Published in final edited form as:

Lancet. 2012 July 21; 380(9838): 219–229. doi:10.1016/S0140-6736(12)61031-9.

Impact of Physical Inactivity on the World's Major Non-Communicable Diseases

I-Min Lee, MBBS, ScD, **Eric J Shiroma, MSc**, **Felipe Lobelo, MD, PhD**, **Pekka Puska, MD**, **Steven N Blair, PED**, and **Peter T Katzmarzyk, PhD for the Lancet Physical Activity Series Working Group***

Division of Preventive Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA (I-M Lee, MBBS, ScD), Department of Epidemiology, Harvard School of Public Health, Boston, MA, USA (EJ Shiroma, MSc), Global Health Promotion Office, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, GA, USA (F Lobelo, MD, PhD), National Institute for Health and Welfare, Helsinki, Finland (P Puska, MD), Departments of Exercise Science and Epidemiology/Biostatistics, Arnold School of Public Health, University of South Carolina, Columbia, SC, USA (SN Blair, PED), Pennington Biomedical Research Center, Baton Rouge, LA, USA (PT Katzmarzyk, PhD)

Summary

Background—Strong evidence shows that physical inactivity increases the risk of many adverse health conditions, including the world's major non-communicable diseases (NCDs) of coronary heart disease (CHD), type 2 diabetes, and breast and colon cancers, and shortens life expectancy. Because much of the world's population is inactive, this presents a major public health problem. We aimed to quantify the impact of physical inactivity on these major NCDs by estimating how much disease could be averted if those inactive were to become active and to estimate gain in life expectancy, at the population level.

Methods—Using conservative assumptions, we calculated population attributable fractions (PAF) associated with physical inactivity for each of the major NCDs, by country, to estimate how much disease could be averted if physical inactivity were eliminated, and used life table analysis to estimate gains in life expectancy of the population.

Correspondence to: Dr. I-Min Lee, Brigham and Women's Hospital, Harvard Medical School, 900 Commonwealth Avenue East, Boston, MA 02215, USA. ilee@rics.bwh.harvard.edu.

*Members listed at the end of the paper

Contributors

I-ML and PTK designed the study, and other authors provided critical input. EJS and PTK carried out data analyses. I-ML, EJS, and FL extracted data from the primary studies used in the meta-analyses. I-ML drafted the manuscript. EJS, FL, PP, SNB, and PTK critically reviewed the manuscript.

Lancet Physical Activity Series working group

Jasem R Alkandari, Lars Bo Andersen, Adrian Bauman, Steven N Blair, Ross C Brownson, Fiona C Bull, Cora L Craig, Ulf Ekelund, Shifalika Goenka, Regina Guthold, Pedro C Hallal, William L Haskell, Gregory W Heath, Shigeru Inoue, Sonja Kahlmeier, Peter T Katzmarzyk, Harold W Kohl III, Vicky Lambert, I-Min Lee, Grit Leetongin, Felipe Lobelo, Ruth Loos, Bess Marcus, Brian Martin, Neville Owen, Diana C Parra, Michael Pratt, Pekka Puska, David Ogilvie, Rodrigo S Reis, James F Sallis, Olga Lucia Sarmiento, and Jonathan C K Wells.

Declarations

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

Conflicts of Interest

We declare that we have no conflicts of interest. 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.

Findings—Worldwide, we estimate that physical inactivity is responsible for 6% of the burden of disease from CHD (range: 3.2% in South-east Asia to 7.8% in the Eastern Mediterranean region); 7% of type 2 diabetes (3.9% to 9.6%), 10% of breast cancer (5.6% to 14.1%), and 10% of colon cancer (5.7% to 13.8%). Inactivity is responsible for 9% of premature mortality (5.1% to 12.5%), or >5.3 of the 57 million deaths that occurred worldwide in 2008. If inactivity were not eliminated, but decreased instead by 10% or 25%, >533,000 and >1.3 million deaths, respectively, may be averted each year. By eliminating physical inactivity, life expectancy of the world's population is estimated to increase by 0.68 (0.41 to 0.95) years.

Interpretation—Physical inactivity has a major health impact on the world. Elimination of physical inactivity would remove between 6% and 10% of the major NCDs of CHD, type 2 diabetes, and breast and colon cancers, and increase life expectancy.

Introduction

Ancient physicians—including those from China in 2600 BC and Hippocrates around 400 BC—believed in the value of physical activity for health. By the twentieth century, however, a diametrically opposite view—that exercise was dangerous—prevailed instead. During the early twentieth century, complete bed rest was prescribed for patients with acute myocardial infarction. And, at the time of the 100th boat race between Oxford and Cambridge in 1954, the Senior Health Officer of Cambridge University conducted a study to investigate the "alleged dangers" of exercise by comparing university sportsmen with "intellectuals".[1]

One of the pioneers whose work helped change that tide of popular opinion was Professor Jerry Morris who conducted the first rigorous, epidemiologic studies investigating physical inactivity and chronic disease risk, published in 1953.[2] Since then, a large body of evidence has clearly documented the many health benefits of physical activity, summarized in Figure 1.[3–5] Despite this knowledge, a large proportion of the world's population remains physically inactive. To quantify the impact of physical inactivity on the world's major non-communicable diseases (NCDs), we estimate how much of these diseases could be averted in the population if those inactive were to become active, as well as how much gain in life expectancy could occur at the population level. We focus on the major NCDs recently highlighted by the United Nations as threats to global health:[6] coronary heart disease (CHD); cancer, specifically breast and colon cancers, which are convincingly related to physical inactivity; and type 2 diabetes.

Methods

Concept of population attributable fraction (PAF)

The population attributable fraction (PAF) is a measure used by epidemiologists to estimate the impact of a risk factor on disease incidence in a population.[7, 8] It estimates the proportion of new cases that would not occur, absent a particular risk factor. Thus, it provides policy makers with useful quantitative estimates of the potential impact of interventions to reduce/eradicate the risk factor.

PAF is related to prevalence of the risk factor and its associated relative risk (RR). At least two formulae are available to calculate PAF (Figure 2). Formula 1 provides an unbiased estimate when there is no confounding of the relationship between the risk factor and disease, and requires knowledge of the prevalence of the risk factor in the population and the RR not adjusted for confounders (crude RR). Formula 2 is preferred when there is confounding;[8] it requires knowledge of the prevalence of the risk factor among persons eventually developing the disease ("cases") and the adjusted RR. Because some confounders (e.g., hypertension in CHD, overweight in diabetes) are exacerbated by inactivity, Formula 2 may over-adjust, while Formula 1 can add perspective. Thus, we sought prevalence estimates of inactivity for the whole population and unadjusted RRs to estimate PAF using Formula 1, and prevalence estimates of inactivity for cases and adjusted RRs to estimate PAF using Formula 2.

Estimation of prevalence of physical inactivity

We define "physical inactivity" to be an activity level insufficient to meet current recommendations; "physical activity", sufficient.[5] The World Health Organization (WHO) collects data, by country, on the prevalence of physical inactivity in the population using two similar standardized questionnaires (described in a companion paper); the latest data are for 2008.[9]

When calculating PAFs using RRs adjusted for confounding factors, the prevalence of physical inactivity at baseline among cases of the outcome of interest is required. These data proved difficult to obtain for countries outside North America and Europe. Further, data on the prevalence of inactivity depended on the instrument used for assessment and varied according to whether a study assessed physical activity during leisure only (most commonly), or also included activities in occupation, transportation, and/or home-based activities.

Thus, to estimate the prevalence of inactivity among cases, we contacted several large cohort studies throughout the world using input from the Lancet Physical Activity Series working group, attempting particularly to gather data outside North America and Europe. For each study, we obtained the prevalence of physical inactivity among all subjects at baseline, and among those eventually developing CHD, type 2 diabetes, breast and colon cancer, and dying (webappendix pp 1–2). For each outcome, we calculated an "adjustment factor", representing the added extent to which physical inactivity occurred among cases, compared with the overall population of the cohort study. For example, in the Shanghai Women's Health Study, the prevalence of inactivity among all women at baseline was 45.4%; among women dying, it was 51.6%, yielding an adjustment factor of 1.14 (51.6/45.4 = 1.14). For each outcome, we calculated the adjustment factor in every study, and averaged this across studies. We applied the average adjustment factor to the prevalence of physical inactivity, by country, to estimate the prevalence of inactivity among cases of CHD, type 2 diabetes, breast and colon cancer, and all-cause mortality.

Estimation of relative risks associated with physical inactivity

We searched electronic databases (MEDLINE and EMBASE) using keywords related to physical activity ('physical activity', 'motor activity', 'energy expenditure', 'walking', 'exercise') and the outcomes of interest, selecting the most recent review.

For all outcomes except breast cancer, published meta-analyses of the pooled relative risk were available.[10–13] For breast cancer, no comprehensive meta-analysis was found (one of only case-control studies is available[14]), so we selected the most recent qualitative review[15] and conducted a meta-analysis of their primary studies.

All the meta-analyses calculated only pooled RRs adjusted for potential confounders (generally selecting maximally adjusted RRs from individual studies); no pooled estimates of crude RRs were reported. Thus, we obtained the primary papers to identify the crude RRs. For most papers, this was not reported; for several, data were provided that allowed its calculation. Where the crude RR was unavailable or could not be calculated, the age-adjusted RR was often available. Thus, to obtain a pooled estimate of the crude RRs, we used either crude RRs or age-adjusted RRs, calling this the "unadjusted RR". This enabled use of data from a larger number of studies, and a closer parallel between studies used to calculate the pooled unadjusted and adjusted RRs. In sensitivity analyses that compared results using only crude RRs with those using both crude and age-adjusted RRs, estimates were generally similar; thus, bias using "unadjusted" instead of crude RRs is unlikely.

We employed simple, random-effects meta-regression to account for heterogeneity across studies, using MIX 2.0.

Calculation of population attributable fractions

We calculated the PAFs for each outcome, by country, and used Monte Carlo simulation techniques (10,000 simulations) to estimate 95% uncertainty intervals. We assumed normal distributions for physical inactivity prevalence and the log of the RRs.

Calculation of gains in life expectancy

We employed life table analysis to estimate gains in life expectancy that could be expected if physical inactivity were eliminated, using life tables published by the WHO which provides age-specific death rates, by country; the latest data are for 2009.[16]

Since the country-specific PAF for all-cause mortality estimates how much of premature mortality can be removed from the population if physical inactivity were eliminated, we assumed that the age-specific death rates for a particular country would be decreased by an amount equal to this PAF (calculated using the adjusted RR), if inactivity were eliminated. Studies of physical activity and all-cause mortality have primarily been in persons aged ≥40 years, with few data available among persons ≥80 years, which also indicate benefit.[3] Thus, we conservatively decreased age-specific death rates by the PAF only for ages 40–79 years, and calculated the revised life expectancy from birth, by country. In sensitivity analysis, we conducted parallel analyses that decreased age-specific death rates for all ages ≥40 years.

Results

Prevalence of physical inactivity

We estimated the prevalence of physical inactivity among cases of the outcomes studied, by country, using adjustment factors of 1.20 (standard error, 0.03) for CHD, 1.23 (0.05) for type 2 diabetes, 1.05 (0.09) for breast cancer, 1.22 (0.08) for colon cancer, and 1.22 (0.07) for all-cause mortality. The highest prevalence is observed among persons who went on to develop type 2 diabetes (overall median, 43%), followed by those eventually dying, and those developing colon cancer, CHD, and breast cancer (overall medians, 43%, 43%, 42%, and 41%, respectively) (Table 1, webappendix pp 3–7).

Relative risks associated with physical inactivity

Table 1 summarises these RRs, unadjusted and adjusted for confounders, for the outcomes studied.

Coronary heart disease—Sattelmair et al recently investigated the dose-response relation between leisure-time energy expenditure and CHD incidence.[10] The pooled RR associated with energy expenditure that fulfilled current recommendations compared with no leisure activity, adjusted for potential confounders, was 0.86 (95% confidence interval [CI] 0.77–0.96). With greater energy expenditure, CHD incidence further declined in a curvilinear fashion.

For this paper, we used the RR corresponding to an activity level that met minimal current recommendations, or 0.86. Reversing this to obtain the adjusted RR for physical inactivity yields 1.16 (1.04–1.30). While these data are from only North America and Europe (i.e., studies with sufficient information to investigate dose-response), they are congruent with findings from the INTERHEART study conducted in 52 countries worldwide, where the adjusted odds ratio for myocardial infarction associated with physical inactivity was identical: 1.16 (1.03–1.32).[17]

We conducted a parallel meta-analysis to obtain the corresponding pooled unadjusted RR (i.e., pooling crude as well as age-adjusted RRs), which was 1.33 (1.18–1.49) (webappendix pp 12). Crude RRs were available for only 4 studies; pooling these yielded a value of 1.54 (1.25–1.92); thus, the pooled unadjusted RR is conservative.

Type 2 diabetes—Jeon et al[11] reported a pooled RR of 0.83 (0.76–0.90) for type 2 diabetes incidence associated with physical activity, adjusted for several confounders including body mass index (BMI). Taking the inverse to obtain the adjusted RR for inactivity produced an RR of 1.20 (1.10–1.33).

We calculated the corresponding, pooled unadjusted RR, which was 1.63 (1.27–2.11) (webappendix pp 13). This magnitude of risk increase was similar to that pooling only the crude RRs, which yielded 1.58 (1.11–2.26).

Breast cancer—We used the primary papers in the qualitative review by Friedenreich et al[15] to conduct a meta-analysis of the pooled adjusted and unadjusted RRs for breast cancer incidence (webappendix pp 14–15). The adjusted RR, including adjustment for BMI, for physical inactivity was 1.33 (1.26, 1.42). This was little different from the unadjusted RR of 1.34 (1.25, 1.43) (similar to that pooling only crude RRs, yielding 1.35 (1.26, 1.45)).

Colon cancer—Wolin et al[12] reported a pooled adjusted RR of 0.76 (0.72, 0.81) for colon cancer incidence associated with physical activity. Reversing these results gives an adjusted RR of 1.32 (1.23–1.39) for inactivity. Our calculation of the pooled unadjusted RR for colon cancer was 1.38 (1.31–1.45) (webappendix pp 16); the pooled crude RR was similar (1.37 (1.29–1.46)).

All-cause mortality—Lollgen et al published a meta-analysis of the RRs for all-cause mortality associated with moderate and high levels of physical activity, qualitatively defined.[13] Investigators reported separate estimates for studies where subjects were categorized into three, four, or five levels of activity. The adjusted RRs for moderate levels compared with a low level ranged from 0.53 to 0.78; for high levels, 0.52 to 0.80. We used their primary papers to conduct a meta-analysis to obtain a single pooled RR that compared low with moderate physical activity—i.e., a conservative estimate of the impact of inactivity. Our pooled adjusted RR was 1.28 (1.21–1.36), while the pooled unadjusted RR was 1.47 (1.38–1.57) and similar to the pooled crude RR of 1.46 (1.34–1.60) (webappendix pp 17–18).

Population attributable fractions associated with physical inactivity

For CHD, the median PAFs calculated using adjusted RRs ranged from 3.2% (in South-east Asia) to 7.8% (in the Eastern Mediterranean region), with an overall median of 6% (Tables 1 and 2). This indicates that 6% of the burden of disease worldwide due to CHD can be eliminated, if all inactive persons become active. For type 2 diabetes, breast and colon cancers, the corresponding burdens of disease were 7% (ranging from 3.9% to 9.6%), 10% (5.6–14.1%), and 10% (5.7–13.8%), respectively.

Thus, removing physical inactivity has the largest impact on colon cancer, and the smallest on CHD, in terms of percent reduction. However, with regard to the number of cases that can potentially be averted, CHD would have a far larger impact than colon cancer because of its higher incidence. While the worldwide incidence of CHD is not readily available, deaths from CHD may be viewed against colorectal cancer deaths to provide some perspective: in 2008, 7.25 million people worldwide died from CHD, 647,000 from colorectal cancer.[18] Applying the median PAFs, we estimate that 15,000 CHD deaths in Africa could have been averted in 2008 by removing physical inactivity. For the Americas, Eastern Mediterranean region, Europe, Southeast Asia, and the Western Pacific region, the corresponding numbers are 60,000, 44,000, 121,000, 59,000, and 100,000, respectively. With regard to breast cancer deaths potentially averted, the numbers are 3,000, 11,000, 4,000, 14,000, 5,000, and 10,000 respectively; for colorectal cancer, 1,000, 14,000, 2,000, 24,000, 4,000 and 24,000, respectively.

For all-cause mortality, the overall median PAF was 9%. Applying this figure to the 57 million deaths worldwide in 2008[18] shows that >5.3 million deaths (range, 525,000 in the Eastern Mediterranean region to 1.5 million in the Western Pacific region) may be averted annually if all inactive persons become active. Because physical inactivity is unlikely to be completely eliminated, we estimated potential deaths averted when assuming a decrease of inactivity prevalence by 10% or 25% with effective public health interventions, instead of 100% (elimination). These alternate scenarios resulted in >533,000 and >1.3 million deaths potentially avoided worldwide each year.

Using an alternate classification of countries by income (data not shown), the median PAFs for all-cause mortality were 4%, 8%, 10%, and 11%, respectively, for low, lower-middle, upper-middle, and high income countries (with number of deaths averted ranging from 409,000 in low income, to 2.5 million in lower-middle income countries). This yielded estimated numbers of CHD deaths potentially averted in 2008 of 15,000, 184,000, 96,000, and 98,000, respectively; breast cancer deaths, 2,000, 16,000, 10,000, and 20,000, respectively; colorectal cancer deaths, 1,000, 19,000, 13,000, and 37,000, respectively.

Gain in life expectancy

We estimated that the median years of life potentially gained worldwide with elimination of physical inactivity was 0.68 years (range: 0.41 years in South-east Asia to 0.95 years in the Eastern Mediterranean region) (Table 3, Figure 3 map). When classifying countries by income, the median gains were 0.37, 0.65, 0.80, and 0.68 years, respectively, for low, lower-middle, upper-middle, and high income countries.

In sensitivity analysis that decreased age-specific death rates by the PAF for all ages ≥40 years (instead of only ages 40–79 years), the new estimate of years gained worldwide increased to a median of 0.92 (range, 0.49–1.25) years.

Finally, we used an example to illustrate gains under less stringent assumptions. A recent study of Taiwanese aged ≥20 years reported an RR for all-cause mortality, comparing most with least active persons, of 1.35.[19] Applying this RR to China for persons aged ≥20 years resulted in PAF of 9.8% and gain in life expectancy of 1.03 years, versus 8.3% and 0.61 years obtained under the standard assumptions of Tables 2 and 3.

Discussion

Worldwide, we estimate that physical inactivity is responsible for between 6% and 10% of the major NCDs of CHD, type 2 diabetes, and breast and colon cancers. And, this unhealthy behaviour is responsible for 9% of premature mortality, or >5.3 of the 57 million deaths in 2008.[18] By eliminating physical inactivity, life expectancy of the world's population may be expected to increase by 0.68 years. This makes inactivity comparable to the established risk factors of smoking and obesity, discussed below. It is important to interpret the added years of life correctly: they appear modest because they represent gains in the whole population (comprising inactive and active persons), not among inactive persons who become active. Because all the gain accrues to those who move from inactive to active, the increase in life expectancy among the inactive alone is greater. For perspective, other research conducted in the United States estimated that inactive persons would gain 1.3–3.7 added years from age 50 by becoming active.[20, 21] And, among East Asians, life expectancy from age 30 among the active was 2.6–4.2 years greater, compared with inactive persons.[19]

How does physical inactivity compare with other risk factors for poor health? While risk factors are categorized on different scales (thus, the proportion "at risk" varies across risk factors), it is nonetheless informative to look at two established risk factors targeted for government action worldwide: smoking and obesity. Smoking was estimated to cause about 5 million deaths worldwide in 2000.[22] The proportion of deaths attributable to smoking in China, one of the top five cigarette consuming countries, has been estimated at 3.1% for women and 12.9% for men.[23] And by eliminating smoking, life expectancy at age 50 was estimated to increase by 2.3–2.5 years in the United States population, and 1.1–2.2 years in the populations of nine other high income countries.[24] At the person level, Beijing never smokers aged ≥55 years enjoyed a life expectancy 4.2–8.8 years longer than current smokers.[25] As for obesity, if all obese persons in the United States, one of the heaviest countries in the world, were to attain normal weight, life expectancy in the population was estimated to increase by 0.7–1.1 years at birth in one analysis[26] and 0.5–0.7 years at age 50 in another.[24] Thus, physical inactivity appears to have an impact comparable to smoking or obesity.

The present analysis updates information from a 2004 WHO report,[27] and additionally estimates added years of life expectancy in the population. In the WHO report, because of unavailability of data required for the preferred PAF formula, the incorrect formula (Figure 2, formula 1) was used. Their PAFs ranged from 10% for breast cancer to 22% for CHD—similar to the present estimate for breast cancer, but larger for CHD. In part, this difference is because the RR of breast cancer for physical inactivity is not confounded by other variables (unadjusted RR, 1.34; adjusted RR, 1.33), while that for CHD is (unadjusted RR, 1.33; adjusted RR, 1.16). Further, we conservatively used a pooled RR for CHD that compared physical inactivity with the minimum recommended activity level using recently published data,[10] while the WHO used available data then that compared extreme activity categories, yielding RRs of larger magnitude.

Our estimates are likely very conservative. First, the RRs were almost always based on self-reported physical activity,[28] which are likely imprecise. In prospective studies where self-reports cannot be biased by the outcomes studied (since they have not yet occurred at the time of reporting), random reporting errors result in underestimation of the RRs. Some studies of physical fitness—a related measure to physical activity that is more objectively measured—show stronger magnitudes of association with NCDs[29] (which also may reflect inherited physiologic and metabolic characteristics related to both fitness and a favourable risk profile). Second, the pooled RRs were derived from maximally adjusted RRs in the primary studies. Often, these RRs adjusted for characteristics such as blood pressure, lipid profile, and glucose/insulin sensitivity. It can be argued that these are over-adjustments, since physical activity reduces risk of CHD and premature mortality partly through beneficial effects on these variables (a recent analysis suggested an attenuation of ~10% in the RR[10]). For type 2 diabetes, we used RRs adjusted for BMI—also conservative, since physical activity plays an important role in weight management.[3] Third, we used the same RR to calculate PAFs for all countries, based on data primarily from North America and Europe. It is unclear whether physical inactivity has similar effects in other populations. For example, we used a pooled adjusted RR for CHD of 1.16; however, a study in India reported an adjusted RR of larger magnitude, 2.27 (1.41–3.70).[30] However, our pooled adjusted RR for all-cause mortality, 1.28, is similar to that of 1.25 (1.18–1.33) among East Asians, comparing inactive persons with those meeting minimal physical activity recommendations.[19] Fourth, we assumed physical activity to reduce all-cause mortality rates only in ages 40–79 years. In sensitivity analysis that extended the benefit to all ages ≥40 years, larger gains in life expectancy were obtained. Fifth, we used a single RR, instead of a range of RRs to reflect the dose-response relation between physical inactivity and NCD risks because sparse data are available on the dose-response relation.[10] In an illustrative example using China, applying less stringent assumptions increased PAF by 18% (9.8% vs. 8.3%) and life expectancy by 69% (1.03 vs. 0.61 years), compared with calculations made under standard assumptions.

Limitations of this study include the use of an adjustment factor to estimate the prevalence of physical inactivity among cases. This adjustment factor was primarily based on populations in North America and Europe, and one study each from China and India; it is unclear how applicable this might be to other countries such as those in Africa or low income countries. Also, successful interventions likely will increase activity levels across the board, instead of shifting persons across a binary divide of “inactive-active” assumed in our calculations, potentially yielding greater benefits. We examined only the major NCDs and all-cause mortality, and not other conditions impacted by physical inactivity (Figure 1) or disability resulting from NCDs. Finally, not all physically inactive persons choose to be so; some may be physically incapable.

In this year of the 2012 summer Olympic Games, we admire the breathtaking feats of athletes who embody “Citius, Altius, Fortius”. But, only the smallest fraction of a fraction of us will attain these heights. However, the overwhelming majority is able to be physically active at very modest levels—e.g., 15–30 minutes a day of brisk walking—which bring significant health benefits.[3–5, 19] We must explore all avenues and support all efforts to reduce physical inactivity in the world.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding

I-Min Lee was supported in part by grant CA154647 from the US National Institutes of Health. Eric J Shiroma was supported in part by grant HL007575 from the US National Institutes of Health. Peter T Katzmarzyk was supported in part by the Louisiana Public Facilities Authority Endowed Chair in Nutrition. None of the funding organisations had any role in the writing of the manuscript or the decision to submit it for publication.

We thank Kenneth E Powell, Shane A Norris, and Beverly J Levine for reviewing a previous draft of the manuscript and providing critical input. We thank the following persons for providing data to calculate the adjustment factor: David Batty, Kennet Harald, Duck-chul Lee, Charles E Matthews, Martin Shipley, Emmanuel Stamatakis, Xuemei Sui, and Nicholas J Wareham. We thank Jacob R Sattelmair and Kathleen Y Wolin for assisting with meta-analyses.

References

1. Rook A. An investigation into the longevity of Cambridge sportsmen. Br Med J. 1954; 1:773–7. [PubMed: 13140858]

2. Blair SN, Davey Smith G, Lee IM, Fox K, Hillsdon M, McKeown RE, et al. A tribute to Professor Jeremiah Morris: the man who invented the field of physical activity epidemiology. Ann Epidemiol. 2011; 20:651–60. [PubMed: 20696405]

3. U.S. Department of Health & Human Services. Physical Activity Guidelines Advisory Committee report. 2008. [cited 1 September 2011]; Available from: http://www.health.gov/paguidelines/

4. Warburton DE, Charlesworth S, Ivey A, Nettlefold L, Bredin SS. A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults. The international journal of behavioral nutrition and physical activity. 2010; 7:39. [PubMed: 20459783]

5. World Health Organization. Global recommendations on physical activity for health. Geneva, Switzerland: WHO; 2010.

6. Beaglehole R, Bonita R, Alleyne G, Horton R, Li L, Lincoln P, et al. UN High-Level Meeting on Non-Communicable Diseases: addressing four questions. Lancet. 2011; 378:449–55. [PubMed: 21665266]

7. Powell KE, Blair SN. The public health burdens of sedentary living habits: theoretical but realistic estimates. Med Sci Sports Exerc. 1994; 26:851–6. [PubMed: 7934758]

8. Rockhill B, Newman B, Weinberg C. Use and misuse of population attributable fractions. Am J Public Health. 1998; 88:15–9. [PubMed: 9584027]

9. World Health Organization. Global status report on noncommunicable diseases 2010. Geneva, Switzerland: WHO Press; 2011.

10. Sattelmair JR, Perman J, Ding EL, Hohl HW III, Haskell WL, Lee I-M. Dose-response between physical activity and risk of coronary heart disease: a meta-analysis. Circulation. 2011; 124:789–95. [PubMed: 21810663]

11. Jeon CY, Lokken RP, Hu FB, van Dam RM. Physical activity of moderate intensity and risk of type 2 diabetes: a systematic review. Diabetes Care. 2007; 30:744–52. [PubMed: 17327354]

12. Wolin KY, Yan Y, Colditz GA, Lee IM. Physical activity and colon cancer prevention: a meta-analysis. Br J Cancer. 2009; 100:611–6. [PubMed: 19209175]

13. Lollgen H, Bockenhoff A, Knapp G. Physical activity and all-cause mortality: an updated meta-analysis with different intensity categories. Int J Sports Med. 2009; 30:213–24. [PubMed: 19199202]

14. Monninkhof EM, Elias SG, Vlems FA, van der Tweel I, Schuit AJ, Voskuil DW, et al. Physical activity and breast cancer: a systematic review. Epidemiology. 2007; 18:137–57. [PubMed: 17130685]

15. Friedenreich CM. Physical activity and breast cancer: review of the epidemiologic evidence and biologic mechanisms. Recent Results Cancer Res. 2011; 188:125–39. [PubMed: 21253795]

16. World Health Organization. Life tables for WHO member states. 2011. [cited 1 September 2011]; Available from: http://www.who.int/healthinfo/statistics/mortality_life_tables/en/

17. Yusuf S, Hawken S, Ounpuu S, Dans T, Avezum A, Lanas F, et al. Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): case-control study. Lancet. 2004; 364:937–52. [PubMed: 15364185]

18. World Health Organization. Global Health Observatory Data Repository. 2011. [cited 4 October 2011]; Available from: http://apps.who.int/ghodata/

19. Wen CP, Wai JPM, Tsai MK, Yang YC, Cheng TYD, Lee M-C, et al. Minimum amount of physical activity for reduced mortality and extended life expectancy: a prospective cohort study. Lancet. 2011; 378:1244–53. [PubMed: 21846575]

20. Franco OH, de Laet C, Peeters A, Jonker J, Mackenbach J, Nusselder W. Effects of physical activity on life expectancy with cardiovascular disease. Arch Intern Med. 2005; 165:2355–60. [PubMed: 16287764]

21. Paffenbarger RS Jr, Hyde RT, Wing AL, Hsieh CC. Physical activity, all-cause mortality, and longevity of college alumni. N Engl J Med. 1986; 314:605–13. [PubMed: 3945246]

22. Ezzati M, Lopez AD. Estimates of global mortality attributable to smoking in 2000. Lancet. 2003; 362:847–52. [PubMed: 13678970]

23. Gu D, Kelly TN, Wu X, Chen J, Samet JM, Huang JF, et al. Mortality attributable to smoking in China. N Engl J Med. 2009; 360:150–9. [PubMed: 19129528]

NIH-PA Author Manuscript

NIH-PA Author Manuscript

24. Crimmins, EM.; Preston, SH.; Cohen, B. Explaining divergent levels of longevity in high-income countries (chapters 3 and 5). National Academies Press; 2011.
25. Tian X, Tang Z, Jiang J, Fang X, Wu X, Han W, et al. Effects of smoking and smoking cessation on life expectancy in an elderly population in Beijing, China, 1992–2000: an 8-year follow-up study. J Epidemiol. 2011; 21:376–84. [PubMed: 21747208]
26. Olshansky SJ, Passaro DJ, Hershow RC, Layden J, Carnes BA, Brody J, et al. A potential decline in life expectancy in the United States in the 21st century. N Engl J Med. 2005; 352:1138–45. [PubMed: 15784668]
27. Ezzati, M.; Lopez, AD.; Rodgers, A.; Murray, CJ., editors. Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors. Geneva, Switzerland: World Health Organization; 2004.
28. Lee, I-M.; Paffenbarger, RS, Jr. Design of present-day epidemiologic studies of physical activity and health. In: Lee, I-M., editor. Epidemiologic methods in physical activity studies. New York, NY: Oxford University Press; 2009. p. 100-23.
29. Kodama S, Saito K, Tanaka S, Maki M, Yachi Y, Asumi M, et al. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis. JAMA. 2009; 301:2024–35. [PubMed: 19454641]
30. Rastogi T, Vaz M, Spiegelman D, Reddy KS, Bharathi AV, Stampfer MJ, et al. Physical activity and risk of coronary heart disease in India. Int J Epidemiol. 2004; 33:759–67. [PubMed: 15044412]

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Strong evidence of lower rates of:

- all-cause mortality
- coronary heart disease
- high blood pressure
- stroke
- metabolic syndrome
- type 2 diabetes
- breast cancer
- colon cancer
- depression
- falling

Strong evidence of:

- higher level of cardiorespiratory and muscular fitness
- healthier body mass and composition
- enhanced bone health
- higher level of functional health
- better cognitive function

Figure 1.
Health benefits of physical activity in adults[3–5]

Formula 1, using unadjusted relative risk:

$$PAF = \frac{P_e (RR_{unadj} - 1)}{P_e (RR_{unadj} - 1) + 1} \times 100\%$$

where P_e is the proportion of inactive persons in the source population, and RR_{unadj} is the relative risk of disease, comparing inactive with active persons, unadjusted for confounding factors.

Formula 2, using adjusted relative risk:

$$PAF = P_d \frac{(RR_{adj} - 1)}{RR_{adj}} \times 100\%$$

where P_d is the proportion of inactive persons among cases, and RR_{adj} is the relative risk of disease, comparing inactive with active persons, adjusted for confounding factors.

Figure 2.

Formulae for calculating population attributable fraction (PAF)

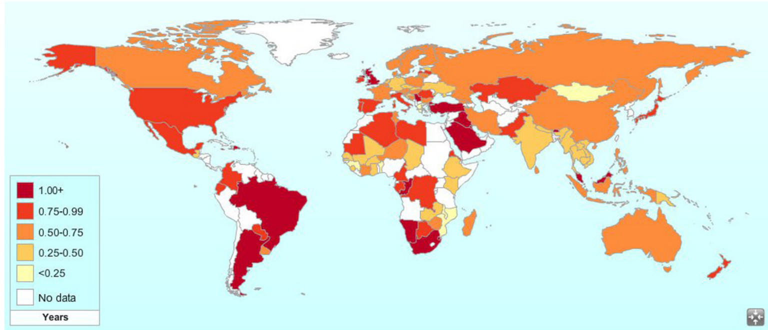

Figure 3.
Map of the world showing estimated gains in life expectancy with elimination of physical inactivity

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 1

Summary of estimates of the prevalence of physical inactivity;* relative risks (RR); and population attributable fractions (PAF) for CHD, type 2 diabetes, breast cancer, colon cancer, and all-cause mortality associated with physical inactivity

	CHD	Type 2 diabetes	Breast cancer	Colon cancer	All-cause mortality
Prevalence of inactivity in population*	35.2 (22.3–40.5)	35.2 (22.3–40.5)	38.8 (23.3–44.3)	35.2 (22.3–40.5)	35.2 (22.3–40.5)
Prevalence of inactivity among persons eventually developing the outcome*	42.2 (23.0–56.2)	43.2 (23.6–57.6)	40.7 (22.5–56.7)	42.9 (23.4–57.1)	42.9 (23.4–57.1)
RR (95% confidence interval), unadjusted†	1.33 (1.18–1.49)	1.63 (1.27–2.11)	1.34 (1.25–1.43)	1.38 (1.31–1.45)	1.47 (1.38–1.57)
RR (95% confidence interval), adjusted†	1.16 (1.04–1.30)	1.20 (1.10–1.33)	1.33 (1.26–1.42)	1.32 (1.23–1.39)	1.28 (1.21–1.36)
PAF, using unadjusted RR‡	10.4 (7.2–13.4)	18.1 (10.8–22.8)	11.6 (6.8–15.5)	11.8 (6.8–15.1)	14.2 (8.3–18.0)
PAF, using adjusted RR‡	5.8 (3.2–7.8)	7.2 (3.9–9.6)	10.1 (5.6–14.1)	10.4 (5.7–13.8)	9.4 (5.1–12.5)

*Defined as insufficient physical activity to meet current recommendations; overall median (range of medians for WHO regions). Details on country-specific values for the population are available from reference 9; country-specific values for persons eventually developing the listed NCDs are provided in webappendix pp 3–7.

†For details on calculation of unadjusted RRs, please refer to webappendix pp 12–18. The unadjusted RR pooled both crude and age-adjusted RRs, since the crude RR was often unavailable. Comparing the pooled unadjusted RR with the pooled RR calculated using only crude RRs, values were similar (see text). The adjusted relative risk of CHD was obtained from Sattelmair et al;[10] type 2 diabetes, Jeon et al; [11] breast cancer, see webappendix pp 14–15; colon cancer, Wolin et al; [12] all-cause mortality, see webappendix pp 17–18.

‡Overall median (range of medians for WHO regions). Details on country-specific values calculated using unadjusted RRs are provided in webappendix pp 8–11; country-specific values calculated using adjusted RRs are shown in Table 3.

Table 2

Estimated population attributable fractions (PAF), calculated using adjusted relative risks,* for CHD, type 2 diabetes, breast cancer, colon cancer, and all-cause mortality associated with physical inactivity, by WHO region

	PAF (95% uncertainty interval)				
WHO region and country	**CHD**	**Type 2 diabetes**	**Breast cancer**	**Colon cancer**	**All-cause mortality**
Africa					
Algeria	6.7 (2.4–11.2)	8.3 (4.2–12.9)	12.8 (5.9–20.0)	12.0 (6.8–17.2)	10.8 (8.6–13.1)
Benin	1.5 (0.5–2.5)	1.9 (0.9–2.9)	2.9 (1.3–4.6)	2.7 (1.5–3.9)	2.4 (1.9–3.0)
Botswana	5.8 (2.1–9.7)	7.2 (3.6–11.3)	11.5 (5.4–18.0)	10.4 (5.9–15.1)	9.4 (7.5–11.4)
Burkina Faso	2.6 (−0.2–6.1)	3.2 (−0.3–7.2)	4.3 (−1.0–9.5)	4.6 (−0.8–9.9)	4.1 (−0.1–8.6)
Cameroon	6.7 (1.0–13.9)	8.3 (1.8–16.2)	12.6 (1.8–23.8)	12.0 (2.3–22.1)	10.9 (3.4–18.6)
Cape Verde	3.4 (1.3–5.7)	4.2 (2.1–6.6)	7.7 (3.5–11.8)	6.1 (3.4–8.9)	5.5 (4.3–6.8)
Chad	4.1 (0.0–9.3)	5.0 (−0.2–11.0)	6.8 (−0.8–14.4)	7.3 (−0.3–15.1)	6.5 (0.4–12.9)
Comoros	1.4 (−0.3–3.6)	1.7 (−0.4–4.2)	2.8 (−0.9–6.4)	2.5 (−0.8–5.7)	2.2 (−0.5–5.0)
Congo	8.0 (1.4–16.4)	10.0 (2.2–19.1)	13.8 (2.8–24.9)	14.4 (3.0–26.2)	13.0 (4.4–22.0)
Cote d’Ivoire	5.4 (0.6–11.9)	6.7 (0.8–13.9)	9.6 (0.7–19.0)	9.7 (0.7–18.5)	8.8 (2.0–16.1)
Democratic Republic of the Congo	7.5 (2.8–12.4)	9.3 (4.7–14.5)	13.6 (6.5–21.1)	13.4 (7.3–19.4)	12.1 (9.6–14.6)
Eritrea	6.7 (2.4–11.2)	8.3 (4.2–12.8)	14.3 (6.7–22.4)	12.0 (6.7–17.1)	10.8 (8.6–13.0)
Ethiopia	3.2 (−0.1–7.6)	4.0 (−0.1–8.9)	5.8 (−0.9–12.7)	5.7 (−0.6–12.1)	5.2 (0.2–10.5)
Gabon	6.1 (0.5–13.3)	7.5 (0.6–15.5)	12.1 (0.7–23.6)	10.8 (0.6–21.5)	9.8 (1.8–18.2)
Gambia	4.1 (1.5–6.7)	5.0 (2.5–7.8)	7.5 (3.5–11.7)	7.3 (4.1–10.5)	6.5 (5.2–7.9)
Ghana	2.9 (1.1–4.8)	3.6 (1.8–5.7)	5.4 (2.5–8.4)	5.2 (2.9–7.5)	4.7 (3.7–5.7)
Guinea	2.0 (−0.2–5.0)	2.5 (−0.2–5.6)	4.7 (−0.7–10.2)	3.6 (−0.6–7.7)	3.2 (−0.1–6.7)
Kenya	2.7 (−0.4–6.8)	3.4 (−0.6–7.9)	4.7 (−1.1–10.6)	4.9 (−1.0–10.9)	4.4 (−0.3–9.3)
Madagascar	3.9 (1.4–6.4)	4.8 (2.4–7.5)	7.4 (3.5–11.5)	6.9 (3.9–10.0)	6.2 (4.9–7.5)
Malawi	1.7 (0.6–2.8)	2.1 (1.0–3.3)	3.4 (1.6–5.3)	3.0 (1.7–4.4)	2.7 (2.1–3.3)
Mali	3.5 (−0.1–8.0)	4.3 (−0.2–9.5)	6.2 (−0.7–13.4)	6.2 (−0.7–13.1)	5.6 (0.2–11.1)
Mauritania	7.3 (1.5–14.3)	9.0 (2.2–16.9)	12.4 (3.3–21.8)	13.0 (3.0–23.0)	11.7 (4.5–19.2)
Mauritius	6.4 (0.7–13.5)	7.9 (1.3–15.9)	10.2 (0.8–20.0)	11.4 (1.2–21.6)	10.3 (2.6–18.2)
Mozambique	1.2 (0.4–2.0)	1.5 (0.7–2.3)	1.9 (0.9–3.0)	2.1 (1.1–3.1)	1.9 (1.5–2.4)
Namibia	9.7 (2.3–18.9)	12.0 (3.5–22.2)	17.0 (4.6–29.5)	17.3 (5.0–29.9)	15.6 (7.0–24.8)
Niger	4.9 (1.8–8.0)	6.0 (3.0–9.3)	8.9 (4.2–14.1)	8.7 (4.8–12.6)	7.8 (6.2–9.5)

NIH-PA Author Manuscript
NIH-PA Author Manuscript

	PAF (95% uncertainty interval)				
WHO region and country	**CHD**	**Type 2 diabetes**	**Breast cancer**	**Colon cancer**	**All-cause mortality**
Sao Tome and Principe	3.1 (1.1–5.2)	3.9 (2.0–6.0)	6.9 (3.1–10.6)	5.6 (3.1–8.2)	5.1 (4.0–6.2)
Senegal	3.8 (0.0–8.8)	4.7 (0.1–10.1)	6.7 (−0.7–14.2)	6.8 (−0.3–13.7)	6.2 (0.5–12.0)
Seychelles	3.7 (1.3–6.1)	4.6 (2.3–7.2)	5.8 (2.6–9.2)	6.6 (3.7–9.6)	6.0 (4.7–7.3)
Sierra Leone	3.3 (1.1–5.4)	4.1 (2.0–6.3)	6.2 (2.9–9.5)	5.9 (3.3–8.5)	5.3 (4.2–6.5)
South Africa	8.7 (3.1–14.5)	10.7 (5.4–16.8)	14.7 (6.7–23.1)	15.5 (8.8–22.4)	14.0 (11.1–16.9)
Swaziland	11.4 (3.2–21.5)	14.2 (4.7–25.1)	18.8 (5.9–32.4)	20.4 (7.3–33.7)	18.4 (9.4–27.7)
Zambia	2.9 (−0.3–7.0)	3.5 (−0.5–8.2)	5.0 (−1.2–11.3)	5.1 (−1.0–11.4)	4.6 (−0.2–9.6)
Zimbabwe	3.9 (0.0–9.0)	4.9 (−0.1–10.7)	6.7 (−0.8–14.3)	7.0 (−0.4–14.6)	6.4 (0.6–12.4)
Median for region	**3.9**	**4.8**	**7.1**	**7.0**	**6.3**
Americas					
Central and South America					
Argentina	11.3 (3.1–21.0)	14.0 (4.8–24.7)	18.5 (5.9–31.7)	20.2 (6.8–33.5)	18.2 (9.5–27.7)
Barbados	7.8 (2.8–13.0)	9.6 (4.8–15.0)	14.5 (6.8–22.7)	13.9 (7.6–20.1)	12.5 (9.9–15.1)
Brazil	8.2 (1.5–16.4)	10.1 (2.4–18.9)	13.4 (2.3–24.7)	14.6 (2.9–26.1)	13.2 (4.8–21.7)
Colombia	7.3 (0.9–15.6)	9.0 (1.3–18.2)	12.5 (1.2–23.9)	13.0 (1.3–24.8)	11.7 (2.8–21.0)
Dominica	4.0 (1.7–16.6)	5.0 (2.7–19.9)	9.0 (4.2–26.1)	7.2 (4.2–27.5)	6.5 (5.3–23.0)
Dominican Republic	9.9 (1.7–16.6)	12.3 (2.7–19.9)	16.4 (4.2–26.1)	17.8 (4.2–27.5)	16.0 (5.3–23.0)
Ecuador	7.1 (1.0–14.6)	8.7 (1.5–17.2)	12.6 (1.5–23.7)	12.6 (2.1–23.5)	11.4 (3.5–19.7)
Guatemala	2.7 (−0.3–6.5)	3.3 (−0.5–7.8)	4.4 (−1.2–10.1)	4.8 (−1.1–10.6)	4.3 (−0.3–9.2)
Jamaica	7.9 (1.4–16.1)	9.8 (2.2–18.5)	13.4 (2.6–24.8)	14.1 (2.5–25.5)	12.8 (4.6–21.6)
Mexico	6.2 (0.8–13.2)	7.7 (1.0–15.8)	10.0 (0.8–19.8)	11.2 (1.1–21.3)	10.1 (2.5–18.2)
Paraguay	6.8 (1.0–14.2)	8.5 (1.4–16.8)	10.9 (1.0–21.2)	12.2 (1.6–22.9)	11.0 (3.0–19.1)
Saint Kitts and Nevis	6.3 (2.3–10.5)	7.9 (3.9–12.2)	12.5 (5.9–19.5)	11.3 (6.4–16.5)	10.2 (8.1–12.4)
Uruguay	5.6 (2.1–9.4)	7.0 (3.5–10.9)	10.5 (4.8–16.4)	10.1 (5.6–14.6)	9.1 (7.2–11.1)
Median for region	**7.1**	**8.7**	**12.5**	**12.6**	**11.4**
North America					
Canada	5.6 (0.5–12.2)	7.0 (0.8–14.4)	9.2 (0.2–18.6)	10.0 (0.7–19.5)	9.1 (1.8–16.6)
United States of America	6.7 (2.5–11.1)	8.3 (4.2–12.9)	12.4 (5.8–19.2)	12.0 (6.7–17.4)	10.8 (8.6–13.1)
Median for region	**6.2**	**7.6**	**10.8**	**11.0**	**9.9**
Eastern Mediterranean					

NIH-PA Author Manuscript
NIH-PA Author Manuscript

WHO region and country	CHD	Type 2 diabetes	Breast cancer	Colon cancer	All-cause mortality
	PAF (95% uncertainty interval)				
Iran (Islamic Republic of)	6.1 (2.2–10.2)	7.6 (3.8–11.8)	12.2 (5.8–18.9)	10.9 (6.2–15.8)	9.9 (7.9–11.9)
Iraq	9.7 (3.5–15.8)	12.0 (6.0–18.7)	14.1 (6.6–21.9)	17.3 (9.7–25.1)	15.6 (12.5–18.8)
Kuwait	10.7 (3.9–17.7)	13.2 (6.6–20.7)	18.8 (8.8–29.2)	19.1 (10.6–27.7)	17.2 (13.7–20.8)
Lebanon	7.8 (2.9–12.9)	9.6 (4.7–14.9)	10.9 (5.1–16.9)	13.8 (7.6–20.0)	12.5 (9.9–15.1)
Libyan Arab Jamahiriya	7.6 (2.8–12.5)	9.4 (4.7–14.7)	14.2 (6.6–21.9)	13.6 (7.4–19.5)	12.2 (9.7–14.8)
Pakistan	6.7 (1.0–14.0)	8.3 (1.4–16.3)	12.5 (1.9–23.6)	12.0 (1.6–22.0)	10.8 (3.2–18.8)
Saudi Arabia	11.4 (4.2–18.8)	14.1 (7.1–21.9)	19.9 (9.2–30.6)	20.4 (11.3–29.3)	18.4 (14.7–22.1)
Tunisia	5.9 (0.7–12.6)	7.4 (1.0–15.0)	10.5 (1.0–20.2)	10.6 (1.0–20.3)	9.6 (2.4–17.1)
United Arab Emirates	10.3 (2.6–19.9)	12.8 (3.8–23.6)	18.0 (5.9–30.9)	18.5 (5.2–31.7)	16.7 (7.3–26.2)
Median for region	**7.8**	**9.6**	**14.1**	**13.8**	**12.5**
Europe					
Austria	5.8 (0.6–12.1)	7.1 (1.0–14.5)	10.2 (0.8–20.1)	10.3 (1.1–19.4)	9.3 (2.3–16.5)
Belgium	7.1 (1.2–14.7)	8.8 (1.9–17.0)	11.7 (2.0–21.5)	12.6 (2.1–23.1)	11.4 (3.7–19.5)
Bosnia and Herzegovina	5.6 (0.4–12.1)	6.9 (0.8–14.1)	9.6 (0.4–19.2)	9.9 (0.7–19.4)	9.0 (1.8–16.5)
Bulgaria	4.4 (0.1–9.9)	5.5 (0.1–11.7)	7.5 (−0.4–15.6)	7.9 (−0.1–16.1)	7.2 (0.9–13.6)
Croatia	3.9 (0.0–8.9)	4.8 (−0.1–10.6)	5.5 (−0.6–11.6)	7.0 (−0.5–14.3)	6.3 (0.5–12.4)
Cyprus	9.2 (2.0–17.9)	11.4 (3.0–21.0)	16.3 (4.2–28.8)	16.4 (4.3–28.8)	14.8 (6.2–24.1)
Czech Republic	4.1 (0.3–9.3)	5.1 (0.2–10.9)	5.8 (−0.4–12.3)	7.4 (0.0–14.8)	6.7 (0.9–12.6)
Denmark	5.8 (0.6–12.4)	7.2 (0.8–14.7)	9.2 (0.2–18.4)	10.4 (1.0–19.9)	9.4 (2.2–17.1)
Estonia	2.9 (−0.2–6.9)	3.5 (−0.4–8.1)	4.9 (−0.9–10.9)	5.1 (−0.9–11.2)	4.6 (−0.2–9.4)
Finland	6.3 (0.8–13.2)	7.8 (1.3–15.6)	9.1 (0.2–18.4)	11.2 (1.1–21.2)	10.1 (2.6–17.8)
France	5.4 (1.9–8.9)	6.7 (3.3–10.3)	9.7 (4.6–15.1)	9.6 (5.4–13.8)	8.7 (6.9–10.5)
Georgia	3.7 (1.3–6.2)	4.6 (2.3–7.1)	6.1 (2.8–9.5)	6.6 (3.6–9.6)	6.0 (4.7–7.2)
Germany	4.6 (0.1–10.4)	5.7 (0.2–12.4)	7.4 (−0.3–15.5)	8.3 (−0.3–16.7)	7.5 (0.9–14.5)
Greece	2.6 (−0.2–6.2)	3.2 (−0.4–7.4)	3.8 (−1.1–8.7)	4.6 (−0.9–10.1)	4.2 (−0.2–8.7)
Hungary	4.3 (0.1–9.5)	5.3 (0.0–11.4)	6.7 (−0.2–13.7)	7.7 (−0.2–15.6)	6.9 (0.7–13.2)
Ireland	8.8 (2.0–17.4)	10.9 (2.9–20.2)	15.2 (3.5–27.3)	15.7 (4.1–27.6)	14.2 (6.0–22.9)
Italy	9.1 (1.9–18.0)	11.2 (3.0–20.9)	15.6 (4.2–28.0)	16.2 (3.9–28.1)	14.6 (5.8–23.7)
Kazakhstan	5.2 (0.4–11.5)	6.5 (0.6–13.4)	8.1 (−0.2–16.3)	9.3 (0.5–18.4)	8.4 (1.5–15.6)
Latvia	5.3 (0.3–11.5)	6.6 (0.5–13.6)	9.4 (0.1–18.7)	9.5 (0.2–18.6)	8.5 (1.4–15.8)

NIH-PA Author Manuscript
NIH-PA Author Manuscript

WHO region and country	PAF (95% uncertainty interval)				
	CHD	Type 2 diabetes	Breast cancer	Colon cancer	All-cause mortality
Lithuania	3.7 (1.3–6.3)	4.6 (2.3–7.2)	6.5 (2.9–10.1)	6.7 (3.7–9.8)	6.0 (4.7–7.5)
Luxembourg	7.9 (1.3–16.0)	9.8 (1.9–19.1)	11.9 (1.2–23.0)	14.1 (2.6–25.8)	12.7 (4.2–21.8)
Malta	11.9 (3.3–22.3)	14.7 (5.3–26.0)	19.1 (6.0–32.4)	21.3 (7.5–35.3)	19.2 (9.8–28.9)
Netherlands	3.0 (−0.1–7.1)	3.7 (−0.3–8.3)	4.0 (−1.1–9.2)	5.4 (−0.6–11.4)	4.9 (0.0–9.8)
Norway	7.3 (1.2–15.3)	9.1 (1.7–17.9)	11.7 (1.5–22.2)	13.1 (2.2–24.1)	11.8 (3.5–20.2)
Poland	4.6 (0.2–10.4)	5.7 (0.3–12.0)	8.2 (−0.2–17.0)	8.2 (−0.1–16.4)	7.4 (1.0–13.9)
Portugal	8.4 (1.7–17.3)	10.5 (2.6–20.2)	14.2 (3.1–25.9)	15.1 (3.6–27.0)	13.6 (5.2–22.6)
Romania	6.4 (0.7–13.6)	7.9 (1.2–15.8)	12.0 (1.2–23.2)	11.4 (1.3–21.9)	10.3 (2.6–18.4)
Russian Federation	3.4 (−0.1–8.1)	4.3 (−0.2–9.5)	4.9 (−0.9–10.7)	6.2 (−0.6–13.1)	5.6 (0.2–11.0)
Serbia	11.3 (3.1–20.9)	14.0 (4.7–24.6)	19.1 (6.9–32.3)	20.2 (7.0–33.5)	18.2 (9.4–27.6)
Slovakia	3.7 (0.1–8.5)	4.6 (0.0–9.9)	5.5 (−0.9–12.1)	6.6 (−0.3–13.7)	5.9 (0.5–11.5)
Slovenia	5.0 (0.3–11.1)	6.2 (0.4–12.9)	8.8 (0.2–17.5)	8.9 (0.0–17.6)	8.0 (1.2–15.2)
Spain	8.3 (1.7–16.7)	10.3 (2.5–19.5)	13.8 (2.6–25.5)	14.9 (3.1–26.6)	13.4 (4.9–22.4)
Sweden	7.3 (1.2–15.1)	9.1 (1.9–17.4)	11.5 (1.6–21.7)	13.1 (2.1–24.1)	11.8 (3.8–20.2)
Turkey	9.3 (2.1–18.3)	11.5 (3.2–21.0)	16.3 (4.0–28.9)	16.6 (4.2–29.0)	15.0 (6.2–23.9)
Ukraine	3.1 (−0.2–7.3)	3.8 (−0.4–8.5)	4.3 (−0.8–9.3)	5.4 (−0.8–11.6)	4.9 (0.0–10.1)
United Kingdom	10.5 (4.0–17.3)	13.0 (6.4–20.2)	17.9 (8.5–27.8)	18.7 (10.5–27.1)	16.9 (13.6–20.3)
Median for region	**5.5**	**6.8**	**9.3**	**9.8**	**8.8**
South-East Asia					
Bangladesh	0.8 (0.3–1.3)	1.0 (0.5–1.5)	1.7 (0.8–2.7)	1.4 (0.8–2.0)	1.3 (1.0–1.5)
Bhutan	8.7 (1.8–17.3)	10.7 (2.6–20.3)	16.6 (4.2–29.0)	15.5 (3.8–27.6)	14.0 (5.3–22.8)
India	2.6 (1.0–4.2)	3.2 (1.6–5.0)	4.8 (2.3–7.4)	4.6 (2.6–6.6)	4.2 (3.3–5.0)
Indonesia	4.9 (1.8–8.2)	6.1 (3.0–9.5)	7.3 (3.3–11.5)	8.8 (4.9–12.8)	8.0 (6.3–9.7)
Maldives	6.5 (0.7–13.9)	8.0 (1.0–16.1)	10.8 (0.5–21.4)	11.5 (1.0–22.1)	10.4 (2.6–18.5)
Myanmar	2.1 (0.8–3.5)	2.6 (1.3–4.1)	3.9 (1.9–6.1)	3.8 (2.1–5.4)	3.4 (2.7–4.1)
Nepal	2.6 (−0.3–6.2)	3.2 (−0.4–7.4)	4.4 (−1.0–10.1)	4.6 (−0.8–10.2)	4.1 (−0.2–8.7)
Sri Lanka	4.3 (1.6–7.1)	5.3 (2.7–8.3)	8.7 (4.2–13.5)	7.7 (4.2–11.1)	6.9 (5.5–8.3)
Thailand	3.2 (1.2–5.2)	3.9 (2.0–6.1)	5.6 (2.5–8.7)	5.7 (3.2–8.2)	5.1 (4.1–6.2)
Median for region	**3.2**	**3.9**	**5.6**	**5.7**	**5.1**
Western Pacific					

WHO region and country	PAF (95% uncertainty interval)				
	CHD	Type 2 diabetes	Breast cancer	Colon cancer	All-cause mortality
Australia	6.3 (0.8–13.1)	7.8 (1.0–15.4)	10.4 (0.9–20.2)	11.2 (1.4–21.2)	10.1 (2.8–18.0)
Cambodia	1.9 (0.7–3.1)	2.3 (1.1–3.6)	2.9 (1.3–4.5)	3.3 (1.8–4.8)	3.0 (2.4–3.6)
China	5.1 (1.9–8.5)	6.4 (3.2–9.8)	8.4 (4.0–13.0)	9.2 (5.2–13.1)	8.3 (6.6–10.0)
Cook Islands	11.9 (4.4–19.7)	14.8 (7.5–23.4)	19.1 (9.0–29.8)	21.3 (11.8–30.9)	19.2 (15.3–23.1)
Japan	10.0 (2.4–19.0)	12.3 (3.6–22.5)	16.1 (3.9–29.1)	17.8 (5.0–30.9)	16.1 (7.2–25.4)
Kiribati	7.7 (2.7–12.8)	9.6 (4.8–15.0)	14.3 (6.9–22.3)	13.8 (7.7–20.0)	12.5 (9.8–15.1)
Lao People's Democratic Republic	3.1 (−0.2–7.5)	3.9 (−0.4–8.7)	5.5 (−1.0–12.1)	5.6 (−0.8–12.0)	5.0 (−0.1–10.3)
Malaysia	10.2 (3.8–16.9)	12.6 (6.3–19.6)	17.1 (8.0–26.6)	18.2 (10.2–26.5)	16.4 (13.0–19.7)
Marshall Islands	8.2 (3.0–13.7)	10.2 (5.1–15.7)	14.5 (6.9–22.5)	14.7 (8.1–21.2)	13.2 (10.6–16.0)
Micronesia (Federated States of)	11.0 (4.1–18.3)	13.6 (6.8–21.1)	19.4 (9.1–30.5)	19.6 (11.0–28.6)	17.7 (14.1–21.3)
Mongolia	1.6 (0.6–2.6)	1.9 (1.0–3.0)	2.5 (1.1–3.9)	2.8 (1.5–4.0)	2.5 (2.0–3.0)
Nauru	7.7 (2.9–12.9)	9.5 (4.8–14.8)	13.0 (6.2–20.3)	13.8 (7.6–19.8)	12.4 (9.8–14.9)
New Zealand	7.9 (2.9–13.1)	9.8 (4.9–15.2)	13.1 (6.2–20.3)	14.1 (7.9–20.3)	12.7 (10.2–15.4)
Papua New Guinea	3.2 (1.2–5.3)	4.0 (1.9–6.2)	5.6 (2.5–8.8)	5.7 (3.1–8.3)	5.2 (4.1–6.3)
Philippines	3.9 (−0.1–9.0)	4.9 (−0.1–10.7)	6.8 (−0.7–14.7)	7.0 (−0.5–14.4)	6.3 (0.4–12.4)
Samoa	8.5 (3.1–14.1)	10.5 (5.3–16.4)	17.0 (8.1–26.7)	15.1 (8.5–21.8)	13.6 (10.9–16.4)
Solomon Islands	7.2 (2.7–11.9)	9.0 (4.5–14.0)	12.9 (6.1–20.2)	12.9 (7.1–18.8)	11.7 (9.2–14.0)
Tonga	6.9 (2.5–11.5)	8.6 (4.2–13.4)	13.5 (6.4–21.1)	12.4 (6.8–18.0)	11.2 (8.8–13.6)
Viet Nam	2.5 (−0.2–6.2)	3.1 (−0.4–7.3)	4.1 (−1.1–9.4)	4.5 (−0.8–9.8)	4.1 (−0.2–8.4)
Median for region	**7.2**	**9.0**	**13.0**	**12.9**	**11.7**
Overall Median	**5.8**	**7.2**	**10.1**	**10.4**	**9.4**

* PAFs calculated using unadjusted relative risks are provided in webappendix pp 8–11.

Table 3

Estimated gains in life expectancy by decreasing physical inactivity, according to WHO region

WHO region and country	Gain in life expectancy (uncertainty interval),* years, if physical inactivity were eliminated
Africa	
Algeria	0·79 (0·62–0·96)
Benin	0·19 (0·15–0·24)
Botswana	0·81 (0·64–0·99)
Burkina Faso	0·31 (−0·01–0·66)
Cameroon	0·85 (0·26–1·49)
Cape Verde	0·46 (0·35–0·56)
Chad	0·46 (0·03–0·93)
Comoros	0·17 (−0·04–0·40)
Congo	1·06 (0·35–1·87)
Cote d’Ivoire	0·72 (0·16–1·37)
Dem· Rep· Congo	0·89 (0·70–1·09)
Eritrea	0·89 (0·70–1·08)
Ethiopia	0·43 (0·02–0·89)
Gabon	0·81 (0·15–1·55)
Gambia	0·52 (0·41–0·63)
Ghana	0·40 (0·32–0·49)
Guinea	0·25 (−0·01–0·53)
Kenya	0·37 (−0·02–0·79)
Madagascar	0·52 (0·41–0·63)
Malawi	0·21 (0·17–0·26)
Mali	0·40 (0·14–0·81)
Mauritania	0·95 (0·35–1·60)
Mauritius	0·90 (0·22–1·62)
Mozambique	0·14 (0·11–0·17)
Namibia	1·45 (0·62–2·39)
Niger	0·57 (0·45–0·69)
Sao Tome and Principe	0·36 (0·28–0·44)
Senegal	0·49 (0·04–0·97)
Seychelles	0·51 (0·40–0·63)
Sierra Leone	0·38 (0·30–0·46)
South Africa	1·26 (0·99–1·53)
Swaziland	1·56 (0·76–2·45)
Zambia	0·36 (−0·02–0·77)
Zimbabwe	0·56 (0·05–1·13)
Median for Region	**0·51**
Americas	
Central and South America	
Argentina	1·39 (0·71–2·14)

WHO region and country	Gain in life expectancy (uncertainty interval),* years, if physical inactivity were eliminated
Barbados	0·91 (0·72–1·11)
Brazil	1·08 (0·38–1·81)
Colombia	0·82 (0·19–1·50)
Dominica	0·51 (0·41–1·86)
Dominican Republic	1·28 (0·41–1·87)
Ecuador	0·80 (0·24–1·41)
Guatemala	0·35 (−0·02–0·74)
Jamaica	1·01 (0·36–1·74)
Mexico	0·76 (0·18–1·40)
Paraguay	0·85 (0·23–1·51)
Saint Kitts and Nevis	0·77 (0·61–0·95)
Uruguay	0·70 (0·55–0·85)
Median for Region	**0·82**
North America	
Canada	0·55 (0·11–1·02)
United States	0·78 (0·62–0·94)
Median for Region	**0·66**
Eastern Mediterranean	
Iran	0·71 (0·57–0·87)
Iraq	1·30 (1·03–1·59)
Kuwait	1·12 (0·89–1·37)
Lebanon	0·95 (0·75–1·16)
Libya	0·93 (0·77–1·18)
Pakistan	0·85 (0·25–1·52)
Saudi Arabia	1·51 (1·19–1·84)
Tunisia	0·64 (0·16–1·16)
United Arab Emirates	1·11 (0·48–1·78)
Median for Region	**0·95**
Europe	
Austria	0·58 (0·14–1·03)
Belgium	0·73 (0·23–1·26)
Bosnia and Herzegovina	0·62 (0·12–1·16)
Bulgaria	0·58 (0·07–1·11)
Croatia	0·45 (0·04–0·91)
Cyprus	0·80 (0·33–1·33)
Czech Republic	0·48 (0·06–0·92)
Denmark	0·64 (0·15–1·19)
Estonia	0·38 (−0·02–0·78)
Finland	0·66 (0·17–1·17)
France	0·55 (0·44–0·67)
Georgia	0·52 (0·41–0·63)
Germany	0·47 (0·06–0·92)

WHO region and country	Gain in life expectancy (uncertainty interval),* years, if physical inactivity were eliminated
Greece	0·23 (−0·01–0·49)
Hungary	0·61 (0·06–1·18)
Ireland	0·87 (0·36–1·42)
Italy	0·80 (0·31–1·32)
Kazakhstan	0·79 (0·14–1·50)
Latvia	0·77 (0·12–1·46)
Lithuania	0·53 (0·41–0·65)
Luxembourg	0·83 (0·27–1·45)
Malta	1·12 (0·56–1·71)
Netherlands	0·29 (0·00–0·59)
Norway	0·68 (0·20–1·18)
Poland	0·60 (0·08–1·14)
Portugal	0·86 (0·33–1·45)
Romania	0·87 (0·21–1·58)
Russian Federation	0·52 (0·02–1·05)
Serbia	1·50 (1·02–2·33)
Slovakia	0·46 (0·04–0·92)
Slovenia	0·54 (0·08–1·05)
Spain	0·78 (0·28–1·32)
Sweden	0·67 (0·22–1·16)
Turkey	1·06 (0·43–1·74)
Ukraine	0·46 (0·00–0·97)
United Kingdom	1·07 (0·85–1·29)
Median for Region	**0·63**
South-East Asian	
Bangladesh	0·10 (0·08–0·12)
Bhutan	1·15 (0·42–1·95)
India	0·34 (0·27–0·41)
Indonesia	0·65 (0·51–0·80)
Maldives	0·75 (0·18–1·37)
Myanmar	0·27 (0·22–0·33)
Nepal	0·33 (−0·02–0·71)
Sri Lanka	0·51 (0·40–0·61)
Thailand	0·41 (0·32–0·49)
Median for Region	**0·41**
Western Pacific	
Australia	0·56 (0·15–1·00)
Cambodia	0·24 (0·19–0·29)
China	0·61 (0·48–0·73)
Cook Islands	1·57 (1·24–1·91)
Japan	0·91 (0·40–1·46)
Kiribati	1·27 (0·99–1·55)

WHO region and country	Gain in life expectancy (uncertainty interval),* years, if physical inactivity were eliminated
Laos	0·43 (−0·01–0·90)
Malaysia	1·35 (1·06–1·65)
Marshall Islands	1·33 (1·04–1·63)
Micronesia	1·45 (1·14–1·77)
Mongolia	0·24 (0·19–0·29)
Nauru	1·21 (0·95–1·47)
New Zealand	0·76 (0·61–0·93)
Papua New Guinea	0·43 (0·34–0·52)
Philippines	0·52 (0·03–1·04)
Samoa	1·17 (0·92–1·42)
Solomon Islands	0·90 (0·70–1·09)
Tonga	1·03 (0·80–1·26)
Vietnam	0·31 (−0·01–0·64)
Median for Region	**0·90**
Overall Median	**0·68**

*The uncertainty interval was calculated based on the lower and upper bounds of the 95% uncertainty interval of the adjusted PAF for all-cause mortality.