[15]

Statistical Analysis

We applied statistical weights and used balanced repeated replication to produce estimates representative of the civilian, non-institutionalized U.S. population and to account for the complex sample design. In the NHIS, only one sampled adult per household is asked questions about physical activity, and we adjusted MEPS person-year weights to account for this sampling.[16] The final step of this adjustment used a raking procedure[17] to adjust weights to match population totals from the full MEPS sample, which are based on U.S. census totals.

Covariates included in all models were: sex, age group, race/ethnicity, census region, marital status, education, poverty level, health insurance status, smoking status, BMI category (i.e., underweight/normal weight (<25 kg/m^2), overweight (25-<30 kg/m^2), and obese (≥30 kg/m^2), and MEPS year.[18]

Attributable Fraction (AF) Approach. To estimate the percentage of condition-specific health care expenditures attributable to a given level of physical activity, the general equation for estimating attributable fractions when confounding exists was used [PAF= p_d * (RR-1)/RR].[19] P_d is the prevalence of the given physical activity level among those reporting depression or anxiety. The RR was estimated using a standardized prevalence risk ratio calculated from a logit model examining the association between physical activity level and the presence of depression or anxiety.[20] To estimate aggregate costs associated with inactive and insufficiently active levels of physical activity, the PAF is multiplied by estimates of aggregate depression- or anxiety-specific health care expenditures derived by summing condition-specific health care expenditures across all adults. To calculate the percentage of depression- and anxiety-specific health care expenditures, aggregate costs associated with inactive and insufficiently active levels of physical activity were estimated separately for depression and anxiety, summed, and then divided by total depression- and anxiety-specific health care expenditures.

Regression Based (RB) Approach. A two-part regression model was implemented for the RB approach.[21] First, a logit model predicted the probability of having a positive condition-specific health care expenditure. Second, a generalized linear model (GLM) with a log link and gamma distribution predicted total condition-specific health care expenditures for adults with a positive condition-specific health care expenditure. Modified Park tests were used to determine the appropriate distribution specification for the GLM models.[22] Predictions from the two-part model were combined to generate total predicted condition-specific health care expenditures for each individual. The percentage of aggregate health care expenditures related to the inactive level was calculated by dividing the mean differences in condition-specific health care expenditures for those inactive compared to active (i.e., predicted expenditure with the inactive variable set to 1 minus predicted expenditure with the inactive variable set to 0) by the total predicted condition-specific expenditures for all adults.[23] Calculations were repeated for those insufficiently active. Models were estimated for depression, anxiety, and combined depression- and anxiety-specific health care expenditures.

Results

From 2005-2010, an average of 9.4% of adults 20 years and older reported depression during the year and 8.5% reported anxiety (Table 5.1). Depression and/or anxiety was reported by 15.4% (6.9% depression alone, 6.1% anxiety alone, 2.4% both). The average total yearly condition-specific expenditures for depression was $17.3 billion and $10.1 billion for anxiety.

The majority of adults who reported depression (63.4%) or who reported anxiety (59.2%) did not meet current physical activity guidelines (Table 5.2). Except for the inactive coefficient in the anxiety model which was borderline insignificant (p=0.05), there was a positive significant association between being inactive or insufficiently active (compared to being active) with reporting the presence of depression, anxiety, and depression or anxiety. There were no significant differences in the strength of the association for the presence of depression, anxiety, or depression and/or anxiety when comparing the inactive and insufficiently active level.

Results from the two-part econometric model are shown in Table 5.3. For the first part of the econometric model, there was a positive association between physical activity and having a positive expenditure for each of the conditions, although for the anxiety model the inactive coefficient was insignificant (p=0.11). The second part of the model examined the amount of the condition-specific expenditure among adults who reported any condition-specific expenditure. The inactive coefficient compared to the active coefficient was significant when examining combined depression- and anxiety-specific expenditures and was borderline insignificant when examining depression- (p=0.08) and anxiety-specific (p= 0.08) health care expenditures separately.

Using either approach, the percentage of condition-specific health care expenditures associated with inadequate levels of leisure-time physical activity (i.e., inactive and insufficiently active) were significantly different from zero for depression and for anxiety (Table 5.4). When examining depression and anxiety separately, the percentage of health care expenditures associated with inadequate levels of physical activity was higher when using the RB approach than the AF approach; however, differences were not significant.

The RB approach yielded a significantly greater estimate for the percentage of total depression- and anxiety-specific health care expenditures associated with inadequate levels of physical activity (21.2%) than the AF approach (11.1%, p=0.02, Table 5.4). Using the AF approach, an estimated $3.0 billion (SE: $0.6 billion) of depression- and anxiety-specific annual health care expenditures were associated with inadequate levels of physical activity. Using the RB approach, an estimated $5.8 billion (SE: $1.4 billion) of annual depression- and anxiety-specific health care expenditures were associated with inadequate levels of physical activity.

Sensitivity analysis

Though we had excluded those who reported being unable to do physical activity, we wanted to address the concern that inactive or insufficiently active adults might have health problems that would keep them from participating in physical activity and potentially increase their depression- or anxiety-specific expenditures. So, we conducted a sensitivity analysis that excluded 4.2% of the population who reported difficulty walking due to a health problem. After this exclusion, estimated total annual depression-and anxiety-specific health care expenditures were $24.5 billion. The prevalence of depression and of anxiety was significantly higher among adults with difficulty walking (depression: 22.2%, anxiety: 16.2%, depression and/or anxiety: 31.6%) than those without (depression: 9.0%, anxiety: 8.1%, depression and/or anxiety: 14.8%). Among adults reporting no difficulty walking, the percentage of depression- and anxiety-specific health care expenditures decreased slightly for the AF approach (10.4%, SE: 2.1) and increased slightly for the RB approach (22.6%, SE: 5.3).

Discussion

Inadequate levels of physical activity are associated with a significant percentage of depression- and anxiety-specific health care expenditures. When the RB approach was used the percentage of depression- and anxiety-specific health care expenditures associated with inadequate levels of physical activity was higher (21.2%) than when an AF approach was used (11.1%). The approach used to estimate the percentage of condition-specific spending can greatly influence estimates. The AF approach can be viewed as a lower bound of the cost estimate.

A major strength of the RB approach is that it is able to capture differences in treatment costs related to depression and/or anxiety among adults who are active. Studies have shown that physical activity can reduce symptoms of depression and anxiety among adults with the condition[6,7] and it is important that this treatment benefit be captured in the analytic approach, which the RB approach does. One limitation of the RB approach is it requires physical activity information from individuals linked to condition-specific health care expenditures and such data can lead to estimates with high variability. If individual expenditure information is available, however, the RB approach can be applied for several conditions within a single model. Health care expenditure estimates for a variety of conditions, such as depression and anxiety, can be helpful especially for programs and medical professionals that target multiple conditions and who may need to prioritize what lifestyle behaviors to target among their patients.

No previous studies have estimated the percentage of depression- and anxiety-specific health care expenditures associated with inadequate levels of physical activity at the national level. One previous study used an AF approach which combined estimates of risk and prevalence across multiple sources. This study estimated that 12% of depression- and anxiety-specific health care expenditures was associated with irregular and inactive levels of physical activity among a major health plan in Minnesota.[24] This is similar to our AF estimate of 11.1%.

The magnitude of the association of physical activity levels with depression found in our study are similar to those found in previous studies where being physical active was associated with a 15 to 25% lower odds of depression compared to being inactive.[5] Few studies have examined the association between physical activity and anxiety. The magnitude of the association between physical activity and anxiety found in our study was smaller (inactive: 1.11, insufficiently active: 1.21 (compared to active)) than a previous U.S. study that found regular physical activity (defined as reporting ‘regularly’ when asked how often they get physical activity) reduced the odds of a generalized anxiety disorder by about 24% when compared to being not regularly active.[25] This difference could be in-part explained by the lower prevalence of anxiety in our study compared to other studies.[3] In MEPS, medical conditions are self-reported; while in other studies, diagnostic interviews are conducted to identify individuals with anxiety.[26] Our measure of the prevalence of anxiety (defined as a condition that bothered someone) may have captured more severe anxiety and this may have resulted in our association being more conservative; although, we cannot be sure of this. Studies that examine the association between physical activity and anxiety using standard measures of anxiety symptoms may prove helpful in further elucidating this association.

This study was limited to depression- and anxiety-specific expenditures. This study does not capture additional costs that may be attributed to these conditions. Costs that may be considered attributable include costs stemming from the role that depression or anxiety plays as a risk factor for other conditions (for example, depression and anxiety have both been linked to hypertension; depression has been shown to be a risk factor for the development and progression of coronary artery disease)[27,28] and the role that depression and anxiety may play on treatment costs for non-etiologically related conditions (for example, presence of depression may influence treatment adherence which can influence disease progression and health care utilization for many conditions).[29] Future studies may wish to examine the interplay between the presence of depression and/or anxiety, physical activity level, and overall health care expenditures.

There are many pathways by which physical activity can influence depression and anxiety; however, the exact pathways are still poorly understood. Physical reactions to physical activity can influence depression and anxiety through physiological changes (e.g., promoting a neurogenic response, altering neurotransmitter function) or through cognitive mechanisms (e.g., diversion from negative thinking, feeling a sense of purpose).[30-33] The social contact often experienced through physical activity may play a role in the relationship between physical activity and reduced depression or anxiety.[30] Physical activity's influence on chronic conditions may also be an important pathway.[32] For example, inactive individuals are more likely to have heart disease[5] which in turn may be associated as a co-morbid condition with depression or anxiety. Because the objective of our study was to estimate the overall financial burden of inadequate levels of physical activity on depression- and anxiety-specific spending, we did not attempt to control for any of these pathways. We did control for two lifestyle indicators (i.e., BMI category and smoking status) that may independently influence depression and anxiety and are also correlated with physical activity. Controlling for BMI category may be overly conservative given the direct relationship between physical activity and weight. When BMI category was not included in our model, estimates for the percentage of health care expenditures associated with inadequate levels of physical activity were higher (RB approach: 23.1% (SE: 4.7), AF approach: 12.7% (SE: 2.0)).

Reverse causality is a concern for this study. If an adult is inactive because of their depression or anxiety then reverse causality can lead to overestimates of the percentage of depression- and anxiety-specific health care expenditures associated with inadequate levels of physical activity. We are unable to completely remove the possibility of reverse causality, although we did address this issue through our study design and sensitivity analysis. First, adults who reported being unable to do physical activity were excluded from the analytic sample; therefore, those who would be limited and reported being unable to do physical activity have been excluded. Second, we conducted a sensitivity analysis that excluded individuals who reported any walking limitation due to a health problem. This exclusion was likely conservative since it is not specific to a limitation due to depression or anxiety; however, findings were similar.

Several limitations of our study are noted. First, use of observational data may bias the observed associations by confounding factors. We attempted to reduce such bias by controlling for several factors; however, we were not able to control for all potential confounding factors. For example, active adults may have had positive health behaviors related to diet, sleep, or participation in preventive care. Second, MEPS relies on one household informant to report conditions and health care expenditures for all household members. Studies have shown that expenditures may be underreported; however, studies concluded that behavioral analyses are largely unaffected by this issue because underreporting is similar across demographic groups.[5,34,35] A larger issue for our study may be that household respondents were unaware of the presence of depression or anxiety for others in the household. This would result in our study underestimating the prevalence of depression and anxiety. This underreporting may be more pronounced when the condition was not related to a health care expenditure and may enhance the difference between estimates from the AF and RB approach. Third, NHIS physical activity data are derived from self-reported information, and studies have indicated that reporting bias can result in high estimates of physical activity.[36] However, individuals overestimating their physical activity would likely lead to a more conservative estimate of the association between physical activity and depression- and anxiety-specific health care expenditures. Finally, the physical activity measure is based only on leisure-time activity and this may result in an underestimation of the amount of physical activity individuals participate in when their work hours and occupations are considered.

This study has several important strengths. First, data from the NHIS and MEPS include a large, nationally representative sample. This allows for the broad generalizability of study findings to non-institutionalized U.S. adults. Second, the surveys included relevant variables that allowed us to include many covariates in our model. Third, our physical activity measure categorized individuals into levels consistent with current aerobic physical activity guidelines.[13] Finally, the dataset contains all data needed for implementing the AF and RB approaches, allowing for the comparison of these two approaches using data from a single source. The AF and the RB approach are often applied by different disciplines and understanding how the two relate can be important when examining and comparing policy analyses related to cost and cost control.

Conclusions

The approach used to estimate the percentage of condition-specific spending can greatly influence estimates. It important to understand what costs an estimation approach accounts for when examining and comparing estimates. However, regardless of the approach used to calculate estimates, inadequate physical activity is associated with a significant percentage of depression- and anxiety-specific health care expenditures.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

References

1. US Department of Health and Human Services. *Mental Health: A Report of the Surgeon General.* Rockville, MD1999.

2. Centers for Disease Control and Prevention. Current depression among adults---United States, 2006 and 2008. *MMWR Morb Mortal Wkly Rep.* 2010;59(38):1229-1235.

3. Kessler RC, Chiu WT, Demler O, Walters EE. Prevalence, severity, and comorbidity of 12-month DSM-IV disorders in the National Comorbidity Survey Replication. *Archives of general psychiatry.* Jun 2005;62(6):617-627.

4. Somers JM, Goldner EM, Waraich P, Hsu L. Prevalence and incidence studies of anxiety disorders: A systematic review of the literature. *Can J Psychiat.* Feb 2006;51(2):100-113.

5. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report, 2008.* Washington, DC: U.S. Department of Health and Human Services;2008.

6. Carek PJ, Laibstain SE, Carek SM. Exercise for the treatment of depression and anxiety. *International journal of psychiatry in medicine.* 2011;41(1):15-28.

7. Strohle A. Physical activity, exercise, depression and anxiety disorders. *Journal of neural transmission.* Jun 2009;116(6):777-784.

8. Brown DR, Wang G, Safran MA. A Preliminary analysis of medical expenditures among active and sedentary US adults with mental disorders. *American journal of health behavior.* May-Jun 2005;29(3):195-205.

9. Wang G, Brown DR. Impact of physical activity on medical expenditures among adults downhearted and blue. *American journal of health behavior.* May-Jun 2004;28(3):208-217.

10. Honeycutt AA, Segel JE, Hoerger TJ, Finkelstein EA. Comparing cost-of-illness estimates from alternative approaches: an application to diabetes. *Health Serv Res.* Feb 2009;44(1):303-320.

11. Agency for Healthcare Research and Quality (AHRQ). Medical Expenditure Panel Survey (MEPS). 2013; http://www.meps.ahrq.gov/mepsweb/. Accessed November 3, 2013.

12. National Center for Health Statistics (NCHS). National Health Interview Survey (NHIS). 2013; http://www.cdc.gov/nchs/nhis.htm. Accessed November 3, 2013.

13. US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans.* Washington, DC: U.S. Department of Health and Human Services;2008.

14. Elixhauser A, Steiner C, Palmer L. Clinical Classifications Software (CCS), 2013. *U.S. Agency for Healthcare Research and Quality* 2013; http://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp.

15. Agency for Healthcare Research and Quality. Using appropriate price indices for analyses of health care expenditues or income across multiple years. 2013; http://meps.ahrq.gov/mepsweb/about_meps/Price_Index.shtml. Accessed June 19, 2013.

16. Cohen SB. *An estimation methodology to permit longitudinal cohort analyses based on the National Health Interview Survey and Medical Expenditure Panel*

Survey. Rockville, MD: Agency for Healthcare Research and Quality (AHRQ);2010.

17. Izrael D, Hoaglin DC, Battaglia MP. A SAS Macro for Balancing a Weighted Sample. *Proceedings of the Twenty-Fifth Annual SAS Users Group International Conference.* 2000(Paper 275).

18. National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. 1998; http://www.nhlbi.nih.gov/guidelines/obesity/ob_gdlns.pdf.

19. Rockhill B, Newman B, Weinberg C. Use and misuse of population attributable fractions. *Am J Public Health.* Jan 1998;88(1):15-19.

20. McNutt LA, Wu C, Xue X, Hafner JP. Estimating the relative risk in cohort studies and clinical trials of common outcomes. *Am J Epidemiol.* May 15 2003;157(10):940-943.

21. Duan N, Manning WG, Morris CN, Newhouse JP. *A comparison of alternative models for the demand for medical care.* Santa Monica, CA: RAND Corporation;1982.

22. Buntin MB, Zaslavsky AM. Too much ado about two-part models and transformation? Comparing methods of modeling Medicare expenditures. *Journal of Health Economics.* May 2004;23(3):525-542.

23. Finkelstein EA, Fiebelkorn IC, Wang G. National medical spending attributable to overweight and obesity: how much, and who's paying? *Health Aff (Millwood).* Jan-Jun 2003;Suppl Web Exclusives:W3-219-226.

24. Garrett NA, Brasure M, Schmitz KH, Schultz MM, Huber MR. Physical inactivity: direct cost to a health plan. *Am J Prev Med.* Nov 2004;27(4):304-309.

25. Goodwin RD. Association between physical activity and mental disorders among adults in the United States. *Prev Med.* Jun 2003;36(6):698-703.

26. Shirneshan E, Bailey J, Relyea G, Franklin BE, Solomon DK, Brown LM. Incremental direct medical expenditures associated with anxiety disorders for the U.S. adult population: Evidence from the Medical Expenditure Panel Survey. *Journal of anxiety disorders.* Oct 2013;27(7):720-727.

27. Jonas BS, Franks P, Ingram DD. Are symptoms of anxiety and depression risk factors for hypertension? Longitudinal evidence from the National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study. *Archives of family medicine.* / 1997;6(1):43-49.

28. Lett HS, Blumenthal JA, Babyak MA, et al. Depression as a risk factor for coronary artery disease: evidence, mechanisms, and treatment. *Psychosomatic medicine.* May-Jun 2004;66(3):305-315.

29. DiMatteo M, Lepper HS, Croghan TW. Depression is a risk factor for noncompliance with medical treatment: Meta-analysis of the effects of anxiety and depression on patient adherence. *Archives of Internal Medicine.* 2000;160(14):2101-2107.

30. Blake H. Physical activity and exercise in the treatment of depression. *Frontiers in psychiatry.* 2012;3:106.

31. Searle A, Calnan M, Lewis G, Campbell J, Taylor A, Turner K. Patients' views of physical activity as treatment for depression: a qualitative study. *The British* *journal of general practice : the journal of the Royal College of General Practitioners.* Apr 2011;61(585):149-156.

32. Zschucke E, Gaudlitz K, Ströhle A. Exercise and Physical Activity in Mental Disorders: Clinical and Experimental Evidence. *J Prev Med Public Health.* 1/ 2013;46(Suppl 1):S12-S21.

33. Morgan WP. *Physical activity and mental health.* Washington DC: Taylor and Francis; 1997.

34. Zuvekas SH, Olin GL. Validating household reports of health care use in the medical expenditure panel survey. *Health Serv Res.* Oct 2009;44(5 Pt 1):1679-1700.

35. Zuvekas SH, Olin GL. Accuracy of Medicare expenditures in the medical expenditure panel survey. *Inquiry.* Spring 2009;46(1):92-108.

36. Sallis JF, Saelens BE. Assessment of physical activity by self-report: status, limitations, and future directions. *Res Q Exerc Sport.* Jun 2000;71(2 Suppl):S1-14.

Table 5.1. Annual prevalence of depression and anxiety by select characteristics, U.S. Adults, NHIS and MEPS 2005-2010[a,b]

Characteristic[c]	Overall		Prevalence of Depression (n=5289)		Prevalence of Anxiety (n=4650)		Prevalence of Depression and/or Anxiety (n=8517)	
	Sample Size	(%)[d]	%	(SE)	%	(SE)	%	(SE)
Overall	51 641		9.4	(0.2)	8.5	(0.2)	15.4	(0.3)
Physical activity level								
Inactive	20 735	(35.2)	10.6	(0.4)	8.8	(0.3)	16.7	(0.5)
Insufficiently active	10 090	(19.7)	11.1	(0.5)	9.9	(0.5)	18.1	(0.6)
Active	20 816	(45.1)	7.6	(0.3)	7.7	(0.3)	13.3	(0.4)
Sex								
Men	22 975	(49.9)	6.4	(0.3)	6.0	(0.2)	10.8	(0.3)
Women	28 666	(50.1)	12.3	(0.3)	11.0	(0.3)	20.0	(0.4)
Age (years)								
20-29	7156	(17.9)	5.3	(0.5)	6.0	(0.4)	9.9	(0.6)
30-39	9721	(17.5)	8.0	(0.5)	9.0	(0.5)	14.2	(0.6)
40-49	10 332	(20.2)	10.1	(0.4)	9.3	(0.4)	16.7	(0.5)
50-59	9565	(19.0)	11.9	(0.5)	9.4	(0.4)	18.1	(0.6)
60-69	6907	(12.7)	12.1	(0.6)	9.5	(0.5)	18.8	(0.8)
70-79	4677	(7.6)	9.9	(0.7)	8.4	(0.6)	16.5	(0.8)
≥ 80	3283	(5.0)	8.0	(0.7)	7.7	(0.7)	14.3	(0.8)
Race/ethnicity								
White, non-Hispanic	28 826	(69.0)	10.7	(0.3)	9.7	(0.3)	17.6	(0.4)
Black, non-Hispanic	9494	(11.2)	5.7	(0.3)	5.7	(0.3)	9.8	(0.4)
Hispanic	9682	(13.2)	6.6	(0.4)	5.9	(0.4)	11.0	(0.6)
Other, non-Hispanic	3639	(6.6)	6.5	(0.6)	6.2	(0.5)	11.3	(0.8)
Education level								
Less than HS graduate	10 876	(14.7)	9.2	(0.5)	8.4	(0.4)	14.9	(0.6)

High school graduate	14 000	(27.3)	10.3	(0.4)	8.6	(0.4)	16.1	(0.5)
Some college	14 485	(29.5)	9.7	(0.4)	9.2	(0.4)	16.2	(0.5)
College graduate	12 280	(28.4)	8.2	(0.4)	7.9	(0.3)	14.2	(0.5)
Marital status								
Married	24 039	(55.8)	8.2	(0.3)	7.6	(0.3)	13.9	(0.4)
Widowed	5399	(7.0)	12.1	(0.8)	9.6	(0.6)	19.3	(0.9)
Divorced/separated	10 270	(14.1)	15.8	(0.7)	12.5	(0.5)	23.5	(0.8)
Never married	11 933	(23.1)	7.4	(0.5)	7.9	(0.4)	13.0	(0.5)
Census region								
Northeast	7860	(18.7)	9.0	(0.4)	8.8	(0.5)	15.2	(0.6)
Midwest	11 201	(21.9)	10.5	(0.3)	9.1	(0.4)	16.9	(0.4)
South	20 026	(36.5)	8.7	(0.4)	7.8	(0.3)	14.5	(0.6)
West	12 554	(23.0)	9.6	(0.7)	8.8	(0.4)	15.7	(0.8)
Poverty level (percentage of the Federal Poverty Level (FPL))								
< 100% FPL	8978	(10.7)	14.0	(0.6)	11.3	(0.6)	20.9	(0.8)
100%-199% FPL	11 465	(17.2)	10.2	(0.5)	8.6	(0.4)	16.2	(0.5)
200%-400% FPL	15 114	(30.6)	9.2	(0.4)	8.4	(0.3)	15.3	(0.5)
> 400% FPL	16 084	(41.5)	7.9	(0.3)	7.8	(0.3)	13.8	(0.4)
Insurance status (coverage for the year)								
Any private coverage	31 879	(69.9)	8.8	(0.3)	8.4	(0.2)	15.1	(0.3)
Public insurance only	11 143	(14.7)	15.5	(0.6)	11.8	(0.5)	22.6	(0.7)
Uninsured for full year	8619	(15.3)	6.3	(0.4)	5.8	(0.4)	10.3	(0.5)
Smoking								
Current	11 132	(21.0)	12.7	(0.5)	11.1	(0.5)	20.0	(0.6)
Former	11 006	(21.9)	11.2	(0.5)	8.9	(0.4)	17.2	(0.6)
Never	29 503	(57.2)	7.4	(0.3)	7.4	(0.2)	13.1	(0.3)

Body mass index (BMI) category[e]								
Underweight/ normal weight	18 621	(38.0)	7.7	(0.3)	8.5	(0.4)	14.1	(0.5)
Overweight	18 321	(35.7)	8.5	(0.3)	7.5	(0.3)	13.8	(0.4)
Obese	14 699	(26.4)	13.0	(0.4)	10.0	(0.4)	19.5	(0.5)

[a] Excludes adults who were pregnant during the MEPS year and those who reported being unable to do physical activity.
[b] Prevalence are average annual figures over the years 2005 through 2010.
[c] Covariate data from the MEPS dataset included: sex, age, race/ethnicity, marital status, census region, poverty level, and insurance status. Covariate data from the NHIS interview included: education level, BMI, and smoking status.
[d] Estimates of percent are weighted.
[e] BMI category is defined as underweight/normal weight (BMI < 25 kg/m^2), overweight (BMI: 25-<30 kg/m^2), and obese (BMI ≥ 30 kg/m^2).

Table 5.2. Prevalence of physical activity and logit model results by condition and physical activity level, U.S. Adults, NHIS and MEPS 2005-2010[a]

Condition by physical activity level	Prevalence of physical activity among those with condition		Logit model for presence of condition[b]			
			Coefficient		Prevalence risk ratio	
	%	(SE)	B	(SE)	PRR	(SE)
Depression						
Inactive	40.0	(1.4)	0.26*	(0.06)	1.25*	(0.07)
Insufficiently active	23.4	(1.0)	0.29*	(0.06)	1.28*	(0.07)
Active	36.6	(1.2)	Referent		Referent	
Anxiety						
Inactive	36.3	(1.4)	0.12	(0.06)	1.11	(0.06)
Insufficiently active	22.9	(1.0)	0.21*	(0.07)	1.21*	(0.07)
Active	40.8	(1.2)	Referent		Referent	
Depression or anxiety						
Inactive	38.0	(1.2)	0.20*	(0.05)	1.17*	(0.05)
Insufficiently active	23.0	(0.8)	0.26*	(0.05)	1.23*	(0.05)
Active	38.9	(1.0)	Referent		Referent	

* Significantly different than zero ($p<0.05$).
[a] Excludes adults who were pregnant during the MEPS year and those who reported being unable to do physical activity.
[b] Covariates include sex, age group, race/ethnicity, census region, marital status, education, poverty level, health insurance status, smoking status, BMI category, and MEPS year.

Table 5.3. Results for the two-part econometric model by condition and physical activity level, U.S. Adults, NHIS and MEPS 2005-2010[a]

Condition by physical activity level	Part 1: Logit model[b,c]		Part 2: GLM model[c,d]			
	Coefficient		Coefficient		Mean Expenditure Difference[e] ($, compared to active)	
	B	(SE)	B	(SE)	Mean	(SE)
Depression						
Inactive	0.28*	(0.07)	0.19	(0.11)	194	(111)
Insufficiently active	0.31*	(0.07)	0.10	(0.14)	109	(148)
Active	Referent		Referent		Referent	
Anxiety						
Inactive	0.11	(0.07)	0.24	(0.13)	188	(106)
Insufficiently active	0.21*	(0.07)	0.05	(0.12)	35	(79)
Active	Referent		Referent		Referent	
Depression or anxiety						
Inactive	0.19*	(0.05)	0.25*	(0.09)	264*	(91)
Insufficiently active	0.27*	(0.06)	0.16	(0.12)	155	(125)
Active	Referent		Referent		Referent	

* Significantly different than zero (p<0.05).
[a] Excludes adults who were pregnant during the MEPS year and those who reported being unable to do physical activity.
[b] 4151 adults reported any depression-specific health care expenditure (79.9% of those who reported depression), 3525 adults reported any anxiety-specific health care expenditure (75.8% of those who reported anxiety), and 6587 adults reported any

depression/anxiety-specific health care expenditure (78.1% of those who reported depression and/or anxiety). The outcome of the logit model is whether individuals reported a condition-specific health care expenditure.

[c] Covariates include sex, age group, race/ethnicity, census region, marital status, education, poverty level, health insurance status, smoking status, BMI category, and MEPS year.

[d] Part 2 of the model is limited to adults who reported a condition-specific health care expenditure. The outcome of the GLM model is the amount of the condition-specific health care expenditure.

[e] Expenditures adjusted to 2011 dollars using the Personal Health Care Expenditure (PHCE) Price Index. Mean difference (compared to active) in health care expenditures among those with any condition-specific health care expenditure was calculated by subtracting the mean for the inactive group of predicted condition-specific health care expenditures with the inactive variable set to 1 in the model (i.e., "as is" predicted cost) minus the mean of predicted expenditures with the inactive variable set to 0 (i.e., "as if" the individual was active).

Table 5.4. Percentage of depression and anxiety-specific health care expenditures associated with inactive and insufficiently active levels of physical activity, U.S. Adults, NHIS and MEPS 2005-2010[a]

Condition by physical activity level	Attributable Fraction (AF) Approach		Regression Based (RB) Approach	
	%	(SE)	%	(SE)
Depression				
Inactive	8.0*	(2.0)	14.3*	(4.1)
Insufficiently active	5.2*	(1.2)	7.5*	(3.1)
Inactive and insufficiently active	13.2*	(2.6)	21.9*	(6.0)
Anxiety				
Inactive	3.6	(1.9)	12.5*	(5.6)
Insufficiently active	3.9*	(1.2)	4.6	(2.8)
Inactive and insufficiently active	7.5*	(2.5)	17.2*	(6.7)
Depression and anxiety[b]				
Inactive	6.4*	(1.6)	13.8*	(3.5)
Insufficiently active	4.7*	(0.9)	7.5*	(2.8)
Inactive and insufficiently active	11.1*	(2.0)	21.2*	(4.9)

* Significantly different than zero ($p<0.05$).

Note: Percentages for inactive and insufficiently active presented separately may not sum to the combined inactive and insufficiently active percentage due to rounding.

[a] Excludes adults who were pregnant during the MEPS year and those who reported being unable to do physical activity.

[b] When depression and anxiety were combined using the AF approach, aggregate costs associated with inactive and insufficiently active were calculated separately for each condition, summed, and then divided by the total condition specific expenditures for depression and anxiety combined to estimate the percentage of depression- and anxiety-specific health care expenditures associated with each physical activity level. For the RB approach, total condition-specific expenditures for depression and anxiety were modeled directly using coefficients from Table 5.3.

Chapter 6: Inadequate Physical Activity and Mortality in the United States

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Abstract

Objective. Estimate the percentage of deaths attributable to inadequate physical activity (i.e., inactive and insufficiently active) in the U.S. by using survival analysis to estimate population attributable fractions (PAFs) by age group.

Methods. Data from the 1990-1991 National Health Interview Survey for adults age 25 years or older linked with mortality data from the National Death Index up to 12/31/2011 (n=67 801 with 19 045 deaths). We used fully-adjusted Cox proportional hazards models to estimate hazard ratios (HRs) and corresponding PAFs for three levels: inactive (no physical activity reported), insufficiently active (some activity but less than meeting guidelines), and active (≥ 150 minutes/week of moderate-intensity equivalent activity).

Results. For adults age 40-69 and 70 or older, inactive (HR for 40-69: 1.24; 70+: 1.19) and insufficiently active adults (HR for 40-69: 1.11; 70+: 1.12) had an increased risk of mortality compared to active adults. Among adults age 25-39, there was no association between physical activity and mortality. Among adults 40-69, 10.1% of premature deaths were attributed to inadequate physical activity. Among adults 70 or older, 9.0% of deaths were attributed to inadequate physical activity.

Conclusion. A significant percentage of premature deaths among adults age 40 or older are attributed to levels of physically activity inadequate to meet current guidelines.

Introduction

Regular participation in physical activity prevents the development of premature death. Compared to those inactive, there is a 20-30% lower risk of dying for active adults during the follow-up period.[1] Current guidelines recommend for substantial health benefits adults participate weekly in at least 150 minutes of moderate-intensity aerobic activity, at least 75 minutes of vigorous-intensity aerobic activity, or an equivalent combination.[2] Population levels of physical activity inadequate to meet current guidelines can place a burden on the U.S. population for premature mortality.

The population attributable fraction (PAF) provides an estimate of the proportion of premature deaths that could be averted if inactive or insufficiently active individuals were physically active at levels consistent with current guidelines.[3] The PAF provides policy makers with useful quantitative estimates of the public health burden of inadequate levels of physical activity and the potential effect of programs aimed at increasing physical activity in the U.S.[4] This information can be important for setting research and program priorities, and for public health planning and resource allocation.

Studies have estimated the PAF for physical inactivity using an equation that combines risk estimates from one source with prevalence estimates from another source.[5-9] Combining estimates across different sources can bias findings if the characteristics of the two source populations differ, if the measure of inactivity differs across sources, or if confounding is not properly accounted for.[10] Estimating the PAF from a survival analysis conducted in a single population can overcome these biases. And if the source population is nationally representative, the PAFs will accurately estimate the burden of inadequate levels of physical activity in the U.S.

To date, no study has estimated the PAF for inadequate levels of physical activity (using criteria based on current guidelines) from a survival analysis of a nationally-representative sample.[2] One study estimated that 10.9% of deaths were attributed to being physically inactive versus not using data from the National Health and Nutrition Examination Survey linked with mortality data.[11] However, this study did not use criteria based on current guidelines to categorize physical activity levels.[2] When estimating the public health burden of inadequate levels of physical activity (i.e., inactive and insufficiently active), it is important to examine physical activity levels consistent with current guidelines and health objectives in the U.S.[2,12]

Currently the evidence of the association between physical activity and mortality comes from studies that have focused on middle aged adults. These studies mainly include adults age 40 years and older, with few data available for those age 80 years and older.[1,4] Studies that have examined the influence of age on the association between physical activity and mortality have suggested that the association generally gets stronger with increasing age.[13-15] If there is a differential risk by age group, it is important to include this when estimating the PAF. One European study with forty-two years of follow-up found that the PAFs for inactivity (defined using a crude measure of physical inactivity (any versus none)) were relatively consistent across age groups ranging from 7.3 for those age 20 to 44 to 9.1 for those 65 and over.[15] Because our study includes adults across the lifespan, we will examine how the association between inadequate levels of physical activity and mortality and the corresponding estimates of the PAF vary by baseline age group.

There are two objectives to this study. The first objective is to examine the influence physical activity level (defined using current guidelines criteria) has on mortality in a sample that is nationally representative of the U.S. population and to examine this association by age group. The second objective is to apply the results from the survival analysis to directly estimate the percentage of deaths attributable to inadequate levels of physical activity in U.S. adults.

Methods

Data

We analyzed data from the 1990 and 1991 National Health Interview Survey (NHIS) which were linked to the National Death Index (NDI), with participants' vital status information available from January 1, 1990, through December 31, 2011.[16,17] The NHIS, conducted yearly by the National Center for Health Statistics, is a face-to-face household survey of a random sample of U.S. households conducted continuously throughout the year.[16] Basic health and demographic information is collected on all household members and additional information, such as physical activity, is collected on one randomly selected adult. The response rates for the adult supplements were 83.4% in 1990 and 87.8% in 1991.[16]

The NDI is a centralized database containing information on all U.S. deaths in the 50 states and the District of Columbia. In 1990-1991, NHIS interviews were completed by 84 836 (1990: 41 104; 1991: 43 732) sample adult respondents. Of these, 83 998 (99.0%) were matched with NDI records and had known vital status information.[14]

In 1990-1991, there were 75 123 NHIS sample adult respondents age 25 years or older. We excluded 3742 who were categorized as physically handicapped or whose handicap status was unknown and thus they were not asked all physical activity questions. Next, we excluded 742 individuals who were either missing the mortality linkage (722) or had incomplete information on date of birth or death (20). Finally, 1113 persons who had missing physical activity data, 1617 who had missing data on covariates, and 108 who were missing both were excluded from the analytic sample (final sample: 67 801).

Measures

Physical Activity Assessment. In the 1990 and 1991 surveys, participants were asked if they had done any exercises, sports, or physically active hobbies in the past 2 weeks. If they responded yes, they were asked how often they did each specific activity during the previous 2 weeks and the average number of minutes they spent participating each time. The physical activities assessed in the 1990 and 1991 surveys varied slightly (e.g., stretching and stair climbing was not assessed in 1990 and hiking, other dancing (not including aerobic dancing), calisthenics, yoga, and skating were not assessed in 1991). In addition, for 1991 the amount of time spent participating in bowling, golf, and skiing were not assessed. We excluded weightlifting which was not considered to be an aerobic physical activity. Therefore, we included participation in 13 physical activities (i.e., walking; jogging or running; gardening or yard work; aerobics or aerobic dancing; tennis; biking; swimming; basketball; baseball or softball; football; soccer; volleyball; and handball, racquetball, or squash).

We categorized activities as moderate- or vigorous-intensity for each individual. This was done by first estimating a 60% VO_{2max} (maximal oxygen uptake) value for each adult based on gender and age.[18] An adult's estimated 60% VO_{2max} was then compared to an assigned Metabolic Equivalent of Task (MET) value.[19] If the MET value of the activity was higher than the adult's estimated 60% VO_{2max} then the activity was categorized as vigorous-intensity; otherwise the activity was categorized as moderate-intensity.

Based on current guidelines, 1 minute of vigorous-intensity activity was counted as 2 minutes of moderate-intensity activity to calculate minutes of moderate-intensity equivalent activity.[2] Using minutes of moderate-intensity equivalent activity, we categorized individuals into 4 activity levels: inactive (no physical activity reported in the past 2 weeks), insufficiently active (some activity reported but less than 150 min/week of moderate-intensity equivalent activity), sufficiently active (150-300 min/week of moderate-intensity equivalent activity), and highly active (>300 min/week of moderate-intensity equivalent activity).[2] We then categorized individuals into 3 physical activity levels by combining those sufficiently active and highly active into an active level (at least 150 min/week of moderate-intensity equivalent activity)

Covariates. In the NHIS, interviewers assessed sex, race, education, cigarette smoking, and hypertension.[16] Participants also reported their height and weight, which were used to compute body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters).

Statistical Analysis

Cox proportional hazards models were used to estimate hazard ratios and 95% confidence intervals for comparison of mortality risk by level of physical activity, while adjusting for: sex (men, women), race/ethnicity (white (non-Hispanic), black (non-Hispanic), other), education level (less than high school graduate, high school graduate, some college, college graduate), cigarette smoking (never, former, current), hypertension (yes, no), and BMI category (underweight, normal weight, overweight, obese).[20]

We decided a priori to examine the association between physical activity and mortality by age group. Because previous research has focused on adults 40 years or older with minimal data for those over 80 years of age,[1,4] we began with three age groups (25-39, 40-79, and 80 or older) that would allow us to address these gaps. We then decided to use a cut-off of 70 years or older for the highest age group because we found the association for adults age 70-79 was more similar to adults in the oldest age group (80 years or older) than those 40-69 and because previous literature has shown a marked tapering in physical activity levels for adults over 70 years of age.[21] We then confirmed that physical activity level within the selected age groups (i.e., 25-39, 40-69, 70 or older) did not violate the proportional hazards assumption. Age was used as the timescale in the Cox models with age at death or the end of follow-up (12/31/2011) as the survival time and age at the NHIS interview as left-censoring.[22]

PAFs were calculated directly from the results of the Cox models. The user-written STATA command punafcc was used.[23] This command estimates the log of the mean rate ratio in deaths between 2 scenarios, a baseline scenario ("as is") and a second scenario (“as if”) in which the inactive variable and/or the insufficiently active variable were set to zero instead of one. This ratio is known as the population unattributable fraction and is subtracted from 1 to estimate the PAF.

The Breslow method was used for handling tied failure times. All analyses applied survey weights and adjusted for the complex sample design.[16] All analyses were conducted with STATA version 13.

Results

The analytic sample included 67 801 adults age 25 years or older where 19 045 adults died during the follow-up period (Table 6.1). At baseline, 40.8% were age 25-39, 47.6% were 40-69, and 11.6% were 70 or older. Among those who died during follow-up: 7.9% were age 25-39, 52.2% were age 40-69, and 39.9% were age 70 or older. The mean follow-up time was 18.5 years.

In our cohort, 34.8% were physically inactive, 25.8% were insufficiently active, and 39.5% were active (17.4% sufficiently active and 22.1% highly active). Overall, the prevalence of physical inactivity was higher among those who died than those who survived through follow-up, while the prevalence of both insufficient and sufficient activity was higher among those who survived than those who died (Table 6.1). Similar physical activity patterns were observed in adults ages 25-39 and 40-69 (Table 6.2). In adults 70 years or older, prevalence of inactivity was higher among those who died than among those who survived and the prevalence of being highly active was higher among those who survived than among those who died (Table 6.2).

When physical activity was categorized into 4 levels (i.e., inactive, insufficiently active, sufficiently active, and highly active), the physical activity variable was significantly associated with mortality for adults age 40-69 (adjusted Wald $p<0.001$) and 70 or older (adjusted Wald $p<0.001$), while the association was not significant for adults age 25-39 at baseline (adjusted Wald $p=0.25$) (Table 6.3). For adults age 40-69, inactive and insufficiently active adults compared to sufficiently active adults had an increased risk of premature mortality in both unadjusted models (inactive HR: 1.42, insufficiently active HR: 1.16) and fully adjusted models (inactive HR: 1.25, insufficiently active HR: 1.14). There was no difference in hazard ratios for those highly active versus sufficiently active. Among adults age 70 or older, physically inactive adults compared to sufficiently active adults had an increased risk of premature mortality before (inactive: 1.12) and after models were fully adjusted (inactive HR: 1.13), while highly active adults had a decreased risk compared to those sufficiently active in the adjusted models (highly active

HR: 0.92). For adults age 25-39, physically inactive adults compared to those sufficiently active had an increased risk of premature mortality in the unadjusted models; however, once models controlled for demographic characteristics, this increased risk was no longer significant. Findings were similar if adults who died in the first 2 years of follow-up were excluded.

When physical activity level was categorized into 3 levels and the comparison group was those meeting or exceeding minimal guidelines (i.e., active) findings were similar (Table 6.4). Results were similar for adults age 40-69 and 70 or older with both inactive (HR for 40-69: 1.24; 70 or older: 1.19) and insufficiently active adults (HR for 40-69: 1.11; 70 or older: 1.12) versus active adults having an increased risk of mortality. There was no association between the 3 level physical activity variable and mortality for adults age 25-39. Findings were similar if adults who died in the first 2 years of follow-up were excluded.

For adults ages 40-69 and 70 or older at baseline, PAFs for premature deaths attributed to inadequate levels of physical activity (i.e., inactive and insufficiently active levels combined) were significant (Table 6.4). For adults age 40-69, 10.1% of premature deaths were attributed to inadequate levels of physical activity. For adults age 70 or older, 9.0% of deaths were attributed to inadequate levels of physical activity. PAFs decreased after removal of adults who died in the first 2 years, but remained significant.

Discussion

In a nationally representative sample of U.S. adults we found that inadequate levels of physical activity were associated with a significant percentage of premature deaths. Among adults age 40-69, 10.1% of premature deaths were attributable to inadequate levels of physical activity. Similarly, among adults age 70 or older, 9.0% of deaths were attributable to inadequate levels of physical activity. Increasing adults' physical activity to levels consistent with current guidelines and *Healthy People 2020* objectives may be one way to decrease premature deaths in the United States.[2,12]

Previous studies have mainly been conducted among adults age 40 years or older and the association between physical activity and overall mortality we found among adults age 40 or older are generally consistent with other studies. In a meta-analysis when studies using three levels of physical activity were summarized, the combined estimator for the moderately active group compared to the sedentary group was 0.81 and for the most active group the combined estimator was 0.78.[24] Taking the inverse would give an estimate of 1.28 for the most active group, which is very close to our estimate of 1.24 for adults age 40-69 and a little higher than our estimate of 1.19 for adults age 70 or older.

It is difficult to compare our PAF estimates to those estimated in other studies because of the different methodologies and measures of physical activity. One study that combined physical activity prevalence estimates from surveillance systems with risk estimates from the literature reported a PAF for physical inactivity in the U.S. of 10.8% (95% CI: 8.6, 13.1).[4] Another study using data from the National Health and Nutrition Examination

Survey linked with mortality data attributed 10.9% (95% CI: 3.0, 18.7) of deaths to physical inactivity versus not (defined as participation in moderate (≥5 times per week) or vigorous (≥3 times per week) intensity aerobic physical activity).[11] We found much of the burden was attributed to physical inactivity (40-69: 7.6%, 70 or older: 7.2%) with a smaller percentage of deaths attributed to insufficient levels of physical activity (40-69: 2.5%, 70 or older: 1.8%). This may suggest that physical activity programs should target inactive adults to have the greatest influence on the burden; however, converting insufficiently active adults to active adults may be easier to do. When using measures of burden to inform program planning and prioritizing, it is important to consider both the magnitude of the burden and the likelihood of changing behavior among the targeted group.

Because previous studies have mainly been conducted among adults age 40 years or older, it is difficult to compare our findings for the younger age group with other studies.[1,4] We found no association between physical activity level and premature mortality in the younger age group. It may be that our follow-up period was not long enough, especially to capture deaths associated with chronic conditions which would be most closely associated with physical activity level. In our cohort, only 5.0% of adults age 25-39 at baseline died during follow-up. One study that examined this association among those 20-44 years of age did find an association between physical activity and mortality; however, this study had follow-up data for 42 years.[15] Future research may wish to examine this association in younger age groups with a longer follow-up period and multiple measures of physical activity over the follow-up period.

Our findings for adults age 70 or older were relatively consistent with those in adults age 40-69. Although the difference in the magnitude of the association of the hazard ratios or the PAF was not substantial between the 2 age groups, we postulate the association may have been slightly diluted in those 70 or older as individuals may decrease their physical activity level as they become older.[21] Therefore, we may have some older adults who have changed to inactive although they had been active over their lifetime. This could potentially result in the measure of physical activity in the older age group to be an underestimation of lifetime activity and thereby a dilution of the association observed in the older age group.

Several limitations of our study are noted. We used observational data, which may have biased the observed associations by introducing confounding factors. We attempted to reduce such bias by controlling for several factors; however, we were not able to control for all potential confounding factors. For example, active adults may have had positive health behaviors related to diet, sleep, or participation in preventive care. Second, NHIS physical activity data are derived from self-reported information, and studies have indicated that reporting bias can result in high estimates of physical activity.[25] However, individuals overestimating their physical activity would lead to a more conservative estimate of the association between physical activity and mortality. Third, the physical activity measure is based only on leisure-time activity and this may have resulted in an underestimate of physical activity levels when individuals’ work hours and occupations are considered. Fourth, only a single baseline assessment is available. A longer follow-up time period is desirable to minimize censoring; however, the longer the follow-up time also means that the longer the interval between baseline and the event. A previous study concluded the risk of physical inactivity is underestimated when it is derived from a prospective study using a single baseline measurement.[26] Finally, reverse causation may explain some of our association as adults may have been ill at baseline which could influence their physical activity level and risk of mortality. This was addressed in two ways. First, adults identified as physically handicapped were excluded from the study. Second, we conducted a sensitivity analysis that removed adults that died in the first two years of follow-up and the results were similar.

In spite of these limitations, our study has several strengths. First, the prospective cohort design of the study allows us to examine causality. Second, information on many important covariates were available which allowed us to adjust our models for confounding factors. Third, our physical activity measure categorized individuals into levels consistent with current physical activity guidelines. Finally, the NHIS is nationally representative, and has near complete mortality follow-up for a long term period. Because our goal was to estimate the percentage of premature deaths associated with inadequate levels of physical activity in the U.S. population, nationally representative data are a preferable data source and the near complete follow-up will help to ensure the generalizability of our study findings to the U.S. population.

Conclusions

Inadequate physical activity is associated with a significant proportion of premature deaths among adults age 40 or older. Increasing adults' physical activity levels to meet current guidelines may be one way to reduce premature deaths in the United States.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

References

1. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report, 2008.* Washington, DC: U.S. Department of Health and Human Services;2008.

2. US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans.* Washington, DC: U.S. Department of Health and Human Services;2008.

3. Rockhill B, Newman B, Weinberg C. Use and misuse of population attributable fractions. *Am J Public Health.* Jan 1998;88(1):15-19.

4. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet.* Jul 21 2012;380(9838):219-229.

5. Rockhill B, Newman B, Weinberg C. Use and misuse of population attributable fractions. *American Journal of Public Health.* 1998;88(1):15-19.

6. Bull FC, Armstrong TP, Dixon T, Ham S, Neiman A, Pratt M. Physical inactivity. In: Ezzati M, Lopez AD, Rodgers A, Murray CJ, eds. *Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors*. Geneva: World Health Organization; 2004.

7. Danaei G, Ding EL, Mozaffarian D, et al. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. *PLoS Med.* Apr 28 2009;6(4):e1000058.

8. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet.* Jul 21 2012;380(9838):219-229.

9. Powell KE, Blair SN. The public health burdens of sedentary living habits: theoretical but realistic estimates. *Med Sci Sports Exerc.* Jul 1994;26(7):851-856.

10. Flegal KM, Williamson DF, Pamuk ER, Rosenberg HM. Estimating deaths attributable to obesity in the United States. *American journal of public health.* Sep 2004;94(9):1486-1489.

11. Yang Q, Cogswell ME, Flanders WD, et al. Trends in cardiovascular health metrics and associations with all-cause and CVD mortality among US adults. *JAMA.* Mar 28 2012;307(12):1273-1283.

12. U.S. Department of Health and Human Services. Healthy People 2020. 2012; http://www.healthypeople.gov/2020/topicsobjectives2020/default.aspx. Accessed December 1, 2012.

13. Andersen LB, Schnohr P, Schroll M, Hein HO. All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. *Arch Intern Med.* Jun 12 2000;160(11):1621-1628.

14. Schoenborn CA, Stommel M. Adherence to the 2008 adult physical activity guidelines and mortality risk. *Am J Prev Med.* May 2011;40(5):514-521.

15. Gulsvik AK, Thelle DS, Samuelsen SO, Myrstad M, Mowe M, Wyller T. Ageing, physical activity, and mortality - a 42-year follow-up study. *International journal of epidemiology.* 2012;41:521-530.

16. National Center for Health Statistics (NCHS). National Health Interview Survey (NHIS). 2013; http://www.cdc.gov/nchs/nhis.htm. Accessed November 3, 2013.

17. National Center for Health Statistics, Office of Analysis and Epidemiology. NCHS 2011 Linked Mortality Files Matching Methodology. 2013; http://www.cdc.gov/nchs/data_access/data_linkage/mortality/linkage_methods_analytical_support/2011_linked_mortality_file_matching_methodology.pdf.

18. Jones N, Campbell E, eds. *Clinical Exercise Testing.* 2 ed. Philadelphia: WB Saunders; 1982.

19. Ainsworth BE, Haskell WL, Herrmann SD, et al. 2011 Compendium of Physical Activities: A Second Update of Codes and MET Values. *Med Sci Sport Exer.* Aug 2011;43(8):1575-1581.

20. National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. 1998; http://www.nhlbi.nih.gov/guidelines/obesity/ob_gdlns.pdf.

21. Lee IM, Paffenbarger RS, Jr., Hsieh CC. Time trends in physical activity among college alumni, 1962-1988. *Am J Epidemiol.* Apr 15 1992;135(8):915-925.

22. Korn EL, Graubard BI, Midthune D. Time-to-event analysis of longitudinal follow-up of a survey: choice of the time-scale. *Am J Epidemiol.* Jan 1 1997;145(1):72-80.

23. Newson RB. Attributable and unattributable risks and fractions and other scenario comparisons. *Stata J.* 2014:in press.

24. Lollgen H, Bockenhoff A, Knapp G. Physical activity and all-cause mortality: an updated meta-analysis with different intensity categories. *International journal of sports medicine.* Mar 2009;30(3):213-224.

25. Sallis JF, Saelens BE. Assessment of physical activity by self-report: status, limitations, and future directions. *Res Q Exerc Sport.* Jun 2000;71(2 Suppl):S1-14.

26. Andersen LB. Relative risk of mortality in the physically inactive is underestimated because of real changes in exposure level during follow-up. *Am J Epidemiol.* Jul 15 2004;160(2):189-195.

Table 6.1. Select Characteristics of Study Participants, Decedents, and Survivors, 1990–91 NHIS Linked Mortality Files[a]

Characteristic	Overall			Among Decedents			Among Survivors		
	Sample size	Percent		Sample size	Percent		Sample size	Percent	
		%	(SE)		%	(SE)		%	(SE)
Total	67 801			19 045			48 756		
Physical activity level									
Inactive	23 644	34.8	(0.5)	7984	41.3	(0.6)	15 660	32.4	(0.5)
Insufficiently active	17 363	25.8	(0.2)	4042	21.4	(0.4)	13 321	27.3	(0.3)
Sufficiently active	11 738	17.4	(0.2)	2799	14.7	(0.3)	8939	18.3	(0.2)
Highly active	15 056	22.1	(0.3)	4220	22.7	(0.5)	10 836	21.9	(0.4)
Sex									
Men	28 458	47.6	(0.2)	8343	50.3	(0.4)	20 115	46.7	(0.3)
Women	39 343	52.4	(0.2)	10 702	49.7	(0.4)	28 641	53.3	(0.3)
Age group (years)									
25-39	27 385	40.8	(0.3)	1409	7.9	(0.3)	25 976	52.2	(0.3)
40-69	30 946	47.6	(0.3)	9252	52.2	(0.5)	21 694	46.1	(0.3)
70 or older	9470	11.6	(0.2)	8384	39.9	(0.5)	1086	1.8	(0.1)
Race/ethnicity									
White, non-Hispanic	52 823	79.3	(0.5)	15 548	83.7	(0.5)	37 275	77.8	(0.5)
Black, non-Hispanic	8564	10.1	(0.4)	2410	9.7	(0.4)	6154	10.2	(0.4)
Other	6414	10.6	(0.4)	1087	6.6	(0.4)	5327	12.0	(0.4)

Education									
Less than high school graduate	14 231	20.0	(0.3)	7066	35.5	(0.5)	7165	14.6	(0.3)
High school graduate	25 207	37.7	(0.3)	6747	35.9	(0.4)	18 460	38.4	(0.4)
Some college	13 341	19.7	(0.2)	2780	15.0	(0.3)	10 561	21.4	(0.2)
College graduate	15 022	22.6	(0.3)	2452	13.6	(0.4)	12 570	25.6	(0.4)
Smoking									
Never	32 405	47.2	(0.3)	7912	39.4	(0.5)	24 493	49.9	(0.3)
Former	17 320	26.5	(0.3)	5964	32.9	(0.4)	11 356	24.3	(0.3)
Current	18 076	26.3	(0.2)	5169	27.7	(0.4)	12 907	25.8	(0.2)
Hypertension									
Yes	16 569	23.4	(0.2)	8294	42.2	(0.5)	8275	16.8	(0.2)
No	51 232	76.6	(0.2)	10 751	57.8	(0.5)	40 481	83.2	(0.2)
Body mass index (BMI) category[b]									
Underweight	1968	2.6	(0.1)	710	3.3	(0.1)	1258	2.4	(0.1)
Normal weight	33 680	48.9	(0.2)	8522	44.0	(0.2)	25 158	50.6	(0.3)
Overweight	22 378	34.2	(0.2)	6675	36.2	(0.2)	15 703	33.5	(0.3)
Obese	9775	14.3	(0.2)	3138	16.5	(0.2)	6 637	13.6	(0.2)
Baseline year									
1990	33 495	50.7	(0.2)	9731	52.6	(0.2)	23 764	50.1	(0.2)
1991	34 306	49.3	(0.2)	9314	47.4	(0.2)	24 992	49.9	(0.2)

[a]: There were 75 123 adults age 25 years or older. Adults categorized as physically handicapped or whose physical handicap status was unknown were excluded (3742) because they were not asked all physical activity questions.

Adults with missing mortality or time scale data were excluded (742). Finally adults missing data on physical activity (1113), covariates (1617), or both (108) were excluded.
[b]: BMI category is defined as underweight (BMI < 18.5 kg/m2), normal weight (BMI 18.5-25 kg/m2), overweight (BMI 25 - < 30 kg/m2), and obese (BMI ≥ 30 kg/m2).

Table 6.2. Prevalence of physical activity by age group for overall sample, among decedents, and among those who survived to the end of follow-up, 1990–91 NHIS Linked Mortality Files[a]

Age group and physical activity level	Overall			Among Decedents			Among Survivors		
	Sample size	Percent %	Percent (SE)	Sample size	Percent %	Percent (SE)	Sample size	Percent %	Percent (SE)
25-39									
Inactive	8765	32.3	(0.6)	542	38.1	(1.6)	8223	32.0	(0.6)
Insufficiently active	7643	28.1	(0.3)	341	24.7	(1.3)	7302	28.3	(0.3)
Sufficiently active	4943	17.9	(0.3)	224	15.1	(1.1)	4719	18.1	(0.3)
Highly Active	6034	21.6	(0.4)	302	22.1	(1.3)	5732	21.6	(0.4)
40-69									
Inactive	10 693	34.6	(0.6)	3641	38.8	(0.8)	7052	32.9	(0.6)
Insufficiently active	8092	26.1	(0.3)	2271	24.7	(0.5)	5821	26.6	(0.4)
Sufficiently active	5501	17.7	(0.3)	1444	15.5	(0.4)	4057	18.6	(0.3)
Highly Active	6660	21.6	(0.4)	1896	21.0	(0.6)	4764	21.9	(0.4)
70 or older									
Inactive	4186	44.0	(0.7)	3801	45.1	(0.8)	385	35.6	(1.8)
Insufficiently active	1628	16.5	(0.4)	1430	16.3	(0.4)	198	17.8	(1.2)
Sufficiently active	1294	13.8	(0.4)	1131	13.6	(0.4)	163	15.0	(1.1)
Highly Active	2362	25.8	(0.6)	2022	25.0	(0.6)	340	31.6	(1.7)

[a]: There were 75 123 adults age 25 years or older. Adults categorized as physically handicapped or whose physical handicap status was unknown were excluded (3742) because they were not asked all physical activity questions. Adults with missing mortality or time scale data were excluded (742). Finally adults who were missing data on physical activity (1113), covariates (1617), or both (108) were excluded.

Table 6.3. Hazard ratios for all-cause mortality by age group and physical activity level, 1990–91 NHIS Linked Mortality Files[a]

Age group and physical activity level	Overall						Exclude those dying in < 2 years[c]	
	Unadjusted		Adjusted for demographics[b]		Fully Adjusted[c]		Fully Adjusted[d]	
	HR	(95 % CI)	HR	(95 % CI)	HR	(95 % CI)	HR	(95 % CI)
25-39								
Inactive	1.43	(1.18, 1.73)	1.20	(0.99, 1.46)	1.14	(0.95, 1.39)	1.12	(0.92, 1.36)
Insufficiently active	1.05	(0.86, 1.28)	1.03	(0.84, 1.25)	1.00	(0.83, 1.22)	1.00	(0.83, 1.23)
Sufficiently active	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
Highly Active	1.21	(0.98, 1.48)	1.15	(0.94, 1.42)	1.14	(0.93, 1.40)	1.13	(0.92, 1.39)
40-69								
Inactive	1.42	(1.34, 1.51)	1.36	(1.27, 1.45)	1.25	(1.18, 1.34)	1.25	(1.17, 1.34)
Insufficiently active	1.16	(1.07, 1.25)	1.16	(1.08, 1.25)	1.14	(1.06, 1.22)	1.13	(1.05, 1.23)
Sufficiently active	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
Highly Active	1.07	(1.00, 1.15)	1.05	(0.98, 1.12)	1.04	(0.96, 1.12)	1.05	(0.98, 1.14)
70 or older								
Inactive	1.12	(1.04, 1.19)	1.13	(1.05, 1.21)	1.13	(1.05, 1.21)	1.08	(1.00, 1.15)
Insufficiently active	1.04	(0.95, 1.13)	1.07	(0.98, 1.16)	1.08	(0.98, 1.16)	1.05	(0.96, 1.14)
Sufficiently active	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
Highly Active	0.95	(0.88, 1.02)	0.91	(0.84, 0.98)	0.92	(0.85, 1.00)	0.92	(0.85, 0.99)

[a]: There were 75 123 adults age 25 years or older. Adults categorized as physically handicapped or whose physical handicap status was unknown were excluded (3742) because they were not asked all physical activity questions. Adults

with missing mortality or time scale data were excluded (742). Finally adults who were missing data on physical activity (1113), covariates (1617), or both (108) were excluded.

[b]: Covariates include: sex, race/ethnicity, and education.

[c]: Covariates include: sex, race/ethnicity, education, smoking status, hypertension, and BMI category.

[d]: Excluded 1163 adults (25-39: 60; 40-69: 429, 70 or older: 674).

Table 6.4. Hazard ratios and population attributable fractions for all-cause mortality by age group and physical activity level, 1990–91 NHIS Linked Mortality Files[a]

Age group and physical activity level	Overall Fully Adjusted Model[b]				Excludes those dying in < 2 years[c] Fully Adjusted Model[b]			
	Hazard Ratios		PAF		Hazard Ratios		PAF	
	HR	(95 % CI)	%	(95 % CI)	HR	(95 % CI)	%	(95 % CI)
25-39								
Inactive	1.06	(0.92, 1.23)	2.3	(-3.4, 7.6)	1.04	(0.90, 1.21)	1.5	(-4.1, 6.8)
Insufficiently active	0.93	(0.81, 1.08)	-1.8	(-5.7, 1.9)	0.94	(0.81, 1.09)	-1.6	(-5.6, 2.3)
Active	1.00	Referent			1.00	Referent		
Inactive and insufficiently active			0.4	(-7.8, 8.0)			-0.1	(-8.4, 7.6)
40-69								
Inactive	1.24	(1.18, 1.31)	7.6	(5.8, 9.4)	1.22	(1.16, 1.28)	6.9	(5.1, 8.7)
Insufficiently active	1.11	(1.05, 1.18)	2.5	(1.1, 3.9)	1.10	(1.04, 1.17)	2.3	(0.8, 3.7)
Active	1.00	Referent			1.00	Referent		
Inactive and insufficiently active			10.1	(7.4, 12.8)			9.1	(6.4, 11.8)
70 or older								
Inactive	1.19	(1.13, 1.26)	7.2	(5.0, 9.3)	1.14	(1.08, 1.20)	5.3	(3.2, 7.4)
Insufficiently active	1.12	(1.04, 1.21)	1.8	(0.7, 2.9)	1.11	(1.03, 1.20)	1.7	(0.5, 2.8)
Active	1.00	Referent			1.00	Referent		
Inactive and insufficiently active			9.0	(6.1, 11.7)			6.9	(4.1, 9.7)

[a]: There were 75 123 adults age 25 years or older. Adults categorized as physically handicapped or whose physical handicap status was unknown were excluded (3742) because they were not asked all physical activity questions. Adults with missing mortality or time scale data were excluded (742). Finally adults who were missing data on physical activity (1113), covariates (1617), or both (108) were excluded.

[b]: Covariates include: sex, race/ethnicity, education, smoking status, hypertension, and BMI category.
[c]: Excluded 1163 adults (25-39: 60; 40-69: 429, 70 or older: 674).

Chapter 7: Conclusions, Implications, and Further Research

Conclusions

Current guidelines for aerobic physical activity recommend for substantial health benefits adults participate weekly in at least 150 minutes of moderate-intensity equivalent aerobic activity.[1] Our findings demonstrate that levels of physical activity inadequate to meet current guidelines are a public health burden in the U.S.

This series of studies makes several additions to the literature by overcoming many of the limitations found in previous studies estimating the burden of inadequate levels of physical activity in the U.S. First, these studies focus on levels of physical activity that are inadequate to meet current guidelines and national health objectives (i.e., inactive and insufficiently active),[1,2] while previous studies have mainly focused only on physical inactivity.[3-15] In addition, this series of studies has used data from nationally, representative samples thereby allowing us to generalize the findings to the non-institutionalized U.S. population and to overcome the limitations of previous studies that were mainly conducted in select populations.[16-23] Finally, this series of studies has calculated estimates of burden directly from individual level data while controlling for important covariates. This removes the bias that may be introduced when estimates of burden are calculated by combining risk and prevalence estimates across different data sources and populations, as done in previous studies.[3-12,24] These studies have used rigorous methodologies to provide the most accurate and up to date estimates of the burden of inadequate levels of physical activity in the U.S.

Inadequate Physical Activity and Health Care Expenditures in the United States

Inadequate levels of physical activity are associated with a significant financial burden in the U.S. During 2006-2010, an estimated 11.5% or $118 billion of aggregate annual health care expenditures independent of BMI were associated with inadequate levels of aerobic physical activity. When estimates were recalculated after excluding adults who reported any difficulty walking, 8.9% or $78 billion of aggregate annual health care expenditures were associated with inadequate levels of physical activity. The considerable financial burden associated with inadequate levels of physical activity could potentially be reduced by increasing adults' physical activity to levels consistent with guidelines and national health objectives.[1,2]

Our analysis used a conservative approach to derive these estimates. Throughout our analysis, we excluded adults reporting being unable to do physical activity and we conducted a further sensitivity analysis that excluded adults who reported any difficulty walking due to a health problem. By excluding these adults, we moderate concerns with reverse causality. That is, we remove those for whom a health problem may have influenced their physical activity level and increased their subsequent health care costs. By excluding this high cost group, however, we have likely provided conservative estimates. When these adults are excluded, we removed the influence physical activity may have had on these adults experiencing the health problem and maintaining physical function after the health problem. Adults who experience difficulty walking after a health problem may be an important target group as physical activity may be one way to improve these adults' physical function, as well as decrease their health care expenditures. Nevertheless, even with the conservative assumptions, we showed that inadequate levels of physical activity are associated with a significant financial burden.

Physical activity and Depression- and Anxiety-Specific Health Care Expenditures

Inadequate levels of physical activity are associated with a significant percentage of depression- and anxiety-specific health care expenditures. The percentage of depression- and anxiety-specific health care expenditures associated with inadequate levels of physical activity ranged from 11.1% or $3.0 billion when an attributable fraction approach was used to 21.2% or $5.8 billion when a regression based approach was used. The approach used to estimate the percentage of condition-specific spending can greatly influence estimates and it is important to understand what costs the different approaches account for. A limitation of the attributable fraction approach is that it does not account for the influence physical activity has on differences in the treatment costs among adults with depression or anxiety conditions; therefore, the attributable fraction approach can be viewed as a lower bound of the cost estimate.

Increasing adults' physical activity to levels consistent with current guidelines can potentially decrease depression- and anxiety-specific health care expenditures in two ways. One way is by decreasing the prevalence of depression and anxiety and the second way is by decreasing the cost to treat these conditions. It is important when examining depression- and anxiety-specific costs associated with inadequate levels of physical activity that physical activity's influence on primary and secondary prevention be considered. In addition, when examining and comparing policy analyses related to cost and cost control, it important to know what costs the estimation approach accounts for and how the approach used may influence the magnitude of these estimates.

Inadequate Physical Activity and Mortality in the United States

We found that a significant percentage of premature deaths among adults forty and older were attributed to inadequate levels of physically activity. Among adults age 40-69, 10.1% of premature deaths were attributed to inadequate levels of physical activity. Similarly, among adults age 70 or older, 9.0% of deaths were attributed to inadequate levels of physical activity. Increasing adults' physical activity levels to meet current guidelines may be one way to reduce premature deaths in the U.S.

We found much of the burden for adults age 40 and older was attributed to physical inactivity (40-69: 7.6%, 70 or older: 7.2%) with a smaller percentage of deaths attributed to insufficient levels of physical activity (40-69: 2.5%, 70 or older: 1.8%). This may suggest that physical activity programs should target inactive adults to have the greatest influence on the burden; however, converting insufficiently active adults to active adults may be easier to do. When using measures of burden to inform program planning and prioritizing, it is important to consider both the magnitude of the burden and the likelihood of changing behavior among the targeted group.

Comparison of Burden

Our findings suggest that improving population levels of physical activity may reduce some of the financial and mortality burden associated with unhealthy lifestyles in the U.S. Although methods and measures of burden can vary across risk factors, it can be informative to compare our findings with estimates of burden for two other unhealthy lifestyle factors: smoking and obesity.[15] In terms of financial burden, inadequate levels of physical activity are associated with a similar magnitude of burden as smoking and obesity. Studies have estimated that smoking (current and former) is associated with 8.9% of aggregate health care expenditures[25] and obesity is associated with 9.1% of aggregate health care expenditures in the U.S.[26] In terms of mortality burden, our estimates of burden for inadequate levels of physical activity were within the range of those estimated for obesity (4.8%)[27] and current smoking (24.5%).[13] Thus, inadequate levels of physical activity appear to have a similar influence on the financial and mortality burdens to that of smoking or obesity. Programs that target multiple unhealthy behaviors may be a viable option that can decrease the burden of unhealthy lifestyles in the U.S. Future work may wish to examine the potential influence programs targeting multiple behaviors could have on decreasing the burden of unhealthy lifestyles in the U.S.

Policy Implications

Improving population levels of physical activity may reduce some of the financial and mortality burden associated with unhealthy lifestyles in the U.S. In order to improve physical activity in the more than half of the U.S. adult population who are inadequately physically active, broad reaching changes in policies and practices are needed.

Strategies that target community level policies and practices are promising as they can have broad reach and can be tailored to the needs of individual communities.[1] The *Guide to Community Preventive Services* provides examples of approaches that communities can implement.[28,29] Communities can implement policies and practices that increase community members' access to physical activity opportunities in conjunction with informational outreach.[29] Communities can improve or implement street-scale urban-design and land-use policies that support physical activity.[28] Community level practices and policies can help create environments that make the healthy choice the easy choice for U.S. adults.

The worksite is another practical setting where policies and practices to promote physical activity in adults can be implemented. Health promotion programs implemented in the workplace can benefit from characteristics of the worksite environment (e.g., many people interact with one another in close physical proximity on a regular basis, the population is relatively stable, and some policies can be more easily mandated and enforced than in community settings).[30] Policies and practices at the worksite can create healthy work environments through health promotion policies, practices, and changes to the physical work environment that support physical activity.

The provision of physical activity counseling by health care professionals can also be influenced by policy levers. Policy changes under the Affordable Care Act (ACA) require that qualified health plans provide coverage (without cost-sharing) for preventive services rated A or B by the U.S. Preventive Services Task Force.[31] Physical activity counseling interventions have been shown to have modest benefits on improving physical activity levels; however, physical activity counseling has been rated as a C for adults in general.[32] Currently, policy changes may have little influence on the provision of physical activity counseling in the overall population; however, the effectiveness of physical activity counseling is under review for those with existing conditions or risk factors (e.g., known cardiovascular disease, obesity, high blood pressure, and high cholesterol).[33] As the evidence of the effectiveness of physical activity counseling grows, policy levers on its provision can play an important role in promoting physical activity counseling by health care professionals. Based on our study findings, we would also encourage that new reviews consider the role that physical activity counseling can play for those with mental health conditions, such as depression and anxiety, which can also be improved by increasing physical activity levels.

Future Research

This series of studies focused on two important measures of burden, health care expenditures and premature death. Future studies are needed to examine other types of burdens potentially related to inadequate levels of physical activity. These burdens may include costs related to long-term care, lost productivity from premature death and disability associated with illness, increased absenteeism in the workplace, and decreased productivity from deficient physical and emotional well-being. Examining these additional burdens will allow us to fully characterize the economic and societal burden of inadequate physical activity in the U.S.

Another area of future research would be to address the association between inadequate levels of physical activity and lifetime health care expenditures. It may be possible that lifetime expenditures are higher for physically active adults because they live longer. This is not only an issue for physical activity but is an issue when discussing the prevention of many risk factors, such as smoking and obesity, and has been debated in the literature.[34-37] Further research into the effect of inadequate levels of physical activity on lifetime costs is an important although challenging area to explore in the future.

Reverse causality is a concern for all three studies and future research may wish to further examine the issue of reverse causality using different study designs. Reverse causality is a concern for this series of studies because adults may be inactive because of poor health or previous health conditions and this may bias findings. Through multiple sensitivity analyses conducted as part of each study, we attempted to fully examine this issue. However, one area of future research would be to follow a cohort of adults over an extended period of time, assess their physical activity levels multiple times, and collect data on their health care expenditures, medical conditions, and mortality. This type of prospective study would allow researchers to closely examine the reverse causality issue and determine what influence it may have on estimates of the association and cost.

The first study of this series examined the association between physical activity and total health care expenditures. Future research may wish to examine this association when expenditures are limited to specific payers (e.g., Medicare, Medicaid, private insurance) or specific types of expenditures (e.g. in-patient, out-patient, prescription drugs). This would help to further define which payers and types of services are most burdened by inadequate levels of physical activity. Since it is likely that the Medicaid patient population, generally poorer and sicker, has higher obesity rates and less access to physical activity opportunities, this would be a payer group of particular interest. Given that the southeastern states are generally not planning to expand access to the Medicaid program, estimates of the costs to Medicaid associated with inadequate levels of physical activity across the four regions of the country would be particularly informative to policy makers in these regions.

The second study of the series focused on two conditions, depression and anxiety. Regular physical activity is associated with numerous health benefits including reduced risk for cardiovascular disease, ischemic stroke, type 2 diabetes, colon and breast cancer, osteoporosis, and fall-related injuries.[23] Future studies may wish to expand our work and examine differences in estimates from attributable fraction and regression based approaches for other conditions. Because physical activity has been shown to play a role in the secondary prevention and treatment of many conditions, such as hypertension,[38,39] hyperlipidemia,[40] diabetes,[41,42] and heart disease,[43] it is likely that physical activity will influence both the presence of the condition and the cost to treat the condition. We expect similar differences between attributable fraction and regression based approaches to be observed for cardio-metabolic conditions as were observed for depression and anxiety.

The second study of the series was limited to health care expenditures specific to depression and anxiety. The study did not capture additional costs that may be attributed to depression and anxiety. Costs that may be considered attributable include costs stemming from the role that depression and/or anxiety plays as a risk factor for other conditions (for example, depression and anxiety have both been linked to hypertension, depression has been shown to be a risk factor for the development and progression of coronary artery disease)[44,45] and the role that depression and anxiety may play on treatment costs for non-etiologically related conditions (for example, the presence of depression may influence treatment adherence which can influence disease progression and health care utilization).[46] Future studies may wish to examine the interplay between the presence of depression and/or anxiety, physical activity level, and overall health care expenditures.

The final study examined the association between physical activity and mortality. We found no association between physical activity and mortality for the youngest age group (25-39 years). Future research may wish to examine this association in younger age groups with a longer follow-up period. In addition, our study was limited to one baseline measure of activity. A previous study concluded the risk of a sedentary lifestyle is underestimated when it is derived from a prospective study using a single baseline measurement.[47] Future studies that examine the association between physical activity and mortality would benefit from multiple measures of physical activity over the follow-up period. This would also allow researchers to examine differences among adults who maintain consistent levels of activity versus those who change activity levels overtime.

Finally, having an accurate estimate of the burden of inadequate levels of physical activity is important for many reasons. Estimates of burden are important for setting research, policy, and program priorities; for use in cost effectiveness analyses; and for public health planning and resource allocation.[3,48] A related area that warrants further research is related to the cost-effectiveness of specific policies and programs aimed at increasing physical activity in communities. The *Guide to Community Preventive Services* provides examples of approaches that communities can implement, including community-wide activity-promotion campaigns, efforts to increase community members' access to physical activity opportunities in conjunction with informational outreach, and street-scale urban-design and land-use policies that support physical activity.[28,29] However, little information is available related to the cost-effectiveness of these approaches.[49] This information is important for policy and program planners when selecting and prioritizing programs to implement in their target populations.

References

1. US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans.* Washington, DC: U.S. Department of Health and Human Services;2008.

2. U.S. Department of Health and Human Services. Healthy People 2020. 2012; http://www.healthypeople.gov/2020/topicsobjectives2020/default.aspx. Accessed December 1, 2012.

3. Allender S, Foster C, Scarborough P, Rayner M. The burden of physical activity-related ill health in the UK. *J Epidemiol Commun H.* Apr 2007;61(4):344-348.

4. Colditz GA. Economic costs of obesity and inactivity. *Med Sci Sports Exerc.* Nov 1999;31(11 Suppl):S663-667.

5. Garrett NA, Brasure M, Schmitz KH, Schultz MM, Huber MR. Physical inactivity: direct cost to a health plan. *Am J Prev Med.* Nov 2004;27(4):304-309.

6. Katzmarzyk P, Janssen I. The economic costs associated with physical inactivity and obesity in Canada: an update. *Can J Appl Physiol.* 2004;29(1):90-115.

7. Katzmarzyk PT, Gledhill N, Shephard RJ. The economic burden of physical inactivity in Canada. *CMAJ.* Nov 28 2000;163(11):1435-1440.

8. Popkin BM, Kim S, Rusev ER, Du S, Zizza C. Measuring the full economic costs of diet, physical activity and obesity-related chronic diseases. *Obes Rev.* Aug 2006;7(3):271-293.

9. Bull FC, Armstrong TP, Dixon T, Ham S, Neiman A, Pratt M. Physical inactivity. In: Ezzati M, Lopez AD, Rodgers A, Murray CJ, eds. *Comparative quantification* *of health risks: global and regional burden of disease attributable to selected major risk factors*. Geneva: World Health Organization; 2004.

10. Danaei G, Ding EL, Mozaffarian D, et al. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. *PLoS Med.* Apr 28 2009;6(4):e1000058.

11. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet.* Jul 21 2012;380(9838):219-229.

12. Powell KE, Blair SN. The public health burdens of sedentary living habits: theoretical but realistic estimates. *Med Sci Sports Exerc.* Jul 1994;26(7):851-856.

13. Yang Q, Cogswell ME, Flanders WD, et al. Trends in cardiovascular health metrics and associations with all-cause and CVD mortality among US adults. *JAMA.* Mar 28 2012;307(12):1273-1283.

14. Pratt M, Macera CA, Wang G. Higher direct medical costs associated with physical inactivity. *Phys Sportsmed.* Oct 2000;28(10):63-70.

15. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet.* Jul 21 2012;380(9838):219-229.

16. Anderson LH, Martinson BC, Crain AL, et al. Health care charges associated with physical inactivity, overweight, and obesity. *Prev Chronic Dis.* Oct 2005;2(4):A09.

17. Bland PC, An L, Foldes SS, Garrett N, Alesci NL. Modifiable health behaviors and short-term medical costs among health plan members. *Am J Health Promot.* Mar-Apr 2009;23(4):265-273.

18. Brown WJ, Hockey R, Dobson AJ. Physical activity, Body Mass Index and health care costs in mid-age Australian women. *Aust N Z J Public Health.* Apr 2008;32(2):150-155.

19. Pronk NP, Goodman MJ, O'Connor PJ, Martinson BC. Relationship between modifiable health risks and short-term health care charges. *Jama-J Am Med Assoc.* Dec 15 1999;282(23):2235-2239.

20. Wang F, McDonald T, Reffitt B, Edington DW. BMI, physical activity, and health care utilization/costs among Medicare retirees. *Obes Res.* Aug 2005;13(8):1450-1457.

21. Yang G, Niu K, Fujita K, et al. Impact of physical activity and performance on medical care costs among the Japanese elderly. *Geriatr Gerontol Int.* Apr 2011;11(2):157-165.

22. 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.* May 2004;46(5):428-436.

23. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report, 2008.* Washington, DC: U.S. Department of Health and Human Services;2008.

24. Rockhill B, Newman B, Weinberg C. Use and misuse of population attributable fractions. *American Journal of Public Health.* 1998;88(1):15-19.

25. US Department of Health and Human Services. *The Health Consequences of Smoking: 50 Years of Progress. A Report of the Surgeon General.* Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health;2014.

26. Finkelstein EA, Trogdon JG, Cohen JW, Dietz W. Annual medical spending attributable to obesity: payer-and service-specific estimates. *Health Aff (Millwood).* Sep-Oct 2009;28(5):w822-831.

27. Flegal KM, Graubard BI, Williamson DF, Gail MH. Excess deaths associated with underweight, overweight, and obesity. *JAMA.* Apr 20 2005;293(15):1861-1867.

28. Heath GW, Brownson RC, Kruger J, et al. The effectiveness of urban design and land use and transport policies and practices to increase physical activity: a systematic review. *Journal of Physical Activity and Health.* 2002;3(Suppl 1):S55-76.

29. Task Force on Community Preventive S. Recommendations to increase physical activity in communities. *Am J Prev Med.* May 2002;22(4 Suppl):67-72.

30. Task Force on Community Preventive S. A recommendation to improve employee weight status through worksite health promotion programs targeting nutrition, physical activity, or both. *Am J Prev Med.* Oct 2009;37(4):358-359.

31. Kaiser Family Foundation. Summary of the Affordable Health Care Act. 2013; http://kaiserfamilyfoundation.files.wordpress.com/2011/04/8061-021.pdf.

32. US Preventive Services Task Force. Behavioral Counseling to Promote a Healthful Diet and Physical Activity for Cardiovascular Disease Prevention in Adults. 2012; http://www.uspreventiveservicestaskforce.org/uspstf/uspsphys.htm

33. US Preventive Services Task Force. Behavioral Counseling to Promote a Healthy Diet and Physical Activity for Cardiovascular Disease Prevention in Adults With Known Risk Factors. 2013; http://www.uspreventiveservicestaskforce.org/uspstf13/cvdhighrisk/cvdhighriskfinalresplan.htm.

34. van Baal PH, Polder JJ, de Wit GA, et al. Lifetime medical costs of obesity: prevention no cure for increasing health expenditure. *PLoS Med.* Feb 2008;5(2):e29.

35. Fries JF, Koop CE, Beadle CE, et al. Reducing health care costs by reducing the need and demand for medical services. The Health Project Consortium. *N Engl J Med.* Jul 29 1993;329(5):321-325.

36. Bonneux L, Barendregt JJ, Nusselder WJ, der Maas PJ. Preventing fatal diseases increases healthcare costs: cause elimination life table approach. *BMJ.* Jan 3 1998;316(7124):26-29.

37. Barendregt JJ, Bonneux L, van der Maas PJ. The health care costs of smoking. *N Engl J Med.* Oct 9 1997;337(15):1052-1057.

38. Hagberg JM, Park JJ, Brown MD. The role of exercise training in the treatment of hypertension: an update. *Sports Med.* Sep 2000;30(3):193-206.

39. Pescatello LS, Franklin BA, Fagard R, et al. American College of Sports Medicine position stand. Exercise and hypertension. *Med Sci Sports Exerc.* Mar 2004;36(3):533-553.

40. Smith SC, Jr., Benjamin EJ, Bonow RO, et al. AHA/ACCF Secondary Prevention and Risk Reduction Therapy for Patients with Coronary and other Atherosclerotic Vascular Disease: 2011 update: a guideline from the American Heart Association and American College of Cardiology Foundation. *Circulation.* Nov 29 2011;124(22):2458-2473.

41. Colberg SR, Albright AL, Blissmer BJ, et al. Exercise and type 2 diabetes: American College of Sports Medicine and the American Diabetes Association: joint position statement. Exercise and type 2 diabetes. *Med Sci Sports Exerc.* Dec 2010;42(12):2282-2303.

42. Colberg SR, Grieco CR. Exercise in the treatment and prevention of diabetes. *Curr Sports Med Rep.* Jul-Aug 2009;8(4):169-175.

43. Lavie CJ, Milani RV. Cardiac rehabilitation and exercise training in secondary coronary heart disease prevention. *Progress in cardiovascular diseases.* May-Jun 2011;53(6):397-403.

44. Jonas BS, Franks P, Ingram DD. Are symptoms of anxiety and depression risk factors for hypertension? Longitudinal evidence from the National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study. *Archives of family medicine.* / 1997;6(1):43-49.

45. Lett HS, Blumenthal JA, Babyak MA, et al. Depression as a risk factor for coronary artery disease: evidence, mechanisms, and treatment. *Psychosomatic medicine.* May-Jun 2004;66(3):305-315.

46. DiMatteo M, Lepper HS, Croghan TW. Depression is a risk factor for noncompliance with medical treatment: Meta-analysis of the effects of anxiety and depression on patient adherence. *Archives of Internal Medicine.* 2000;160(14):2101-2107.

47. Andersen LB. Relative risk of mortality in the physically inactive is underestimated because of real changes in exposure level during follow-up. *Am J Epidemiol.* Jul 15 2004;160(2):189-195.

48. Caspersen CJ, Powell KE, Merriitt RK. Measurement of health status and well being. In: Bouchard C, Shephard RJ, Stephens T, eds. *Physical activity, fitness, and health: International proceeding and consensus statement*. Champaign, IL: Human Kinetics; 1994.

49. Roux L, Pratt M, Tengs TO, et al. Cost effectiveness of community-based physical activity interventions. *Am J Prev Med.* Dec 2008;35(6):578-588.