Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy

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Summary

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

Methods **For our analysis of burden of disease, we calculated population attributable fractions (PAFs) associated with physical inactivity using conservative assumptions for each of the major non-communicable diseases, by country, to estimate how much disease could be averted if physical inactivity were eliminated. We used life-table analysis to estimate gains in life expectancy of the population.**

Findings **Worldwide, we estimate that physical inactivity causes 6% (ranging from 3·2% in southeast Asia to 7·8% in the eastern Mediterranean region) of the burden of disease from coronary heart disease, 7% (3·9–9·6) of type 2 diabetes, 10% (5·6–14·1) of breast cancer, and 10% (5·7–13·8) of colon cancer. Inactivity causes 9% (range 5·1–12·5) of premature mortality, or more than 5·3 million of the 57 million deaths that occurred worldwide in 2008. If inactivity were not eliminated, but decreased instead by 10% or 25%, more than 533 000 and more than 1·3 million deaths, respectively, could be averted every year. We estimated that elimination of physical inactivity would increase the life expectancy of the world's population by 0·68 (range 0·41–0·95) years.**

Interpretation **Physical inactivity has a major health effect worldwide. Decrease in or removal of this unhealthy behaviour could improve health substantially.**

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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 20th century, however, a diametrically opposite view—that exercise was dangerous—prevailed instead.[1] During the early 20th century, complete bed rest was prescribed for patients with acute myocardial infarction. And, at the time of the 100th boat race between the Universities of Oxford and Cambridge, UK, in 1954, the senior health officer of Cambridge University undertook a study to investigate the alleged dangers of exercise by comparing university sportsmen with intellectuals.[1]

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

Methods

Population attributable fraction

The population attributable fraction (PAF) is a measure used by epidemiologists to estimate the effect 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 effect of interventions to reduce or 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 (panel 2). Formula 1 provides an unbiased estimate when there is no confounding of the relation between the risk factor and disease, and

Panel 1: **Health benefits of physical activity in adults**[3–5]

Strong evidence of reduced 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:
- Increased cardiorespiratory and muscular fitness
- Healthier body mass and composition
- Improved bone health
- Increased functional health
- Improved cognitive function

Panel 2: **Formulae for calculation of population attributable fraction (PAF)**

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

Formula 2, using adjusted relative risk:

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

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

See Online for appendix

requires knowledge of the prevalence of the risk factor in the population and the RR not to be adjusted for confounders (crude RR). Formula 2 is preferred when there is confounding;[8] it requires knowledge of the prevalence of the risk factor in people eventually developing the disease (cases) and the adjusted RR. Because some confounders (eg, hypertension in coronary heart disease, overweight in diabetes) are exacerbated by inactivity, formula 2 might overadjust, whereas 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 defined physical inactivity to be an activity level insufficient to meet present recommendations.[5] WHO obtains data, by country, for the prevalence of physical inactivity in the population using two similar standardised questionnaires; the latest data are for 2008.[9] For calculation of PAFs with RRs adjusted for confounding factors, the prevalence of physical inactivity at baseline in cases of the outcome of interest was needed. These data proved difficult to obtain for countries outside North America and Europe. Further, data for 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, or home-based activities.

Thus, to estimate the prevalence of inactivity in 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 in all participants at baseline, and in those eventually developing coronary heart disease, type 2 diabetes, and breast and colon cancer and those who died (appendix). For each outcome, we calculated an adjustment factor, representing the added extent to which physical inactivity occurred in cases compared with the overall population of the cohort study. For example, in the Shanghai Women's Health Study (appendix), the prevalence of inactivity in all women at baseline was 45·4% versus 51·6% in women who died, 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 factor across studies. We applied the average adjustment factor to the prevalence of physical inactivity, by country, to estimate the prevalence of inactivity in cases of coronary heart disease, type 2 diabetes, breast and colon cancer, and death from any cause.

Estimation of RRs associated with physical inactivity

We searched electronic databases (Medline and Embase) using keywords related to physical activity ("physical activity", "motor activity", "energy expenditure", "walking", and "exercise") and the outcomes of interest ("breast cancer", "breast carcinoma", "colon cancer", "colorectal cancer", "colon carcinoma", "colorectal carcinoma", "diabetes", "type 2 diabetes", "all-cause mortality", "mortality", "cardiovascular disease", "coronary heart disease", and "heart disease") for peer-reviewed reviews of adults published in English, selecting the most recent one as of June 30, 2011. For all outcomes apart from breast cancer, published meta-analyses of the pooled RR were available.[10–13] For breast cancer, no comprehensive

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meta-analysis was found (one of only case-control studies is available[14]), so we selected the most recent qualitative review[15] and did 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 information was not reported; for several, data were provided that allowed its calculation. When 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 value the unadjusted RR. This method 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 used simple, random-effects meta-regression to account for heterogeneity across studies, using MIX 2.0.

Calculation of PAFs and gains in life expectancy

We calculated PAFs for each outcome, by country, and used Monte Carlo simulation techniques (10 000 simulations) to estimate 95% CIs. We assumed normal distributions for physical inactivity prevalence and the log of the RRs. We used life-table analysis to estimate gains in life expectancy that could be expected if physical inactivity were eliminated, using life tables published by WHO that provide 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 premature mortality can be removed from the population if physical inactivity were eliminated, we assumed that the age-specific death rates for a 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 mainly been in people aged 40 years and older, with few data available for those aged 80 years and older, which also suggest 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 a sensitivity analysis, we did parallel analyses that decreased age-specific death rates for all ages 40 years and older.

Role of the funding source

No funding organisation had any role in the writing of the report or the decision to submit for publication. The corresponding author had full access to all data in the study and final responsibility for the decision to submit for publication.

Results

We estimated the prevalence of physical inactivity in cases of the outcomes studied, by country, using adjustment factors of 1·20 (SE 0·03) for coronary heart disease, 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 was noted in people who went on to develop type 2 diabetes, followed by those who died and those who developed colon cancer, coronary heart disease, and breast cancer (table 1, appendix).

Table 1 summarises the RRs associated with physical inactivity, unadjusted and adjusted for confounders, for the outcomes studied. Sattelmair and colleagues[10] investigated the dose-response relation between leisure-time energy expenditure and incidence of coronary heart disease. The pooled RR associated with energy expenditure that fulfilled present recommendations compared

	Coronary heart disease	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 in people 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, 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, 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 with 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 with 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)

Physical inactivity was defined as insufficient physical activity to meet present recommendations. RR=relative risk. PAF=population attributable fraction. *Women only. †Data are overall median (range of medians for WHO regions); details of country-specific values for the population are available from reference 9; country-specific values for people eventually developing these diseases are provided in the appendix. ‡Data are RR (95% CI); for details of calculation of unadjusted RRs, see appendix; the unadjusted RRs pooled both crude and age-adjusted RRs, since the crude RR was often unavailable; the adjusted RR of coronary heart disease was obtained from Sattelmair and colleagues,[10] for type 2 diabetes from Jeon and colleagues,[11] for breast cancer and all-cause mortality see appendix, and for colon cancer from Wolin and co-workers.[12] §Data are overall median (range of medians for WHO regions); details of country-specific values calculated with unadjusted RRs are provided in appendix; country-specific values calculated with adjusted RRs are shown in table 2.

Table 1: **Summary of estimates of the prevalence of physical inactivity, RRs, and PAFs for coronary heart disease, type 2 diabetes, breast cancer, colon cancer, and all-cause mortality associated with physical inactivity**

	Coronary heart disease	Type 2 diabetes	Breast cancer	Colon cancer	All-cause mortality
Africa					
Algeria	6·7% (2·4 to 11·2)	8·3% (4·2 to 12·9)	12·8% (5·9 to 20·0)	12·0% (6·8 to 17·2)	10·8% (8·6 to 13·1)
Benin	1·5% (0·5 to 2·5)	1·9% (0·9 to 2·9)	2·9% (1·3 to 4·6)	2·7% (1·5 to 3·9)	2·4% (1·9 to 3·0)
Botswana	5·8% (2·1 to 9·7)	7·2% (3·6 to 11·3)	11·5% (5·4 to 18·0)	10·4% (5·9 to 15·1)	9·4% (7·5 to 11·4)
Burkina Faso	2·6% (–0·2 to 6·1)	3·2% (–0·3 to 7·2)	4·3% (–1·0 to 9·5)	4·6% (–0·8 to 9·9)	4·1% (–0·1 to 8·6)
Cameroon	6·7% (1·0 to 13·9)	8·3% (1·8 to 16·2)	12·6% (1·8 to 23·8)	12·0% (2·3 to 22·1)	10·9% (3·4 to 18·6)
Cape Verde	3·4% (1·3 to 5·7)	4·2% (2·1 to 6·6)	7·7% (3·5 to 11·8)	6·1% (3·4 to 8·9)	5·5% (4·3 to 6·8)
Chad	4·1% (0·0 to 9·3)	5·0% (–0·2 to 11·0)	6·8% (–0·8 to 14·4)	7·3% (–0·3 to 15·1)	6·5% (0·4 to 12·9)
Comoros	1·4% (–0·3 to 3·6)	1·7% (–0·4 to 4·2)	2·8% (–0·9 to 6·4)	2·5% (–0·8 to 5·7)	2·2% (–0·5 to 5·0)
Congo (Brazzaville)	8·0% (1·4 to 16·4)	10·0% (2·2 to 19·1)	13·8% (2·8 to 24·9)	14·4% (3·0 to 26·2)	13·0% (4·4 to 22·0)
Côte d'Ivoire	5·4% (0·6 to 11·9)	6·7% (0·8 to 13·9)	9·6% (0·7 to 19·0)	9·7% (0·7 to 18·5)	8·8% (2·0 to 16·1)
Democratic Republic of the Congo	7·5% (2·8 to 12·4)	9·3% (4·7 to 14·5)	13·6% (6·5 to 21·1)	13·4% (7·3 to 19·4)	12·1% (9·6 to 14·6)
Eritrea	6·7% (2·4 to 11·2)	8·3% (4·2 to 12·8)	14·3% (6·7 to 22·4)	12·0% (6·7 to 17·1)	10·8% (8·6 to 13·0)
Ethiopia	3·2% (–0·1 to 7·6)	4·0% (–0·1 to 8·9)	5·8% (–0·9 to 12·7)	5·7% (–0·6 to 12·1)	5·2% (0·2 to 10·5)
Gabon	6·1% (0·5 to 13·3)	7·5% (0·6 to 15·5)	12·1% (0·7 to 23·6)	10·8% (0·6 to 21·5)	9·8% (1·8 to 18·2)
Ghana	2·9% (1·1 to 4·8)	3·6% (1·8 to 5·7)	5·4% (2·5 to 8·4)	5·2% (2·9 to 7·5)	4·7% (3·7 to 5·7)
Guinea	2·0% (–0·2 to 5·0)	2·5% (–0·2 to 5·6)	4·7% (–0·7 to 10·2)	3·6% (–0·6 to 7·7)	3·2% (–0·1 to 6·7)
Kenya	2·7% (–0·4 to 6·8)	3·4% (–0·6 to 7·9)	4·7% (–1·1 to 10·6)	4·9% (–1·0 to 10·9)	4·4% (–0·3 to 9·3)
Madagascar	3·9% (1·4 to 6·4)	4·8% (2·4 to 7·5)	7·4% (3·5 to 11·5)	6·9% (3·9 to 10·0)	6·2% (4·9 to 7·5)
Malawi	1·7% (0·6 to 2·8)	2·1% (1·0 to 3·3)	3·4% (1·6 to 5·3)	3·0% (1·7 to 4·4)	2·7% (2·1 to 3·3)
Mali	3·5% (–0·1 to 8·0)	4·3% (–0·2 to 9·5)	6·2% (–0·7 to 13·4)	6·2% (–0·7 to 13·1)	5·6% (0·2 to 11·1)
Mauritania	7·3% (1·5 to 14·3)	9·0% (2·2 to 16·9)	12·4% (3·3 to 21·8)	13·0% (3·0 to 23·0)	11·7% (4·5 to 19·2)
Mauritius	6·4% (0·7 to 13·5)	7·9% (1·3 to 15·9)	10·2% (0·8 to 20·0)	11·4% (1·2 to 21·6)	10·3% (2·6 to 18·2)
Mozambique	1·2% (0·4 to 2·0)	1·5% (0·7 to 2·3)	1·9% (0·9 to 3·0)	2·1% (1·1 to 3·1)	1·9% (1·5 to 2·4)
Namibia	9·7% (2·3 to 18·9)	12·0% (3·5 to 22·2)	17·0% (4·6 to 29·5)	17·3% (5·0 to 29·9)	15·6% (7·0 to 24·8)
Niger	4·9% (1·8 to 8·0)	6·0% (3·0 to 9·3)	8·9% (4·2 to 14·1)	8·7% (4·8 to 12·6)	7·8% (6·2 to 9·5)
São Tomé and Príncipe	3·1% (1·1 to 5·2)	3·9% (2·0 to 6·0)	6·9% (3·1 to 10·6)	5·6% (3·1 to 8·2)	5·1% (4·0 to 6·2)
Senegal	3·8% (0·0 to 8·8)	4·7% (0·1 to 10·1)	6·7% (–0·7 to 14·2)	6·8% (–0·3 to 13·7)	6·2% (0·5 to 12·0)
Seychelles	3·7% (1·3 to 6·1)	4·6% (2·3 to 7·2)	5·8% (2·6 to 9·2)	6·6% (3·7 to 9·6)	6·0% (4·7 to 7·3)
Sierra Leone	3·3% (1·1 to 5·4)	4·1% (2·0 to 6·3)	6·2% (2·9 to 9·5)	5·9% (3·3 to 8·5)	5·3% (4·2 to 6·5)
South Africa	8·7% (3·1 to 14·5)	10·7% (5·4 to 16·8)	14·7% (6·7 to 23·1)	15·5% (8·8 to 22·4)	14·0% (11·1 to 16·9)
Swaziland	11·4% (3·2 to 21·5)	14·2% (4·7 to 25·1)	18·8% (5·9 to 32·4)	20·4% (7·3 to 33·7)	18·4% (9·4 to 27·7)
The Gambia	4·1% (1·5 to 6·7)	5·0% (2·5 to 7·8)	7·5% (3·5 to 11·7)	7·3% (4·1 to 10·5)	6·5% (5·2 to 7·9)
Zambia	2·9% (–0·3 to 7·0)	3·5% (–0·5 to 8·2)	5·0% (–1·2 to 11·3)	5·1% (–1·0 to 11·4)	4·6% (–0·2 to 9·6)
Zimbabwe	3·9% (0·0 to 9·0)	4·9% (–0·1 to 10·7)	6·7% (–0·8 to 14·3)	7·0% (–0·4 to 14·6)	6·4% (0·6 to 12·4)
Median for region	3·9%	4·8%	7·1%	7·0%	6·3%
Latin America and Caribbean					
Argentina	11·3% (3·1 to 21·0)	14·0% (4·8 to 24·7)	18·5% (5·9 to 31·7)	20·2% (6·8 to 33·5)	18·2% (9·5 to 27·7)
Barbados	7·8% (2·8 to 13·0)	9·6% (4·8 to 15·0)	14·5% (6·8 to 22·7)	13·9% (7·6 to 20·1)	12·5% (9·9 to 15·1)
Brazil	8·2% (1·5 to 16·4)	10·1% (2·4 to 18·9)	13·4% (2·3 to 24·7)	14·6% (2·9 to 26·1)	13·2% (4·8 to 21·7)
Colombia	7·3% (0·9 to 15·6)	9·0% (1·3 to 18·2)	12·5% (1·2 to 23·9)	13·0% (1·3 to 24·8)	11·7% (2·8 to 21·0)
Dominica	4·0% (1·7 to 16·6)	5·0% (2·7 to 19·9)	9·0% (4·2 to 26·1)	7·2% (4·2 to 27·5)	6·5% (5·3 to 23·0)
Dominican Republic	9·9% (1·7 to 16·6)	12·3% (2·7 to 19·9)	16·4% (4·2 to 26·1)	17·8% (4·2 to 27·5)	16·0% (5·3 to 23·0)
Ecuador	7·1% (1·0 to 14·6)	8·7% (1·5 to 17·2)	12·6% (1·5 to 23·7)	12·6% (2·1 to 23·5)	11·4% (3·5 to 19·7)
Guatemala	2·7% (–0·3 to 6·5)	3·3% (–0·5 to 7·8)	4·4% (–1·2 to 10·1)	4·8% (–1·1 to 10·6)	4·3% (–0·3 to 9·2)
Jamaica	7·9% (1·4 to 16·1)	9·8% (2·2 to 18·5)	13·4% (2·6 to 24·8)	14·1% (2·5 to 25·5)	12·8% (4·6 to 21·6)
Mexico	6·2% (0·8 to 13·2)	7·7% (1·0 to 15·8)	10·0% (0·8 to 19·8)	11·2% (1·1 to 21·3)	10·1% (2·5 to 18·2)
Paraguay	6·8% (1·0 to 14·2)	8·5% (1·4 to 16·8)	10·9% (1·0 to 21·2)	12·2% (1·6 to 22·9)	11·0% (3·0 to 19·1)
Saint Kitts and Nevis	6·3% (2·3 to 10·5)	7·9% (3·9 to 12·2)	12·5% (5·9 to 19·5)	11·3% (6·4 to 16·5)	10·2% (8·1 to 12·4)
Uruguay	5·6% (2·1 to 9·4)	7·0% (3·5 to 10·9)	10·5% (4·8 to 16·4)	10·1% (5·6 to 14·6)	9·1% (7·2 to 11·1)
Median for region	7·1%	8·7%	12·5%	12·6%	11·4%

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	Coronary heart disease	Type 2 diabetes	Breast cancer	Colon cancer	All-cause mortality
(Continued from previous page)					
North America					
Canada	5·6% (0·5 to 12·2)	7·0% (0·8 to 14·4)	9·2% (0·2 to 18·6)	10·0% (0·7 to 19·5)	9·1% (1·8 to 16·6)
USA	6·7% (2·5 to 11·1)	8·3% (4·2 to 12·9)	12·4% (5·8 to 19·2)	12·0% (6·7 to 17·4)	10·8% (8·6 to 13·1)
Median for region	6·2%	7·6%	10·8%	11·0%	9·9%
Eastern Mediterranean					
Iran	6·1% (2·2 to 10·2)	7·6% (3·8 to 11·8)	12·2% (5·8 to 18·9)	10·9% (6·2 to 15·8)	9·9% (7·9 to 11·9)
Iraq	9·7% (3·5 to 15·8)	12·0% (6·0 to 18·7)	14·1% (6·6 to 21·9)	17·3% (9·7 to 25·1)	15·6% (12·5 to 18·8)
Kuwait	10·7% (3·9 to 17·7)	13·2% (6·6 to 20·7)	18·8% (8·8 to 29·2)	19·1% (10·6 to 27·7)	17·2% (13·7 to 20·8)
Lebanon	7·8% (2·9 to 12·9)	9·6% (4·7 to 14·9)	10·9% (5·1 to 16·9)	13·8% (7·6 to 20·0)	12·5% (9·9 to 15·1)
Libya	7·6% (2·8 to 12·5)	9·4% (4·7 to 14·7)	14·2% (6·6 to 21·9)	13·6% (7·4 to 19·5)	12·2% (9·7 to 14·8)
Pakistan	6·7% (1·0 to 14·0)	8·3% (1·4 to 16·3)	12·5% (1·9 to 23·6)	12·0% (1·6 to 22·0)	10·8% (3·2 to 18·8)
Saudi Arabia	11·4% (4·2 to 18·8)	14·1% (7·1 to 21·9)	19·9% (9·2 to 30·6)	20·4% (11·3 to 29·3)	18·4% (14·7 to 22·1)
Tunisia	5·9% (0·7 to 12·6)	7·4% (1·0 to 15·0)	10·5% (1·0 to 20·2)	10·6% (1·0 to 20·3)	9·6% (2·4 to 17·1)
United Arab Emirates	10·3% (2·6 to 19·9)	12·8% (3·8 to 23·6)	18·0% (5·9 to 30·9)	18·5% (5·2 to 31·7)	16·7% (7·3 to 26·2)
Median for region	7·8%	9·6%	14·1%	13·8%	12·5%
Europe					
Austria	5·8% (0·6 to 12·1)	7·1% (1·0 to 14·5)	10·2% (0·8 to 20·1)	10·3% (1·1 to 19·4)	9·3% (2·3 to 16·5)
Belgium	7·1% (1·2 to 14·7)	8·8% (1·9 to 17·0)	11·7% (2·0 to 21·5)	12·6% (2·1 to 23·1)	11·4% (3·7 to 19·5)
Bosnia and Herzegovina	5·6% (0·4 to 12·1)	6·9% (0·8 to 14·1)	9·6% (0·4 to 19·2)	9·9% (0·7 to 19·4)	9·0% (1·8 to 16·5)
Bulgaria	4·4% (0·1 to 9·9)	5·5% (0·1 to 11·7)	7·5% (–0·4 to 15·6)	7·9% (–0·1 to 16·1)	7·2% (0·9 to 13·6)
Croatia	3·9% (0·0 to 8·9)	4·8% (–0·1 to 10·6)	5·5% (–0·6 to 11·6)	7·0% (–0·5 to 14·3)	6·3% (0·5 to 12·4)
Cyprus	9·2% (2·0 to 17·9)	11·4% (3·0 to 21·0)	16·3% (4·2 to 28·8)	16·4% (4·3 to 28·8)	14·8% (6·2 to 24·1)
Czech Republic	4·1% (0·3 to 9·3)	5·1% (0·2 to 10·9)	5·8% (–0·4 to 12·3)	7·4% (0·0 to 14·8)	6·7% (0·9 to 12·6)
Denmark	5·8% (0·6 to 12·4)	7·2% (0·8 to 14·7)	9·2% (0·2 to 18·4)	10·4% (1·0 to 19·9)	9·4% (2·2 to 17·1)
Estonia	2·9% (–0·2 to 6·9)	3·5% (–0·4 to 8·1)	4·9% (–0·9 to 10·9)	5·1% (–0·9 to 11·2)	4·6% (–0·2 to 9·4)
Finland	6·3% (0·8 to 13·2)	7·8% (1·3 to 15·6)	9·1% (0·2 to 18·4)	11·2% (1·1 to 21·2)	10·1% (2·6 to 17·8)
France	5·4% (1·9 to 8·9)	6·7% (3·3 to 10·3)	9·7% (4·6 to 15·1)	9·6% (5·4 to 13·8)	8·7% (6·9 to 10·5)
Georgia	3·7% (1·3 to 6·2)	4·6% (2·3 to 7·1)	6·1% (2·8 to 9·5)	6·6% (3·6 to 9·6)	6·0% (4·7 to 7·2)
Germany	4·6% (0·1 to 10·4)	5·7% (0·2 to 12·4)	7·4% (–0·3 to 15·5)	8·3% (–0·3 to 16·7)	7·5% (0·9 to 14·5)
Greece	2·6% (–0·2 to 6·2)	3·2% (–0·4 to 7·4)	3·8% (–1·1 to 8·7)	4·6% (–0·9 to 10·1)	4·2% (–0·2 to 8·7)
Hungary	4·3% (0·1 to 9·5)	5·3% (0·0 to 11·4)	6·7% (–0·2 to 13·7)	7·7% (–0·2 to 15·6)	6·9% (0·7 to 13·2)
Ireland	8·8% (2·0 to 17·4)	10·9% (2·9 to 20·2)	15·2% (3·5 to 27·3)	15·7% (4·1 to 27·6)	14·2% (6·0 to 22·9)
Italy	9·1% (1·9 to 18·0)	11·2% (3·0 to 20·9)	15·6% (4·2 to 28·0)	16·2% (3·9 to 28·1)	14·6% (5·8 to 23·7)
Kazakhstan	5·2% (0·4 to 11·5)	6·5% (0·6 to 13·4)	8·1% (–0·2 to 16·3)	9·3% (0·5 to 18·4)	8·4% (1·5 to 15·6)
Latvia	5·3% (0·3 to 11·5)	6·6% (0·5 to 13·6)	9·4% (0·1 to 18·7)	9·5% (0·2 to 18·6)	8·5% (1·4 to 15·8)
Lithuania	3·7% (1·3 to 6·3)	4·6% (2·3 to 7·2)	6·5% (2·9 to 10·1)	6·7% (3·7 to 9·8)	6·0% (4·7 to 7·5)
Luxembourg	7·9% (1·3 to 16·0)	9·8% (1·9 to 19·1)	11·9% (1·2 to 23·0)	14·1% (2·6 to 25·8)	12·7% (4·2 to 21·8)
Malta	11·9% (3·3 to 22·3)	14·7% (5·3 to 26·0)	19·1% (6·0 to 32·4)	21·3% (7·5 to 35·3)	19·2% (9·8 to 28·9)
Netherlands	3·0% (–0·1 to 7·1)	3·7% (–0·3 to 8·3)	4·0% (–1·1 to 9·2)	5·4% (–0·6 to 11·4)	4·9% (0·0 to 9·8)
Norway	7·3% (1·2 to 15·3)	9·1% (1·7 to 17·9)	11·7% (1·5 to 22·2)	13·1% (2·2 to 24·1)	11·8% (3·5 to 20·2)
Poland	4·6% (0·2 to 10·4)	5·7% (0·3 to 12·0)	8·2% (–0·2 to 17·0)	8·2% (–0·1 to 16·4)	7·4% (1·0 to 13·9)
Portugal	8·4% (1·7 to 17·3)	10·5% (2·6 to 20·2)	14·2% (3·1 to 25·9)	15·1% (3·6 to 27·0)	13·6% (5·2 to 22·6)
Romania	6·4% (0·7 to 13·6)	7·9% (1·2 to 15·8)	12·0% (1·2 to 23·2)	11·4% (1·3 to 21·9)	10·3% (2·6 to 18·4)
Russia	3·4% (–0·1 to 8·1)	4·3% (–0·2 to 9·5)	4·9% (–0·9 to 10·7)	6·2% (–0·6 to 13·1)	5·6% (0·2 to 11·0)
Serbia	11·3% (3·1 to 20·9)	14·0% (4·7 to 24·6)	19·1% (6·9 to 32·3)	20·2% (7·0 to 33·5)	18·2% (9·4 to 27·6)
Slovakia	3·7% (0·1 to 8·5)	4·6% (0·0 to 9·9)	5·5% (–0·9 to 12·1)	6·6% (–0·3 to 13·7)	5·9% (0·5 to 11·5)
Slovenia	5·0% (0·3 to 11·1)	6·2% (0·4 to 12·9)	8·8% (0·2 to 17·5)	8·9% (0·0 to 17·6)	8·0% (1·2 to 15·2)
Spain	8·3% (1·7 to 16·7)	10·3% (2·5 to 19·5)	13·8% (2·6 to 25·5)	14·9% (3·1 to 26·6)	13·4% (4·9 to 22·4)
Sweden	7·3% (1·2 to 15·1)	9·1% (1·9 to 17·4)	11·5% (1·6 to 21·7)	13·1% (2·1 to 24·1)	11·8% (3·8 to 20·2)
Turkey	9·3% (2·1 to 18·3)	11·5% (3·2 to 21·0)	16·3% (4·0 to 28·9)	16·6% (4·2 to 29·0)	15·0% (6·2 to 23·9)

(Continues on next page)

	Coronary heart disease	Type 2 diabetes	Breast cancer	Colon cancer	All-cause mortality
(Continued from previous page)					
Ukraine	3·1% (–0·2 to 7·3)	3·8% (–0·4 to 8·5)	4·3% (–0·8 to 9·3)	5·4% (–0·8 to 11·6)	4·9% (0·0 to 10·1)
UK	10·5% (4·0 to 17·3)	13·0% (6·4 to 20·2)	17·9% (8·5 to 27·8)	18·7% (10·5 to 27·1)	16·9% (13·6 to 20·3)
Median for region	5·5%	6·8%	9·3%	9·8%	8·8%
Southeast Asia					
Bangladesh	0·8% (0·3 to 1·3)	1·0% (0·5 to 1·5)	1·7% (0·8 to 2·7)	1·4% (0·8 to 2·0)	1·3% (1·0 to 1·5)
Bhutan	8·7% (1·8 to 17·3)	10·7% (2·6 to 20·3)	16·6% (4·2 to 29·0)	15·5% (3·8 to 27·6)	14·0% (5·3 to 22·8)
Burma	2·1% (0·8 to 3·5)	2·6% (1·3 to 4·1)	3·9% (1·9 to 6·1)	3·8% (2·1 to 5·4)	3·4% (2·7 to 4·1)
India	2·6% (1·0 to 4·2)	3·2% (1·6 to 5·0)	4·8% (2·3 to 7·4)	4·6% (2·6 to 6·6)	4·2% (3·3 to 5·0)
Indonesia	4·9% (1·8 to 8·2)	6·1% (3·0 to 9·5)	7·3% (3·3 to 11·5)	8·8% (4·9 to 12·8)	8·0% (6·3 to 9·7)
Maldives	6·5% (0·7 to 13·9)	8·0% (1·0 to 16·1)	10·8% (0·5 to 21·4)	11·5% (1·0 to 22·1)	10·4% (2·6 to 18·5)
Nepal	2·6% (–0·3 to 6·2)	3·2% (–0·4 to 7·4)	4·4% (–1·0 to 10·1)	4·6% (–0·8 to 10·2)	4·1% (–0·2 to 8·7)
Sri Lanka	4·3% (1·6 to 7·1)	5·3% (2·7 to 8·3)	8·7% (4·2 to 13·5)	7·7% (4·2 to 11·1)	6·9% (5·5 to 8·3)
Thailand	3·2% (1·2 to 5·2)	3·9% (2·0 to 6·1)	5·6% (2·5 to 8·7)	5·7% (3·2 to 8·2)	5·1% (4·1 to 6·2)
Median for region	3·2%	3·9%	5·6%	5·7%	5·1%
Western Pacific					
Australia	6·3% (0·8 to 13·1)	7·8% (1·0 to 15·4)	10·4% (0·9 to 20·2)	11·2% (1·4 to 21·2)	10·1% (2·8 to 18·0)
Cambodia	1·9% (0·7 to 3·1)	2·3% (1·1 to 3·6)	2·9% (1·3 to 4·5)	3·3% (1·8 to 4·8)	3·0% (2·4 to 3·6)
China	5·1% (1·9 to 8·5)	6·4% (3·2 to 9·8)	8·4% (4·0 to 13·0)	9·2% (5·2 to 13·1)	8·3% (6·6 to 10·0)
Cook Islands	11·9% (4·4 to 19·7)	14·8% (7·5 to 23·4)	19·1% (9·0 to 29·8)	21·3% (11·8 to 30·9)	19·2% (15·3 to 23·1)
Federated States of Micronesia	11·0% (4·1 to 18·3)	13·6% (6·8 to 21·1)	19·4% (9·1 to 30·5)	19·6% (11·0 to 28·6)	17·7% (14·1 to 21·3)
Japan	10·0% (2·4 to 19·0)	12·3% (3·6 to 22·5)	16·1% (3·9 to 29·1)	17·8% (5·0 to 30·9)	16·1% (7·2 to 25·4)
Kiribati	7·7% (2·7 to 12·8)	9·6% (4·8 to 15·0)	14·3% (6·9 to 22·3)	13·8% (7·7 to 20·0)	12·5% (9·8 to 15·1)
Laos	3·1% (–0·2 to 7·5)	3·9% (–0·4 to 8·7)	5·5% (–1·0 to 12·1)	5·6% (–0·8 to 12·0)	5·0% (–0·1 to 10·3)
Malaysia	10·2% (3·8 to 16·9)	12·6% (6·3 to 19·6)	17·1% (8·0 to 26·6)	18·2% (10·2 to 26·5)	16·4% (13·0 to 19·7)
Marshall Islands	8·2% (3·0 to 13·7)	10·2% (5·1 to 15·7)	14·5% (6·9 to 22·5)	14·7% (8·1 to 21·2)	13·2% (10·6 to 16·0)
Mongolia	1·6% (0·6 to 2·6)	1·9% (1·0 to 3·0)	2·5% (1·1 to 3·9)	2·8% (1·5 to 4·0)	2·5% (2·0 to 3·0)
Nauru	7·7% (2·9 to 12·9)	9·5% (4·8 to 14·8)	13·0% (6·2 to 20·3)	13·8% (7·6 to 19·8)	12·4% (9·8 to 14·9)
New Zealand	7·9% (2·9 to 13·1)	9·8% (4·9 to 15·2)	13·1% (6·2 to 20·3)	14·1% (7·9 to 20·3)	12·7% (10·2 to 15·4)
Papua New Guinea	3·2% (1·2 to 5·3)	4·0% (1·9 to 6·2)	5·6% (2·5 to 8·8)	5·7% (3·1 to 8·3)	5·2% (4·1 to 6·3)
Philippines	3·9% (–0·1 to 9·0)	4·9% (–0·1 to 10·7)	6·8% (–0·7 to 14·7)	7·0% (–0·5 to 14·4)	6·3% (0·4 to 12·4)
Samoa	8·5% (3·1 to 14·1)	10·5% (5·3 to 16·4)	17·0% (8·1 to 26·7)	15·1% (8·5 to 21·8)	13·6% (10·9 to 16·4)
Solomon Islands	7·2% (2·7 to 11·9)	9·0% (4·5 to 14·0)	12·9% (6·1 to 20·2)	12·9% (7·1 to 18·8)	11·7% (9·2 to 14·0)
Tonga	6·9% (2·5 to 11·5)	8·6% (4·2 to 13·4)	13·5% (6·4 to 21·1)	12·4% (6·8 to 18·0)	11·2% (8·8 to 13·6)
Vietnam	2·5% (–0·2 to 6·2)	3·1% (–0·4 to 7·3)	4·1% (–1·1 to 9·4)	4·5% (–0·8 to 9·8)	4·1% (–0·2 to 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%

Data are PAF (95% CI). PAF=population attributable fraction. *PAFs calculated with unadjusted relative risks are shown in the appendix.

***Table 2:* Estimated PAFs, calculated with adjusted relative risks,* for coronary heart disease, type 2 diabetes, breast cancer, colon cancer, and all-cause mortality associated with physical inactivity, by WHO region and country**

with no leisure activity, adjusted for potential confounders, was 0·86 (95% CI 0·77–0·96). With increasing energy expenditure, coronary heart disease incidence fell further, in a curvilinear fashion. For this report, we used the RR corresponding to an activity level that met minimum present recommendations (0·86). Taking the inverse of this number to obtain the adjusted RR for physical inactivity yielded 1·16 (95% CI 1·04–1·30). Although these data are from only North America and Europe (ie, studies with sufficient information to investigate dose response), they are congruent with findings from the INTERHEART study[17] undertaken in 52 countries worldwide, in which the adjusted odds ratio for myocardial infarction associated with physical inactivity was identical (1·16, 95% CI 1·03–1·32). We did a parallel meta-analysis to obtain the corresponding pooled unadjusted RR (ie, pooling crude and age-adjusted RRs), which was 1·33 (95% CI 1·18–1·49; appendix). Crude RRs were available for only four studies and pooling of these yielded a value of 1·54 (95% CI 1·25–1·92); thus, the pooled unadjusted RR is conservative.

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	Gain in life expectancy (years)
Africa	
Algeria	0·79 (0·62 to 0·96)
Benin	0·19 (0·15 to 0·24)
Botswana	0·81 (0·64 to 0·99)
Burkina Faso	0·31 (–0·01 to 0·66)
Cameroon	0·85 (0·26 to 1·49)
Cape Verde	0·46 (0·35 to 0·56)
Chad	0·46 (0·03 to 0·93)
Comoros	0·17 (–0·04 to 0·40)
Congo (Brazzaville)	1·06 (0·35 to 1·87)
Côte d'Ivoire	0·72 (0·16 to 1·37)
Democratic Republic of the Congo	0·89 (0·70 to 1·09)
Eritrea	0·89 (0·70 to 1·08)
Ethiopia	0·43 (0·02 to 0·89)
Gabon	0·81 (0·15 to 1·55)
Ghana	0·40 (0·32 to 0·49)
Guinea	0·25 (–0·01 to 0·53)
Kenya	0·37 (–0·02 to 0·79)
Madagascar	0·52 (0·41 to 0·63)
Malawi	0·21 (0·17 to 0·26)
Mali	0·40 (0·14 to 0·81)
Mauritania	0·95 (0·35 to 1·60)
Mauritius	0·90 (0·22 to 1·62)
Mozambique	0·14 (0·11 to 0·17)
Namibia	1·45 (0·62 to 2·39)
Niger	0·57 (0·45 to 0·69)
São Tomé and Príncipe	0·36 (0·28 to 0·44)
Senegal	0·49 (0·04 to 0·97)
Seychelles	0·51 (0·40 to 0·63)
Sierra Leone	0·38 (0·30 to 0·46)
South Africa	1·26 (0·99 to 1·53)
Swaziland	1·56 (0·76 to 2·45)
The Gambia	0·52 (0·41 to 0·63)
Zambia	0·36 (–0·02 to 0·77)
Zimbabwe	0·56 (0·05 to 1·13)
Median for region	0·51
Latin America and Caribbean	
Argentina	1·39 (0·71 to 2·14)
Barbados	0·91 (0·72 to 1·11)
Brazil	1·08 (0·38 to 1·81)
Colombia	0·82 (0·19 to 1·50)
Dominica	0·51 (0·41 to 1·86)
Dominican Republic	1·28 (0·41 to 1·87)
Ecuador	0·80 (0·24 to 1·41)
Guatemala	0·35 (–0·02 to 0·74)
Jamaica	1·01 (0·36 to 1·74)
Mexico	0·76 (0·18 to 1·40)
Paraguay	0·85 (0·23 to 1·51)
Saint Kitts and Nevis	0·77 (0·61 to 0·95)
Uruguay	0·70 (0·55 to 0·85)
Median for region	0·82

(Continues in next column)

	Gain in life expectancy (years)
(Continued from previous column)	
North America	
Canada	0·55 (0·11 to 1·02)
USA	0·78 (0·62 to 0·94)
Median for region	0·66
Eastern Mediterranean	
Iran	0·71 (0·57 to 0·87)
Iraq	1·30 (1·03 to 1·59)
Kuwait	1·12 (0·89 to 1·37)
Lebanon	0·95 (0·75 to 1·16)
Libya	0·93 (0·77 to 1·18)
Pakistan	0·85 (0·25 to 1·52)
Saudi Arabia	1·51 (1·19 to 1·84)
Tunisia	0·64 (0·16 to 1·16)
United Arab Emirates	1·11 (0·48 to 1·78)
Median for region	0·95
Europe	
Austria	0·58 (0·14 to 1·03)
Belgium	0·73 (0·23 to 1·26)
Bosnia and Herzegovina	0·62 (0·12 to 1·16)
Bulgaria	0·58 (0·07 to 1·11)
Croatia	0·45 (0·04 to 0·91)
Cyprus	0·80 (0·33 to 1·33)
Czech Republic	0·48 (0·06 to 0·92)
Denmark	0·64 (0·15 to 1·19)
Estonia	0·38 (–0·02 to 0·78)
Finland	0·66 (0·17 to 1·17)
France	0·55 (0·44 to 0·67)
Georgia	0·52 (0·41 to 0·63)
Germany	0·47 (0·06 to 0·92)
Greece	0·23 (–0·01 to 0·49)
Hungary	0·61 (0·06 to 1·18)
Ireland	0·87 (0·36 to 1·42)
Italy	0·80 (0·31 to 1·32)
Kazakhstan	0·79 (0·14 to 1·50)
Latvia	0·77 (0·12 to 1·46)
Lithuania	0·53 (0·41 to 0·65)
Luxembourg	0·83 (0·27 to 1·45)
Malta	1·12 (0·56 to 1·71)
Netherlands	0·29 (0·00 to 0·59)
Norway	0·68 (0·20 to 1·18)
Poland	0·60 (0·08 to 1·14)
Portugal	0·86 (0·33 to 1·45)
Romania	0·87 (0·21 to 1·58)
Russia	0·52 (0·02 to 1·05)
Serbia	1·50 (1·02 to 2·33)
Slovakia	0·46 (0·04 to 0·92)
Slovenia	0·54 (0·08 to 1·05)
Spain	0·78 (0·28 to 1·32)
Sweden	0·67 (0·22 to 1·16)
Turkey	1·06 (0·43 to 1·74)

(Continues in next column)

	Gain in life expectancy (years)
(Continued from previous column)	
Ukraine	0·46 (0·00 to 0·97)
UK	1·07 (0·85 to 1·29)
Median for region	0·63
Southeast Asia	
Bangladesh	0·10 (0·08 to 0·12)
Bhutan	1·15 (0·42 to 1·95)
Burma	0·27 (0·22 to 0·33)
India	0·34 (0·27 to 0·41)
Indonesia	0·65 (0·51 to 0·80)
Maldives	0·75 (0·18 to 1·37)
Nepal	0·33 (–0·02 to 0·71)
Sri Lanka	0·51 (0·40 to 0·61)
Thailand	0·41 (0·32 to 0·49)
Median for region	0·41
Western Pacific	
Australia	0·56 (0·15 to 1·00)
Cambodia	0·24 (0·19 to 0·29)
China	0·61 (0·48 to 0·73)
Cook Islands	1·57 (1·24 to 1·91)
Federated States of Micronesia	1·45 (1·14 to 1·77)
Japan	0·91 (0·40 to 1·46)
Kiribati	1·27 (0·99 to 1·55)
Laos	0·43 (–0·01 to 0·90)
Malaysia	1·35 (1·06 to 1·65)
Marshall Islands	1·33 (1·04 to 1·63)
Mongolia	0·24 (0·19 to 0·29)
Nauru	1·21 (0·95 to 1·47)
New Zealand	0·76 (0·61 to 0·93)
Papua New Guinea	0·43 (0·34 to 0·52)
Philippines	0·52 (0·03 to 1·04)
Samoa	1·17 (0·92 to 1·42)
Solomon Islands	0·90 (0·70 to 1·09)
Tonga	1·03 (0·80 to 1·26)
Vietnam	0·31 (–0·01 to 0·64)
Median for region	0·90
Overall	
Median	0·68

Data in parentheses are 95% CI. Uncertainty interval calculated on the basis of the lower and upper bounds of the 95% CI of the adjusted population attributable fraction for all-cause mortality.

Table 3: **Estimated gains in life expectancy if physical inactivity were eliminated, by WHO region and country**

For the association of type 2 diabetes incidence with physical activity, Jeon and co-workers[11] reported a pooled RR of 0·83 (95% CI 0·76–0·90), adjusted for several confounders including body-mass index (BMI). Taking the inverse to obtain the adjusted RR for inactivity, we calculated an RR of 1·20 (95% CI 1·10–1·33). We calculated the corresponding, pooled unadjusted RR, which was 1·63 (95% CI 1·27–2·11; appendix). This magnitude of risk increase was similar to that pooling only the crude RRs, which yielded 1·58 (95% CI 1·11–2·26).

We used the primary papers in the qualitative review by Friedenreich and colleagues[15] to undertake a meta-analysis of the pooled adjusted and unadjusted RRs for breast cancer incidence (appendix). The adjusted RR for physical inactivity, including adjustment for BMI, was 1·33 (95% CI 1·26–1·42). This result was little different from the unadjusted RR of 1·34 (95% CI 1·25–1·43; similar to that pooling only crude RRs, yielding 1·35, 95% CI 1·26–1·45).

For the association of colon cancer incidence and physical activity, Wolin and colleagues[12] reported a pooled adjusted RR of 0·76 (95% CI 0·72–0·81). Taking the inverse of these results gave an adjusted RR of 1·32 (95% CI 1·23–1·39) for inactivity. Our calculation of the pooled unadjusted RR for colon cancer was 1·38 (95% CI 1·31–1·45; appendix); the pooled crude RR was similar (1·37, 95% CI 1·29–1·46).

Lollgen and colleagues[13] reported a meta-analysis of RRs for all-cause mortality associated with moderate and high levels of physical activity, qualitatively defined. Investigators reported separate estimates for studies in which participants were classified 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, from 0·52 to 0·80. We used their primary papers to do a meta-analysis to obtain one pooled RR that compared low with moderate physical activity—ie, a conservative estimate of the effect of inactivity. Our pooled adjusted RR was 1·28 (95% CI 1·21–1·36), whereas the pooled unadjusted RR was 1·47 (95% CI 1·38–1·57) and similar to the pooled crude RR of 1·46 (95% CI 1·34–1·60; appendix).

For coronary heart disease, median PAFs associated with physical inactivity, calculated with adjusted RRs, ranged from 3·2% (in southeast Asia) to 7·8% (in the eastern Mediterranean region), with an overall median of 6% (tables 1, 2). These results suggest that 6% of the burden of disease worldwide due to coronary heart disease can be eliminated, if all inactive people become active. The burden of disease was 7% for type 2 diabetes (ranging from 3·9% to 9·6%), 10% (5·6–14·1) for breast cancer, and 10% (5·7–13·8) for colon cancer.

Removal of physical inactivity had the largest effect on colon cancer, and the smallest on coronary heart disease, in terms of percentage reduction. However, with respect to the number of cases that can potentially be averted, coronary heart disease would have a far larger effect than would colon cancer because of its higher incidence. Although the worldwide incidence of coronary heart disease is not readily available, deaths from coronary heart disease can be viewed against colorectal cancer deaths to provide some perspective; in 2008, 7·25 million people worldwide died from coronary heart disease versus 647 000 from colorectal cancer.[18] Applying the median PAFs, we estimated that 15 000 deaths from

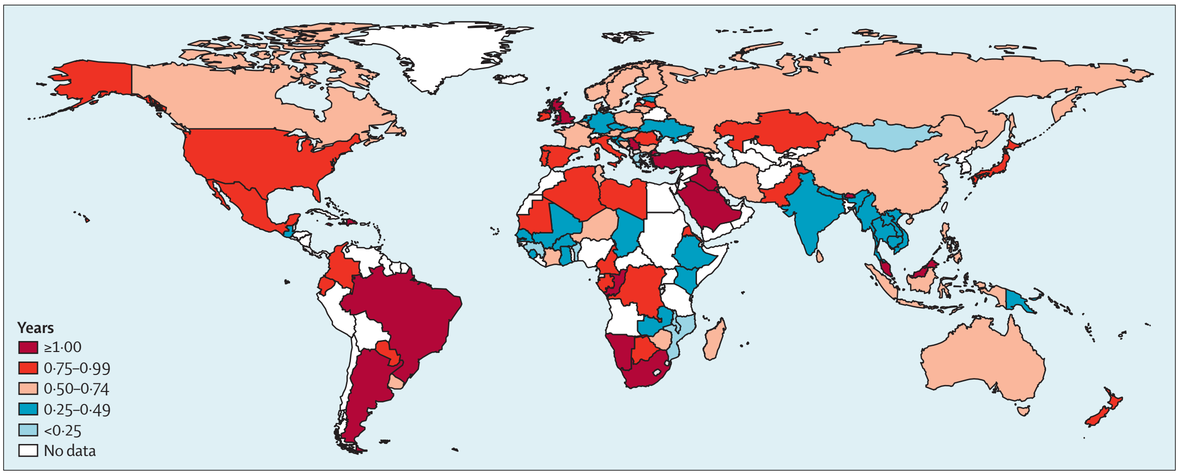

Figure: **Estimated gains in life expectancy worldwide with elimination of physical inactivity**

coronary heart disease in Africa could have been averted in 2008 by removal of physical inactivity. 60 000 could have been avoided in the Americas, 44 000 in the eastern Mediterranean region, 121 000 in Europe, 59 000 in southeast Asia, and 100 000 in the western Pacific region. With respect to deaths from breast cancer, 3000 could have been averted in Africa, 11 000 in the Americas, 4000 in the eastern Mediterranean, 14 000 in Europe, 5000 in southeast Asia, and 10 000 in the western Pacific; for deaths from colorectal cancer, these numbers were 1000, 14 000, 2000, 24 000, 4000, 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] we estimated that more than 5·3 million deaths (ranging from 525 000 in the eastern Mediterranean to 1·5 million in the western Pacific region) could be averted every year if all inactive people become active. Because physical inactivity is unlikely to be completely eliminated, we further 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 more than 533 000 and 1·3 million deaths potentially avoided worldwide each year.

Using an alternate classification of countries by income (data not shown), we calculated median PAFs for all-cause mortality of 4% for countries with low incomes, 8% for lower-middle incomes, 10% for upper-middle incomes, and 11% for high incomes (with number of deaths averted ranging from 409 000 in countries with low incomes to 2·5 million in those with lower-middle incomes). This analysis yielded estimated numbers of deaths potentially averted in 2008 from coronary heart disease of 15 000, 184 000, 96 000, and 98 000; from breast cancer of 2000, 16 000, 10 000, and 20 000; and from colorectal cancer of 1000, 19 000, 13 000, and 37 000, respectively.

We estimated that the median years of life potentially gained worldwide with elimination of physical inactivity was 0·68 years (ranging from 0·41 years in southeast Asia to 0·95 years in the eastern Mediterranean region; table 3, figure). When we classified countries by income, the median gains were 0·37 years for countries with low incomes, 0·65 for lower-middle incomes, 0·80 for upper-middle incomes, and 0·68 years for high incomes. In a sensitivity analysis that decreased age-specific death rates by the PAF for all ages 40 years or older (instead of only ages 40–79 years), the new estimate of years gained worldwide increased to a median of 0·92 years (range 0·49–1·25).

Finally, we used an example to illustrate gains under less stringent assumptions. A recent study of Taiwanese people aged 20 years and older comparing most with least active groups reported an RR for all-cause mortality of 1·35.[19] Applying this RR to China for people aged 20 years and older, we calculated a 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 estimated that physical inactivity causes 6–10% of the major non-communicable diseases of coronary heart disease, type 2 diabetes, and breast and colon cancers. Furthermore, this unhealthy behaviour causes 9% of premature mortality, or more than 5·3 of the 57 million deaths in 2008.[18] With elimination of physical inactivity, life expectancy of the world's population might be expected to increase by 0·68 years. These findings make inactivity similar to the established risk factors of smoking and obesity. The added years of life need to be interpreted correctly: they seem low because they represent gains in the whole population (including inactive and active people), rather than in inactive people who become active. Because all the gain accrues to people who move from inactive to active, the increase in life expectancy in the inactive group alone is greater. For perspective, other research done in the USA estimated that inactive people would gain 1·3–3·7 years from age 50 years by becoming active.[20,21] In an east Asian population, life expectancy from age 30 years in active people was 2·6–4·2 years greater than that in inactive people.[19]

How does physical inactivity compare with other risk factors for poor health? Although risk factors are classified 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] By elimination of smoking, life expectancy at age 50 years was estimated to increase by 2·3–2·5 years in the US population and 1·1–2·2 years in the populations of nine other high-income countries.[24] At an individual level, Beijing never-smokers aged 55 years and older had a life expectancy 4·2–8·8 years longer than that of present smokers.[25] As for obesity, if all obese people in the USA 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 years in another.[24] Thus, physical inactivity seems to have an effect similar to that of 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 needed for the preferred PAF formula, the incorrect formula (formula 1) was used. Their PAFs ranged from 10% for breast cancer to 22% for coronary heart disease—similar to the present estimate for breast cancer, but larger for coronary heart disease. 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), whereas that for coronary heart disease is (unadjusted RR 1·33, adjusted RR 1·16). Further, we conservatively used a pooled RR for coronary heart disease that compared physical inactivity with the minimum recommended activity level using recently published data,[10] whereas WHO used data available at the time of their analysis that compared extreme activity categories, yielding RRs of larger magnitude.

Our estimates are likely to be very conservative. First, the RRs were almost always based on self-reported physical activity levels,[28] which are imprecise. In prospective studies in which 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 non-communicable diseases[29] (which also might reflect inherited physiological 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 were adjusted for characteristics such as blood pressure, lipid profile, and glucose or insulin sensitivity. These could be overadjustments, since physical activity reduces risk of coronary heart disease and premature mortality partly through beneficial effects on these variables (a recent analysis suggested an attenuation of about 10% in the RR[10]). For type 2 diabetes, we used RRs adjusted for BMI—also conservative, since physical activity plays an important part in weight management.[3] Third, we used the same RR to calculate PAFs for all countries, based on data mainly from North America and Europe. Whether physical inactivity has similar effects in other populations is unclear. For example, we used a pooled adjusted RR for coronary heart disease of 1·16; however, a study in India reported a larger adjusted RR (2·27, 95% CI 1·41–3·70).[30] However, our pooled adjusted RR for all-cause mortality, 1·28, is similar to that of 1·25 (95% CI 1·18–1·33) in an east Asian study, comparing inactive people with those meeting minimum physical activity recommendations.[19] Fourth, we assumed physical activity to reduce all-cause mortality rates only at ages 40–79 years. In a sensitivity analysis that extended the benefit to age 40 years and older, larger gains in life expectancy were obtained. Fifth, we used one RR instead of a range of RRs to reflect the dose-response relation between physical inactivity and risks of non-communicable disease because sparse data are available for the dose-response relation.[10] In an illustrative example using China, we showed that 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 in cases. This adjustment factor was mainly based on populations in North America and Europe, and one study each from China and India; how applicable this factor might be to other countries such as those in Africa or with low incomes is unclear. Also, successful interventions will probably increase activity levels across the board, instead of shifting people across a binary divide of inactive to active assumed in our calculations, potentially yielding greater benefits. We examined only the major non-communicable diseases and all-cause mortality, and not other disorders affected by physical inactivity (panel 1) or disability resulting from non-communicable diseases. Finally, not all physically inactive people choose to be so; some might be physically incapable.

This summer, we will admire the breathtaking feats of athletes competing in the 2012 Olympic Games. Although only the smallest fraction of the population will attain these heights, the overwhelming majority of us are

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able to be physically active at very modest levels—eg, 15–30 min a day of brisk walking—which bring substantial health benefits.[3–5,19] We must explore all avenues and support all efforts to reduce physical inactivity worldwide.

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

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Conflicts of interest
We declare that we have no conflicts of interest.

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