The economic burden of physical inactivity: a global analysis of major non-communicable diseases

Ding Ding, Kenny D Lawson, Tracy L Kolbe-Alexander, Eric A Finkelstein, Peter T Katzmarzyk, Willem van Mechelen, Michael Pratt, for the Lancet *Physical Activity Series 2 Executive Committee**

Summary

Background **The pandemic of physical inactivity is associated with a range of chronic diseases and early deaths. Despite the well documented disease burden, the economic burden of physical inactivity remains unquantified at the global level. A better understanding of the economic burden could help to inform resource prioritisation and motivate efforts to increase levels of physical activity worldwide.**

Methods **Direct health-care costs, productivity losses, and disability-adjusted life-years (DALYs) attributable to physical inactivity were estimated with standardised methods and the best data available for 142 countries, representing 93·2% of the world's population. Direct health-care costs and DALYs were estimated for coronary heart disease, stroke, type 2 diabetes, breast cancer, and colon cancer attributable to physical inactivity. Productivity losses were estimated with a friction cost approach for physical inactivity related mortality. Analyses were based on national physical inactivity prevalence from available countries, and adjusted population attributable fractions (PAFs) associated with physical inactivity for each disease outcome and all-cause mortality.**

Findings **Conservatively estimated, physical inactivity cost health-care systems international $ (INT$) 53·8 billion worldwide in 2013, of which $31·2 billion was paid by the public sector, $12·9 billion by the private sector, and $9·7 billion by households. In addition, physical inactivity related deaths contribute to $13·7 billion in productivity losses, and physical inactivity was responsible for 13·4 million DALYs worldwide. High-income countries bear a larger proportion of economic burden (80·8% of health-care costs and 60·4% of indirect costs), whereas low-income and middle-income countries have a larger proportion of the disease burden (75·0% of DALYs). Sensitivity analyses based on less conservative assumptions led to much higher estimates.**

Interpretation **In addition to morbidity and premature mortality, physical inactivity is responsible for a substantial economic burden. This paper provides further justification to prioritise promotion of regular physical activity worldwide as part of a comprehensive strategy to reduce non-communicable diseases.**

Funding **None.**

Lancet 2016; 388: 1311–24

Published Online July 27, 2016 http://dx.doi.org/10.1016/S0140-6736(16)30383-X

See Comment pages 1254, 1255, 1257, and 1258

See Articles page 1302

See Series pages 1325 and 1337

This paper forms part of the Physical Activity 2016 Series

*Full list of committee members at end of paper

Prevention Research Collaboration/the Charles Perkins Centre, Sydney School of Public Health, The University of Sydney, Camperdown, NSW, Australia (D Ding PhD); **Centre for Chronic Disease Prevention, College of Public Health, Medical and Veterinary Sciences, James Cook University, Cairns, QLD, Australia** (D Ding, K D Lawson PhD); **Centre for Health Research, School of Medicine, Western Sydney University, Sydney, NSW, Australia** (K D Lawson); **Centre for Research on Exercise, Physical Activity and Health, School of Human Movement and Nutrition Sciences, The University of Queensland, St Lucia, QLD, Australia** (T L Kolbe-Alexander PhD, Prof W van Mechelen PhD); **Research Unit for Exercise Science and Sports Medicine (ESSM), Department of Human Biology, Faculty of Health Sciences, University of Cape Town, Cape Town, South Africa** (T L Kolbe-Alexander, Prof W van Mechelen); **Duke University-National University of Singapore, Singapore** (Prof E A Finkelstein PhD); **Pennington Biomedical Research Center, Louisiana State University, Baton Rouge, LA, USA** (Prof P T Katzmarzyk PhD); **Department of Public and Occupational Health and EMGO+ Institute, VU**

Introduction

Around the world, efforts to address risk factors for non-communicable diseases (NCDs) are often hampered by an absence of understanding of the true burden that these risk factors impose on societies. This deficiency is problematic because information about disease burden is used to galvanise public support for health promotion, to convince key decision makers to take action, and to prioritise funding decisions in an era of increasingly tight budgets.[1,2] Typically, burden estimates include mortality, morbidity, and economic costs, all of which are indispensable for informed decision making.

Physical inactivity is recognised as a global pandemic that requires global action.[3] Based on a large body of scientific literature and data from global surveillance, Lee and colleagues[4] quantified the global burden of physical inactivity in terms of morbidity and mortality. However, estimation of the economic burden of physical inactivity remains a major gap in the field.[5] As Kohl and colleagues[3] advocated in the previous *Lancet* Physical Activity Series, an "in-depth global analysis [of the economic burden of inactivity] is needed".

To date, for several countries national estimates of the economic costs of physical inactivity have been published.[5] However, most of these analyses were limited to direct health-care costs only, without estimating indirect costs (eg, productivity losses due to morbidity and premature mortality), and almost all analyses were conducted in high-income countries. This latter point is a major limitation because low-income and middle-income countries now account for most of the global NCD burden,[6] and also have high levels of physical inactivity.[7] Furthermore, methods used in published studies varied, making it difficult to compare data across countries or to extrapolate existing estimates to other countries. Most previous studies were also subject to major methodological limitations, such as not taking into account confounding or comorbidity. Additionally, although existing studies report aggregate estimates, it is important to also consider where the economic burden falls, including on the public sector, private sector, and out-of-pocket household expenditure. This inclusion will provide additional information regarding who pays for the

University Medical Center, Amsterdam, Netherlands (Prof W van Mechelen)**; School of Public Health, Physiotherapy and Population Sciences, University College Dublin, Dublin, Ireland** (Prof W van Mechelen)**; and Hubert Department of Global Health, Rollins School of Public Health, Emory University, Atlanta, GA, USA** (Prof M Pratt MD)

Correspondence to: Dr Ding Ding, Prevention Research Collaboration, Sydney School of Public Health, (6N55) Level 6, The Charles Perkins Centre (D17), The University of Sydney, Camperdown, NSW 2006, Australia
melody.ding@sydney.edu.au

Research in context

Evidence before this study

The pandemic of physical inactivity is known to cause substantial disease burden worldwide in terms of morbidity and mortality. However, less is known about the economic burden of physical inactivity and how this burden varies across countries. We systematically searched the literature and identified a few studies that estimated the national costs of physical inactivity. Based on these estimates, physical inactivity contributed to 1–4% of total direct health-care costs. However, these studies were all conducted in high-income countries, using heterogeneous methods, and most did not estimate indirect costs. A comprehensive global estimate of the economic burden of physical inactivity is needed.

Added value of this study

To our knowledge, this study is the first ever to estimate the economic burden of physical inactivity worldwide. Using consistent methods, we estimated direct health-care costs and indirect productivity costs for 142 countries, representing 93% of the world's population. We also included a "who pays" analysis for each country to apportion the amount of health-care costs paid by the public sector, private sector or third party, and households. For the first time, our study showed that the economic burden of physical inactivity is distributed unequally across regions and disproportionately in relation to the disease burden (as measured by disability-adjusted life-years attributable to physical inactivity). Generally, poorer countries have more unmet health need, due to less developed health and economic systems. Ultimately, poor households pay the most in terms of premature morbidity and mortality, showing inequalities. Although the current economic costs are borne mainly in high-income countries, the expectation is that as low-income and middle-income countries develop economically, their economic burden due to physical inactivity will also escalate. Overall, this study helps to make the economic case for a global response to promote physical activity to tackle non-communicable diseases, and mitigate the current and future economic burden, and by so doing also reduce health inequalities.

Implications of all the available evidence

The analysis of the economic costs contributes to a more comprehensive understanding of the overall burden of the physical inactivity pandemic. This is intended to help to emphasise the need to promote physical activity, undertake economic evaluations to identify cost-effective interventions, and further encourage resource-constrained decision makers to prioritise and invest in physical activity strategies.

downstream costs of inactivity, and might help to focus prevention efforts by coordinating responses from different sectors.

Therefore, the primary aim of this study is to use a consistent method to produce country-specific estimates and an overall global estimate of the economic burden of physical inactivity by taking into account both direct costs (health-care expenditure) and indirect costs (productivity losses). The second aim is to determine where the burden of inactivity falls by investigating the distribution of costs across the public and private sectors and households. The expectation is that the economic burden will be driven by high-income countries given more developed health and economic systems. Therefore, a third aim is to estimate the lifetime disease burden attributable to physical inactivity in terms of disability-adjusted life-years (DALYs), as an initial analysis to investigate the extent to which the global distribution of economic burden is consistent with the disease burden. This is intended to show potential inequality issues if the disease burden is driven by countries that can least afford to respond to the pandemic of physical inactivity.

This paper represents the first detailed quantification of the global economic burden of physical inactivity. It provides key information to help researchers and decision makers tackle the global pandemic of physical inactivity.

See Online for appendix

Panel 1: **Nine steps to estimate global health-care costs of physical inactivity**

1. Identify major non-communicable diseases where physical inactivity is a recognised risk factor
2. For each disease, quantify the relative risk (RR) as a result of physical inactivity
3. Quantify prevalence of physical inactivity for each country
4. Calculate country-specific adjusted population attributable fractions (PAFs) to quantify the fraction of each disease (from Step 1) that is attributable to physical inactivity
5. Estimate the total number of cases for each disease in each country
6. Estimate the average annual costs per case of disease for each country
7. Calculate disease-specific and country-specific health-care costs attributable to physical inactivity based on estimates from Steps 4–6
8. For each country and globally, quantify the total health-care costs attributable to physical inactivity by summing across disease-specific estimates from Step 7, and subtracting potential double counting between diseases due to common comorbidity
9. Address the "who pays" question by estimating the health-care costs paid by the public sector, private sector or third party, and households within each country, and sum the costs for each sector across countries

Methods

General approach

We estimated direct health-care costs, productivity losses, and DALYs due to physical inactivity based on existing data and established methods. The approach for each is discussed in the subsections below and further in the appendix. Overall, all costs were estimated for the year 2013, without projecting future costs incurred by morbidity and mortality that occurred in 2013. Following standard practice, to enable comparison of the economic burden between countries, all costs were converted to international $ (INT$, and

	Direct costs		Indirect costs	Total costs (direct + indirect costs)
	Cost amount (uncertainty level)	% of total health–care costs	Cost amount (uncertainty level)	Cost amount (uncertainty level)
Africa				
Algeria	117 641 (41 629–272 639)	0·4 (0·14–0·92)	50 092 (17 556–105 764)	167 733 (59 186–378 402)
Benin	283 (92–685)	0·03 (0·01–0·08)	597 (190–1 317)	880 (282–2 001)
Botswana	4 516 (1 387–11 386)	0·24 (0·07–0·61)	3 724 (855–10 788)	8 240 (2 241–22 174)
Burkina Faso	1 865 (617–4 624)	0·1 (0·03–0·25)	2 845 (987–5 901)	4 710 (1 604–10 525)
Cameroon	7 022 (904–24 175)	0·23 (0·03–0·79)	12 911 (1 263–44 171)	19 933 (2 167–68 346)
Cape Verde	342 (103–842)	0·24 (0·07–0·59)	225 (57–615)	566 (160–1 457)
Central African Republic	24 (2–110)	0·02 (0–0·1)	298 (19–1 293)	322 (22–1 403)
Chad	1 201 (131–4 555)	0·12 (0·01–0·47)	5 078 (400–19 133)	6 279 (531–23 688)
Comoros	44 (14–113)	0·06 (0·02–0·17)	73 (21–177)	117 (35–290)
Republic of the Congo	390 (37–1 724)	0·04 (0–0·16)	3 986 (328–14 847)	4 376 (365–16 572)
Côte d'Ivoire	5 153 (511–20 123)	0·14 (0·01–0·54)	9 155 (754–34 475)	14 309 (1 265–54 598)
Democratic Republic of the Congo	536 (144–1 551)	0·03 (0·01–0·08)	8 970 (2 758–19 904)	9 505 (2 902–21 455)
Eritrea	75 (24–187)	0·04 (0·01–0·1)	484 (157–1 078)	560 (181–1 264)
Ethiopia	3 751 (348–15 941)	0·06 (0·01–0·25)	13 260 (1 039–49 966)	17 011 (1 387–65 907)
Gabon	780 (73–3 508)	0·06 (0·01–0·29)	6 148 (473–23 858)	6 927 (546–27 366)
The Gambia	192 (62–481)	0·1 (0·03–0·26)	310 (82–840)	502 (144–1 321)
Ghana	6 793 (2 317–16 509)	0·12 (0·04–0·29)	7 844 (2 603–16 594)	14 637 (4 920–33 104)
Guinea	504 (48–2 135)	0·07 (0·01–0·3)	890 (60–3 715)	1 394 (108–5 850)
Kenya	4 056 (413–16 711)	0·09 (0·01–0·38)	10 780 (821–44 746)	14 836 (1 235–61 457)
Lesotho	427 (134–976)	0·07 (0·02–0·16)	388 (132–850)	815 (265–1 826)
Liberia	1 123 (384–2 649)	0·3 (0·1–0·7)	519 (172–1 102)	1 641 (556–3 751)
Madagascar	942 (308–2 405)	0·07 (0·02–0·18)	2 715 (853–6 211)	3 658 (1 161–8 616)
Malawi	527 (186–1 310)	0·04 (0·01–0·09)	654 (228–1 380)	1 181 (414–2 690)
Mali	2 794 (303–10 250)	0·14 (0·01–0·51)	4 335 (361–16 134)	7 129 (663–26 383)
Mauritania	2 342 (382–7 075)	0·44 (0·07–1·33)	3 057 (386–9 673)	5 399 (767–16 748)
Mauritius	8 457 (996–30 363)	0·78 (0·09–2·79)	3 038 (272–10 645)	11 495 (1 268–41 009)
Mozambique	421 (129–1 084)	0·02 (0·01–0·06)	1 201 (328–2 696)	1 622 (457–3 780)
Namibia	2 914 (361–10 156)	0·17 (0·02–0·58)	4 150 (373–14 751)	7 064 (735–24 907)
Niger	1 192 (389–2 952)	0·11 (0·04–0·27)	2 593 (890–5 338)	3 786 (1 279–8 290)
Nigeria	31 616 (3 394–119 736)	0·08 (0·01–0·32)	143 714 (12 644–507 269)	175 329 (16 038–627 004)
Rwanda	1 014 (326–2 553)	0·06 (0·02–0·14)	1 236 (426–2 571)	2 250 (751–5 124)
São Tomé and Príncipe	52 (18–125)	0·14 (0·05–0·34)	37 (12–83)	89 (30–208)
Senegal	5 584 (697–19 462)	0·41 (0·05–1·42)	3 500 (297–12 707)	9 085 (994–32 169)
Seychelles	426 (154–978)	0·51 (0·18–1·16)	265 (93–523)	691 (247–1 501)
Sierra Leone	1 075 (336–2 665)	0·08 (0·02–0·19)	1 128 (369–2 475)	2 202 (704–5 140)
South Africa	408 375 (143 716–958 690)	0·69 (0·24–1·61)	226 036 (76 651–479 128)	634 410 (220 366–1 437 818)
Swaziland	2 486 (341–8 171)	0·35 (0·05–1·16)	2 564 (258–8 569)	5 050 (599–16 740)
Togo	435 (149–1 055)	0·05 (0·02–0·13)	511 (172–1 091)	946 (321–2 146)
Tanzania	891 (249–2 547)	0·01 (0–0·04)	4 534 (1 523–9 825)	5 425 (1 772–12 372)
Zambia	2 476 (257–9 882)	0·08 (0·01–0·34)	7 825 (614–30 691)	10 301 (871–40 573)
Zimbabwe*	1 075 (132–3 877)	..	4 110 (305–16 338)	5 184 (437–20 215)
Regional total	631 810 (202 193–1 596 959)	0·33 (0·11–0·84)	555 780 (127 781–1 539 228)	1 187 590 (329 974–3 136 187)
Americas†				
Latin America and Caribbean				
Argentina	328 567 (42 967–1 092 225)	0·45 (0·06–1·49)	207 047 (25 550–607 920)	535 613 (68 518–1 700 145)
The Bahamas	1 244 (336–3 461)	0·2 (0·05–0·54)	1 927 (559–4 478)	3 171 (895–7 939)
Barbados	3 155 (1 072–7 478)	1·05 (0·36–2·5)	798 (259–1 745)	3 953 (1 331–9 223)
Brazil	1 634 368 (191 754–5 866 486)	0·55 (0·06–1·98)	365 211 (34 587–1 222 533)	1 999 579 (226 341–7 089 019)

(Table 1 continues on next page)

	Direct costs		Indirect costs	Total costs (direct + indirect costs)
	Cost amount (uncertainty level)	% of total health–care costs	Cost amount (uncertainty level)	Cost amount (uncertainty level)
(Continued from previous page)				
Chile	69 226 (23 410–172 085)	0·23 (0·08–0·58)	34 078 (12 244–67 542)	103 304 (35 655–239 626)
Colombia	372 615 (127 745–881 621)	0·93 (0·32–2·21)	133 642 (45 693–283 585)	506 257 (173 438–1 165 205)
Dominica	239 (70–1 060)	0·56 (0·16–2·47)	77 (19–411)	315 (90–1 471)
Dominican Republic	41 084 (7 570–116 012)	0·63 (0·12–1·79)	18 825 (2 962–60 285)	59 909 (10 533–176 296)
Ecuador	15 839 (1 628–66 122)	0·13 (0·01–0·54)	16 204 (1 337–62 233)	32 042 (2 965–128 355)
Grenada	473 (157–1 125)	0·61 (0·2–1·46)	204 (69–423)	676 (226–1 548)
Guatemala	12 268 (1 244–51 954)	0·17 (0·02–0·71)	5 027 (402–20 718)	17 295 (1 646–72 671)
Jamaica	7 020 (821–24 853)	0·51 (0·06–1·79)	3 047 (250–11 576)	10 068 (1 071–36 429)
Mexico	699 578 (261 007–1 504 875)	0·53 (0·2–1·15)	186 036 (66 491–361 906)	885 614 (327 499–1 866 781)
Paraguay	15 333 (1 636–58 075	0·33 (0·03–1·24)	5 093 (391–19 353)	20 426 (2 027–77 427)
Saint Lucia	1 245 (424–2 983)	0·76 (0·26–1·82)	403 (129–898)	1 648 (554–3 881)
Trinidad and Tobago	23 295 (7 988–55 757)	1·04 (0·36–2·49)	10 279 (3 562–21 061)	33 574 (11 550–76 818)
Uruguay	24 131 (7 512–62 115)	0·41 (0·13–1·06)	14 277 (4 888–29 642)	38 408 (12 400–91 756)
Regional total	3 249 679 (677 343–9 968 286)	0·53 (0·11–1·63)	1 002 173 (199 393–2 776 306)	4 251 852 (876 737–12 744 592)
North America				
Canada	946 441 (98 291–3 696 008)	0·57 (0·06–2·21)	182 243 (15 390–646 082)	1 128 684 (113 681–4 342 091)
USA	24 733 376 (8 629 173–58 651 943)	0·85 (0·3–2·03)	3 059 178 (1 148 712–5 990 063)	27 792 555 (9 777 885–64 642 006)
Regional total	25 679 818 (8 727 465–62 347 951)	0·84 (0·29–2·04)	3 241 421 (1 164 102–6 636 145)	28 921 239 (9 891 567–68 984 097)
Eastern Mediterranean				
Egypt	174 849 (58 719–422 749)	0·37 (0·12–0·89)	120 451 (42 009–250 992)	295 301 (100 728–673 742)
Iran	504 393 (173 112–1 182 579)	0·46 (0·16–1·08)	104 903 (36 571–223 362)	609 296 (209 683–1 405 941)
Iraq	222 827 (76 509–503 970)	0·95 (0·33–2·15)	79 242 (24 569–181 319)	302 069 (101 078–685 289)
Jordan	24 535 (9 181–54 828)	0·5 (0·19–1·12)	2 429 (808–5 143)	26 964 (9 989–59 970)
Kuwait	126 342 (47 888–275 334)	1·48 (0·56–3·23)	17 978 (6 737–34 674)	144 320 (54 625–310 009)
Lebanon	40 589 (13 842–96 165)	0·83 (0·28–1·96)	11 047 (3 511–25 581)	51 636 (17 354–121 745)
Libya	48 552 (17 929–108 576)	1·01 (0·37–2·27)	13 337 (4 260–29 148)	61 889 (22 188–137 724)
Pakistan	92 215 (11 118–319 497)	0·4 (0·05–1·4)	106 279 (8 256–417 463)	198 494 (19 374–736 960)
Qatar	58 222 (20 388–133 036)	0·96 (0·34–2·2)	9 490 (3 169–20 388)	67 712 (23 557–153 425)
Saudi Arabia	869 019 (336 673–1 880 725)	1·71 (0·66–3·71)	169 442 (57 332–363 040)	1 038 461 (394 005–2 243 765)
Tunisia	30 811 (3 259–115 735)	0·36 (0·04–1·34)	10 161 (765–39 716)	40 972 (4 024–155 452)
United Arab Emirates	163 031 (23 159–523 622)	0·81 (0·11–2·59)	21 037 (1 859–83 048)	184 068 (25 018–606 670)
Regional total	2 355 384 (791 777–5 616 816)	0·76 (0·25–1·80)	665 796 (189 847–1 673 874)	3 021 180 (981 623–7 290 691)
Europe				
Andorra	1 369 (168–4 988)	0·54 (0·07–1·97)	553 (59–1 800)	1 922 (227–6 787)
Austria	194 326 (19 776–758 844)	0·47 (0·05–1·83)	61 229 (5 400–212 635)	255 555 (25 176–971 479)
Belgium	283 073 (35 250–971 197)	0·56 (0·07–1·92)	105 580 (10 374–340 628)	388 653 (45 625–1 311 826)
Bosnia and Herzegovina	12 899 (1 392–49 298)	0·36 (0·04–1·39)	4 162 (363–15 514)	17 061 (1 755–64 812)
Bulgaria	36 760 (3 882–146 381)	0·42 (0·04–1·66)	24 295 (2 099–86 796)	61 055 (5 981–233 177)
Croatia	26 660 (2 673–109 198)	0·41 (0·04–1·69)	11 910 (931–44 701)	38 570 (3 604–153 899)
Cyprus	15 619 (2 006–53 493)	0·62 (0·08–2·13)	4 360 (458–13 956)	19 979 (2 464–67 449)
Czech Republic	129 484 (40 694–321 634)	0·62 (0·2–1·54)	52 012 (18 062–103 295)	181 496 (58 755–424 929)
Denmark	79 694 (7 946–329 122)	0·31 (0·03–1·29)	38 411 (3 318–136 809)	118 105 (11 264–465 931)
Estonia	4 480 (461–20 054)	0·23 (0·02–1·05)	3 274 (241–12 676)	7 754 (702–32 730)
Finland	149 872 (15 172–594 883)	0·76 (0·08–3·03)	33 316 (2 724–117 174)	183 188 (17 896–712 057)
France	1 040 124 (313 158–2 607 358)	0·36 (0·11–0·91)	350 416 (127 335–689 751)	1 390 540 (440 493–3 297 109)
Georgia	14 900 (5 328–34 810)	0·48 (0·17–1·11)	5 350 (1 978–10 607)	20 250 (7 306–45 417)
Germany	2 150 731 (227 602–8 601 791)	0·55 (0·06–2·22)	565 523 (49 398–2 014 108)	2 716 254 (277 000–10 615 899)
Greece	116 452 (10 819–524 515)	0·42 (0·04–1·89)	30 531 (2 500–116 447)	146 983 (13 320–640 961)

(Table 1 continues on next page)

	Direct costs		Indirect costs	Total costs (direct + indirect costs)
	Cost amount (uncertainty level)	% of total health–care costs	Cost amount (uncertainty level)	Cost amount (uncertainty level)
(Continued from previous page)				
Hungary	67 684 (7 078–268 088)	0·37 (0·04–1·47)	35 426 (2 867–130 220)	103 110 (9 944–398 309)
Ireland	132 224 (15 966–479 653)	0·74 (0·09–2·7)	33 383 (3 471–111 764)	165 607 (19 437–591 417)
Italy	906 680 (98 788–3 464 606)	0·48 (0·05–1·84)	498 021 (49 542–1 604 263)	1 404 701 (148 330–5 068 869)
Kazakhstan	60 028 (7 000–219 610)	0·34 (0·04–1·26)	49 331 (3 996–191 222)	109 359 (10 996–410 833)
Kyrgyzstan	2 149 (767–4 963)	0·17 (0·06–0·39)	1 108 (387–2 253)	3 257 (1 154–7 216)
Latvia	10 903 (1 098–43 228)	0·41 (0·04–1·64)	8 956 (729–31 715)	19 859 (1 827–74 943)
Lithuania	21 251 (5 776–57 677)	0·46 (0·12–1·24)	12 335 (3 755–26 649)	33 586 (9 532–84 327)
Luxembourg	24 385 (2 627–90 733)	0·69 (0·07–2·56)	6 888 (605–24 241)	31 272 (3 231–114 974)
Malta	9 909 (1 323–31 880)	0·88 (0·12–2·84)	2 401 (292–7 345)	12 310 (1 616–39 225)
Netherlands	356 616 (35 755–1 481 410)	0·38 (0·04–1·57)	71 838 (5 788–281 164)	428 454 (41 543–1 762 574)
Norway	169 574 (18 280–656 606)	0·53 (0·06–2·05)	47 890 (4 338–160 267)	217 464 (22 618–816 873)
Poland	272 385 (27 692–1 124 067)	0·46 (0·05–1·91)	119 487 (10 252–440 347)	391 872 (37 944–1 564 414)
Portugal	256 331 (32 560–845 928)	0·98 (0·12–3·23)	70 327 (7 458–222 370)	326 658 (40 019–1 068 298)
Moldova	3 009 (1 000–23 538)	0·15 (0·05–1·2)	1 526 (559–11 234)	4 535 (1 558–34 772)
Romania	120 526 (13 597–446 361)	0·61 (0·07–2·26)	77 720 (7 129–266 621)	198 246 (20 726–712 982)
Russia	292 419 (83 109–745 860)	0·13 (0·04–0·33)	290 193 (96 840–603 315)	582 612 (179 949–1 349 175)
Serbia	84 169 (11 541–268 387)	1·19 (0·16–3·8)	31 032 (3 906–91 386)	115 200 (15 448–359 774)
Slovakia	46 187 (4 915–177 119)	0·4 (0·04–1·52)	17 029 (1 335–61 264)	63 216 (6 250–238 384)
Slovenia	25 365 (2 691–97 747)	0·47 (0·05–1·83)	8 644 (710–32 308)	34 009 (3 401–130 055)
Spain	2 024 831 (248 392–6 745 047)	1·53 (0·19–5·08)	286 821 (30 311–940 645)	2 311 652 (278 703–7 685 692)
Sweden	163 850 (15 887–664 072)	0·4 (0·04–1·63)	80 499 (7 360–269 538)	244 349 (23 247–933 610)
Turkey	508 709 (63 820–1 707 173)	0·64 (0·08–2·16)	169 711 (15 921–574 787)	678 420 (79 742–2 281 960)
Ukraine	54 448 (5 551–237 789)	0·17 (0·02–0·76)	47 766 (3 460–183 885)	102 214 (9 011–421 674)
UK	1 849 940 (681 317–4 103 191)	0·87 (0·32–1·93)	558 020 (212 382–1 056 970)	2 407 960 (893 699–5 160 162)
Uzbekistan	23 206 (8 139–52 339)	0·23 (0·08–0·52)	12 102 (3 855–27 108)	35 308 (11 994–79 447)
Regional total	11 743 217 (2 080 997–39 164 640)	0·55 (0·10–1·1·84)	3 829 379 (702 489–11 269 780)	15 572 597 (2 783 486–50 434 419)
Southeast Asia				
Bangladesh	43 773 (16 041–99 389)	0·29 (0·11–0·66)	51 156 (16 491–106 375)	94 929 (32 532–205 764)
Bhutan	292 (102–678)	0·14 (0·05–0·33)	199 (54–548)	490 (156–1 226)
India	495 943 (170 309–1 124 002)	0·18 (0·06–0·41)	489 405 (160 015–1 042 358)	985 348 (330 324–2 166 360)
Indonesia	243 932 (89 176–581 886)	0·33 (0·12–0·79)	249 986 (82 592–526 274)	493 918 (171 768–1 108 159)
Maldives	2 331 (285–8 053)	0·53 (0·06–1·82)	302 (27–1 076)	2 632 (312–9 129)
Myanmar	4 077 (1 403–9 891)	0·21 (0·07–0·51)	7 915 (2 033–21 862)	11 992 (3 436–31 753)
Nepal	1 249 (377–2 773)	0·03 (0·01–0·07)	976 (332–2 186)	2 225 (709–4 959)
Sri Lanka	27 946 (9 578–65 453)	0·45 (0·15–1·05)	20 343 (6 978–42 197)	48 290 (16 556–107 650)
Thailand	116 287 (41 964–279 000)	0·26 (0·09–0·63)	73 624 (23 950–156 046)	189 911 (65 914–435 045)
Regional total	935 830 (329 234–2 171 123)	0·22 (0·08–0·52)	893 906 (292 473–1 898 922)	1 829 736 (621 707–4 070 045)
Western Pacific				
Australia	441 498 (46 819–1 700 424)	0·46 (0·05–1·75)	114 113 (10 160–394 851)	555 611 (56 980–2 095 275)
Cambodia	1 907 (646–4 778)	0·06 (0·02–0·14)	2 560 (901–5 225)	4 467 (1 548–10 003)
China	3 075 139 (1 194 333–6 635 493)	0·35 (0·14–0·76)	1 783 000 (622 150–3 555 485)	4 858 139 (1 816 483–10 190 978)
Fiji	1 114 (401–2 582)	0·39 (0·14–0·89)	661 (208–1 512)	1 776 (609–4 094)
Japan	4 171 889 (542 475–14 270 968)	0·88 (0·11–3·)	1 090 581 (118 658–3 418 006)	5 262 470 (661 132–17 688 974)
Kiribati	108 (35–260)	0·53 (0·17–1·28)	46 (13–113)	153 (47–373)
Laos	909 (317–2 222)	0·15 (0·05–0·35)	1 615 (448–4 061)	2 524 (765–6 284)
Malaysia	284 269 (104 258–649 278)	1·03 (0·38–2·35)	119 313 (42 378–235 990)	403 582 (146 636–885 268)
Marshall Islands	181 (55–438)	0·49 (0·15–1·18)	59 (17–145)	241 (72–583)
Micronesia	234 (84–554)	0·5 (0·18–1·19)	60 (17–158)	294 (101–713)

(Table 1 continues on next page)

	Direct costs		Indirect costs	Total costs (direct + indirect costs)
	Cost amount (uncertainty level)	% of total health–care costs	Cost amount (uncertainty level)	Cost amount (uncertainty level)
(Continued from previous page)				
Mongolia	3 491 (1 282–7 904)	0·22 (0·08–0·49)	3 567 (1 203–7 661)	7 059 (2 486–15 565)
New Zealand	107 402 (36 691–259 763)	0·71 (0·24–1·72)	31 028 (11 690–59 995)	138 430 (48 382–319 758)
Papua New Guinea	1 894 (667–4 302)	0·23 (0·08–0·52)	1 716 (489–4 402)	3 610 (1 156–8 704)
Philippines	65 760 (6 776–261 741)	0·23 (0·02–0·93)	37 078 (2 559–162 221)	102 838 (9 334–423 962)
South Korea	831 859 (107 464–2 423 806)	0·69 (0·09–2·01)	236 263 (31 029–667 249)	1 068 122 (138 493–3 091 054)
Samoa	201 (71–464)	0·28 (0·1–0·64)	70 (23–158)	271 (95–622)
Singapore	159 627 (58 218–352 413)	0·83 (0·3–1·82)	41 459 (15 552–80 082)	201 086 (73 770–432 495)
Solomon Islands	374 (133–870)	0·63 (0·22–1·46)	205 (56–542)	579 (189–1 412)
Tonga	102 (35–237)	0·39 (0·13–0·9)	55 (17–123)	157 (52–360)
Vanuatu	28 (9–72)	0·1 (0·03–0·25)	32 (9–83)	60 (18–154)
Vietnam	67 367 (19 786–170 990)	0·24 (0·07–0·62)	45 401 (12 007–113 181)	112 769 (31 793–284 172)
Regional total	9 215 354 (2 120 555–26 749 559)	0·54 (0·13–1·58)	3 508 884 (869 586–8 711 243)	12 724 238 (2 990 141–35 460 802)
Global total	53 811 093 (14 929 564–147 615 335)	0·64 (0·18–1·75)	13 697 338 (3 545 671–34 505 499)	67 508 432 (18 475 235–182 120 834)

Uncertainty levels calculated based on analysis of extremes. *Direct health-care cost data are incomplete for Zimbabwe due to the lack of WHO health expenditure data; the current total direct costs were estimated based on type 2 diabetes only. †The Region of the Americas is further divided into Latin America and Caribbean and North America (Canada and USA only) due to different patterns of disease burden, levels of economic development, and health-care expenditure.

Table 1: **Direct, indirect, and total costs attributable to physical inactivity, by country and WHO region (in 1000 Int$, 2013)**

For **World Bank PPP conversion factors** see http://data.worldbank.org/indicator/PA.NUS.PPP

$ thereafter) using purchasing power parity (PPP) conversion factors in 2013.

Direct health-care costs

are costs attributable to physical inactivity were d using a population attributable fraction (PAF) n.[8] This approach requires nine steps (panel 1). pecific information regarding each step is presented in the appendix.

Step 1: in addition to coronary heart disease, type 2 diabetes, breast cancer, and colon cancer, which were included in the paper by Lee and colleagues,[4] we expanded this list to include stroke, based on the US Physical Activity Guidelines Advisory Committee report and available data on health-care costs.[9] Step 2: we used the adjusted relative risks (RRs) reported in Lee and colleagues[4] for coronary heart disease, type 2 diabetes, breast cancer, and colon cancer. For stroke, we derived the adjusted RR from a meta-analysis.[10] Step 3: we used the most recent country-specific prevalence estimates of physical inactivity (defined as not meeting the WHO recommendations of 150 min of moderate-to-vigorous physical activity per week[11]) for 146 countries, which are presented in this Series (overall prevalence 23·3% [range 4·1–65·0]).[12] Step 4: PAFs are calculated based on the prevalence of physical inactivity and the adjusted RR using the formula presented in the appendix (p 3). The PAFs can be interpreted as the proportion of disease or mortality that would not exist if physical inactivity (based on the WHO recommendations) was eliminated. We used Monte Carlo simulation techniques (50 000 simulations) to estimate the 95% CIs for PAFs (appendix p 11). Step 5: we extracted prevalent cases of all diseases identified in Step 1 from the 2013 Global Burden of Disease (GBD) Study,[13] which provides prevalence estimates for major diseases in 187 countries. In view that the evidence on the protective effects of physical activity only applies to type 2 diabetes and colon cancer, and that the GBD provides overall prevalence estimates for "diabetes mellitus" and "colon and rectal cancer", we applied adjustment factors derived from international literature[14,15] to extrapolate prevalence of type 2 diabetes and colon cancer from GBD estimates (appendix p 3). Step 6: we estimated country-specific average annual health-care costs per case of disease. For type 2 diabetes, this information was obtained from the International Diabetes Federation (IDF).[16,17] For coronary heart disease, stroke, breast cancer, and colon cancer, because there were no global per case cost estimates, we extracted national disease-specific health-care cost data for 27 European Union countries (EU-27).[18,19] We then calculated per case costs for EU-27 using GBD disease prevalence data and extrapolated costs to other countries using a country weighting factor (appendix p 27). The country weighting factor was based on health-care expenditure per capita and was previously used by the Economist Intelligence Unit[20] and the World Economic Forum[21] reports. It is comparable with the IDF's approach to estimate health-care expenditure for diabetes.[17] Step 7: for each disease, we calculated disease-specific total health-care costs per country by multiplying the total number of prevalent cases by the estimated average annual costs per case. Then, we applied country-specific adjusted PAFs to the total costs of each disease to generate disease-specific health-care costs attributable to physical inactivity (appendix p 31). Step 8: in view that cardiovascular disease is likely to co-occur with diabetes, we

estimated the probable double counting between diabetes and coronary heart disease or stroke based on a meta-analysis of 102 prospective studies.[22] For each country, we summed the total costs across diseases, minus the overlap due to comorbidity. Step 9: to determine who bears the health-care costs of inactivity within each country, we used the health expenditure data provided by the WHO to calculate the amount of expenditure paid by: (1) the public sector (resources channelled to health services through government budgets, parastatals, or extra-budgetary entities); (2) the private sector or third party (expenditure from pooled non-governmental resources, such as voluntary health insurance); and (3) households (out-of-pocket payments).

Indirect productivity costs

Physical inactivity related diseases indirectly cost society in many ways.[18,19] Owing to the absence of data regarding morbidity effect on absenteeism, presenteeism (compromised productivity at work due to ill health), and informal care at the global level, we restricted the analysis to the financial value of lost productivity due to premature mortality using a friction cost approach that takes into account replacement within the labour market (3-month friction period).[23]

We estimated the total costs of productivity losses from physical inactivity related deaths for each country using the formula in the appendix (p 4), based on the mortality data from the GBD, the employment rates among the population aged 15 years or older from the International Labour Organization, the 2013 GDP data from the World Bank,[24] and adjusted PAFs for physical activity and all-cause mortality (appendix p 11).

Lifetime disease burden: DALYs

We estimated lifetime disease burden using DALYs, which sum the years of life lost due to premature mortality (years of life lost [YLLs]) and to morbidity or disability, while alive (years lost due to disability [YLDs]). The GBD study estimated the DALYs lost for each disease for all 187 countries.[25] We extracted DALYs for each of the five diseases and applied the relevant PAFs described above to calculate the DALYs lost for each disease attributable to physical inactivity. We then summed these DALYs across diseases as the total DALYs lost due to physical inactivity. The GBD estimates already accounted for comorbidity, therefore, we did not further adjust for double counting due to comorbidity.[13]

Sensitivity analysis

We did an "analysis of extremes" to generate a base estimate, a lower estimate, and a higher estimate, based on mean, lower, and upper limits of all input variables. Additionally, to facilitate comparison of our estimates with previous national-level estimates,[5] all of which used unadjusted PAFs, we repeated all analyses using unadjusted PAFs.

Results

Based on the prevalence of physical inactivity presented in this Series,[12] we estimated the global median adjusted PAFs to be 4·0% for coronary heart disease, 4·5% for stroke, 4·9% for type 2 diabetes, 7·1% for breast cancer, 7·0% for colon cancer, and 6·4% for all-cause mortality. Overall, PAFs are the largest in the Eastern Mediterranean region and smallest in southeast Asia.

For **WHO health expenditure data** see http://apps.who.int/gho/data/node.main.75

Globally, summed across five major NCDs, we estimated the health-care costs of physical inactivity to be $53·8 billion in 2013 (table 1). Of this, $5·0 billion were spent on coronary heart disease, $6·0 billion on stroke, $37·6 billion on type 2 diabetes, $2·7 billion on breast cancer, and $2·5 billion on colon cancer (appendix p 31). By WHO region, physical inactivity was responsible for more than $0·6 billion of health-care costs in Africa, $3·2 billion in Latin America and the Caribbean, $25·7 billion in North America, $2·4 billion in the Eastern Mediterranean region, $11·7 billion in Europe, $0·9 billion in southeast Asia, and $9·2 billion in the Western Pacific region. In the context of national health-care expenditure, physical inactivity related direct costs represent an average of 0·33% of total health-care expenditure in Africa, 0·53% in Latin America and Caribbean, 0·84% in North America, 0·76% in the Eastern Mediterranean region, 0·55% in Europe, 0·22% in southeast Asia, 0·54% in the Western Pacific region, and 0·64% globally.

For **ILO employment rate data** see http://www.ilo.org/global/research/global-reports/global-employment-trends/2014/WCMS_234879/lang--en/index.htm

The proportion of health-care costs borne by households, public and private sectors differed remarkably by WHO region and country. Globally, in 2013 the largest proportion of economic burden of physical inactivity ($31·2 billion, 58·0%) was borne by the public sector, ranging from 40·5% in southeast Asia to 75·3% in Europe. Globally, the smallest proportion of health-care costs attributable to physical inactivity was paid by households ($9·7 billion); however, the relative burden on households was particularly high in southeast Asia, where nearly half of the health-care costs were paid out-of-pocket. $12·9 billion health-care costs were paid by private sectors, and 80·0% occurred in North America ($10·3 billion; table 2).

Physical inactivity related deaths cost $13·7 billion in productivity losses in 2013. Of those, $0·6 billion occurred in Africa, $0·7 billion in the Eastern Mediterranean region, $0·9 billion in southeast Asia, $1·0 billion in Latin America and Caribbean, $3·2 billion in North America, $3·5 billion in the Western Pacific region, and $3·8 billion in Europe.

When indirect costs were combined with direct costs, physical inactivity was responsible for a total cost of $67·5 billion worldwide.

Physical inactivity was responsible for 13·4 million DALYs worldwide (appendix p 49). In table 3, we compared the global distribution of direct costs, indirect costs, and DALYs attributable to physical inactivity. The economic burden, particularly direct health-care costs, is distributed disproportionately with population size and DALYs. For

	The public sector		The private sector/third party		Households	
	Amount	% of total direct costs	Amount	% of total direct costs	Amount	% of total direct costs
Africa						
Algeria	87290	74·2	823	0·7	29528	25·1
Benin	153	54·2	14	4·9	116	40·9
Botswana	2579	57·1	1694	37·5	244	5·4
Burkina Faso	1091	58·5	155	8·3	619	33·2
Cameroon	2437	34·7	267	3·8	4319	61·5
Cape Verde	252	73·7	11	3·2	79	23·1
Central African Republic	12	50·3	1	4·7	11	45·0
Chad	443	36·9	25	2·1	733	61·0
Comoros	14	32·7	10	22·2	20	45·1
Republic of the Congo	302	77·5	3	0·8	85	21·7
Côte d'Ivoire	1706	33·1	809	15·7	2638	51·2
Democratic Republic of the Congo	284	53·1	76	14·2	175	32·7
Eritrea	34	45·4	0	0	41	54·6
Ethiopia	2288	61·0	135	3·6	1328	35·4
Gabon	424	54·4	52	6·7	303	38·9
The Gambia	115	60·1	36	18·9	40	21·0
Ghana	4116	60·6	217	3·2	2459	36·2
Guinea	180	35·8	39	7·8	284	56·4
Kenya	1691	41·7	556	13·7	1809	44·6
Lesotho	338	79·1	28	6·5	61	14·4
Liberia	403	35·9	428	38·1	292	26·0
Madagascar	590	62·6	69	7·3	284	30·1
Malawi	263	50·0	202	38·3	62	11·7
Mali	1109	39·7	6	0·2	1679	60·1
Mauritania	1147	49·0	110	4·7	1084	46·3
Mauritius	4152	49·1	372	4·4	3932	46·5
Mozambique	195	46·4	199	47·2	27	6·4
Namibia	1760	60·4	947	32·5	207	7·1
Niger	438	36·7	122	10·2	633	53·1
Nigeria	8726	27·6	980	3·1	21910	69·3
Rwanda	596	58·8	231	22·8	187	18·4
São Tomé and Príncipe	15	28·8	6	11·3	31	59·9
Senegal	2921	52·3	603	10·8	2061	36·9
Seychelles	392	92·0	22	5·1	12	2·9
Sierra Leone	154	14·3	262	24·4	659	61·3
South Africa	197653	48·4	181727	44·5	28995	7·1
Swaziland	1857	74·7	365	14·7	263	10·6
Togo	227	52·1	32	7·4	176	40·5
Tanzania	324	36·3	272	30·5	296	33·2
Zambia	1444	58·3	344	13·9	688	27·8
Zimbabwe*	..	..	..	..	..	..
Regional total	330116	52·2	192249	30·4	108370	17·2
Americas†						
Latin America and Caribbean						
Argentina	222440	67·7	36799	11·2	69328	21·1
The Bahamas	547	44·0	321	25·8	376	30·2
Barbados	1925	61·0	224	7·1	1006	31·9
Brazil	787765	48·2	356292	21·8	490310	30·0
Chile	32813	47·4	14468	20·9	21945	31·7

(Table 2 continues on next page)

	The public sector		The private sector/third party		Households	
	Amount	% of total direct costs	Amount	% of total direct costs	Amount	% of total direct costs
(Continued from previous page)						
Colombia	283188	76·0	37634	10·1	51794	13·9
Dominica	168	70·6	6	2·5	64	26·9
Dominican Republic	21446	52·2	3615	8·8	16023	39·0
Ecuador	8442	53·3	428	2·7	6969	44·0
Grenada	224	47·3	10	2·2	239	50·5
Guatemala	4588	37·4	1448	11·8	6232	50·8
Jamaica	4079	58·1	1158	16·5	1783	25·4
Mexico	361682	51·7	29382	4·2	308514	44·1
Paraguay	5903	38·5	751	4·9	8678	56·6
SaintLucia	688	55·3	29	2·3	528	42·4
Trinidad and Tobago	11554	49·6	1537	6·6	10203	43·8
Uruguay	16940	70·2	3089	12·8	4102	17
Regional total	1764392	54·3	487193	15·0	998094	30·7
North America						
Canada	660616	69·8	142913	15·1	142913	15·1
USA	11649420	47·1	10165418	41·1	2918538	11·8
Regional total	12310036	47·9	10308330	40·1	3061451	11·9
Eastern Mediterranean						
Egypt	71164	40·7	2273	1·3	101412	58·0
Iran	205792	40·8	35812	7·1	262789	52·1
Iraq	141495	63·5	0	0	81332	36·5
Jordan	16193	66·0	2576	10·5	5766	23·5
Kuwait	104358	82·6	2148	1·7	19836	15·7
Lebanon	20579	50·7	6088	15·0	13922	34·3
Libya	34132	70·3	0	0	14420	29·7
Pakistan	33935	36·8	7654	8·3	50626	54·9
Qatar	48790	83·8	4541	7·8	4891	8·4
Saudi Arabia	557910	64·2	139043	16·0	172066	19·8
Tunisia	18271	59·3	1664	5·4	10876	35·3
United Arab Emirates	114611	70·3	17770	10·9	30650	18·8
Regional total	1367230	58·0	219570	9·3	768585	32·6
Europe						
Andorra	1031	75·3	86	6·3	252	18·4
Austria	147105	75·7	16518	8·5	30703	15·8
Belgium	214569	75·8	12172	4·3	56332	19·9
Bosnia and Herzegovina	9029	70·0	129	1·0	3741	29·0
Bulgaria	21799	59·3	404	1·1	14557	39·6
Croatia	21328	80·0	2000	7·5	3333	12·5
Cyprus	7310	46·8	984	6·3	7325	46·9
Czech Republic	107860	83·3	1295	1·0	20329	15·7
Denmark	68059	85·4	1434	1·8	10201	12·8
Estonia	3490	77·9	143	3·2	847	18·9
Finland	112854	75·3	9292	6·2	27726	18·5
France	806096	77·5	157059	15·1	76969	7·4
Georgia	3204	21·5	2473	16·6	9223	61·9
Germany	1651761	76·8	221525	10·3	277444	12·9
Greece	80934	69·5	4775	4·1	30743	26·4
Hungary	43047	63·6	6024	8·9	18613	27·5
Ireland	89516	67·7	20495	15·5	22214	16·8

(Table 2 continues on next page)

	The public sector		The private sector/third party		Households	
	Amount	% of total direct costs	Amount	% of total direct costs	Amount	% of total direct costs
(Continued from previous page)						
Italy	707 210	78·0	36 267	4·0	163 202	18·0
Kazakhstan	31 875	53·1	360	0·6	27 793	46·3
Kyrgyzstan	1268	59·0	99	4·6	782	36·4
Latvia	6760	62·0	164	1·5	3980	36·5
Lithuania	14 153	66·6	170	0·8	6928	32·6
Luxembourg	20 410	83·7	1341	5·5	2634	10·8
Malta	6570	66·3	208	2·1	3131	31·6
Netherlands	284 580	79·8	52 779	14·8	19 257	5·4
Norway	144 986	85·5	1017	0·6	23 571	13·9
Poland	189 580	69·6	20 701	7·6	62 104	22·8
Portugal	165 846	64·7	22 301	8·7	68 184	26·6
Moldova	1384	46·0	283	9·4	1342	44·6
Romania	96 059	79·7	723	0·6	23 744	19·7
Russian	140 654	48·1	11 404	3·9	140 361	48·0
Serbia	50 922	60·5	1347	1·6	31 900	37·9
Slovakia	32 331	70·0	3649	7·9	10 207	22·1
Slovenia	18 162	71·6	4135	16·3	3069	12·1
Spain	1 425 481	70·4	137 689	6·8	461 661	22·8
Sweden	133 538	81·5	3605	2·2	26 708	16·3
Turkey	393 741	77·4	38 662	7·6	76 306	15·0
Ukraine	29 674	54·5	1470	2·7	23 304	42·8
UK	1 544 700	83·5	133 196	7·2	172 044	9·3
Uzbekistan	11 835	51·0	673	2·9	10 698	46·1
Regional total	8 840 706	75·3	929 050	7·9	1 973 461	16·8
Southeast Asia						
Bangladesh	15 452	35·3	1970	4·5	26 352	60·2
Bhutan	215	73·8	2	0·8	74	25·4
India	159 694	32·2	47 611	9·6	288 639	58·2
Indonesia	95 133	39·0	37 078	15·2	111 721	45·8
Maldives	1342	57·6	114	4·9	874	37·5
Myanmar	1109	27·2	188	4·6	2781	68·2
Nepal	541	43·3	131	10·5	577	46·2
Sri Lanka	12 268	43·9	2683	9·6	12 995	46·5
Thailand	93 146	80·1	10 001	8·6	13 140	11·3
Regional total	378 901	40·5	99 777	10·7	457 152	48·8
Western Pacific						
Australia	293 155	66·4	62 693	14·2	85 651	19·4
Cambodia	391	20·5	378	19·8	1139	59·7
China	1 715 927	55·8	316 739	10·3	1 042 472	33·9
Fiji	751	67·4	130	11·7	233	20·9
Japan	3 425 121	82·1	146 016	3·5	600 752	14·4
Kiribati	89	82·5	19	17·4	0	0·1
Laos	448	49·3	97	10·7	364	40·0
Malaysia	155 779	54·8	25 868	9·1	102 621	36·1
Marshall Islands	152	83·6	7	4·0	22	12·4
Micronesia	211	90·3	0	0·2	22	9·5
Mongolia	2102	60·2	98	2·8	1292	37·0
New Zealand	89 144	83·0	6766	6·3	11 492	10·7

(Table 2 continues on next page)

	The public sector		The private sector/third party		Households	
	Amount	% of total direct costs	Amount	% of total direct costs	Amount	% of total direct costs
(Continued from previous page)						
Papua New Guinea	1523	80·4	163	8·6	208	11·0
Philippines	20780	31·6	7694	11·7	37286	56·7
South Korea	444213	53·4	83186	10·0	304460	36·6
Samoa	180	89·5	8	3·9	13	6·6
Singapore	63532	39·8	5427	3·4	90668	56·8
Solomon Islands	352	94·0	10	2·6	13	3·4
Tonga	83	81·8	6	5·8	13	12·4
Vanuatu	25	87·3	2	5·5	2	7·2
Vietnam	28227	41·9	5861	8·7	33279	49·4
Regional total	6242183	67·7	661168	7·2	2312003	25·1
Global total	31233565	..	12897338	..	9679116	..

Percentages of health-care costs paid by the public, households, and private sector are from WHO. *Direct health-care cost data are incomplete for Zimbabwe due to the lack of WHO health expenditure data; the current total direct cost was estimated based on type 2 diabetes only. †The Region of the Americas is further divided into Latin America and Caribbean and North America (Canada and USA only) due to different patterns of disease burden, levels of economic development, and health-care expenditure.

Table 2: **Direct health-care costs attributable to physical inactivity paid by the public sector, private sector, and households, by country and WHO region (in 1000 Int$, 2013)**

	Population (1 000 000, global %)	Direct costs (INT$1 00 000, global %)	Per capita direct costs (INT$)	Indirect costs (INT$1 000 000, global %)	Per capita indirect costs (INT$)	DALYs (1000, global %)	DALYs per 1000 persons
By WHO region*							
Africa	853 (12·8%)	632 (1·2%)	0·7	556 (4·1%)	0·7	859 (6·4%)	1·0
Latin America and the Caribbean	492 (7·4%)	3250 (6·0%)	6·6	1002 (7·3%)	2·0	1157 (8·6%)	2·4
North America	352 (5·3%)	25 680 (47·7%)	73·0	3241 (23·7%)	9·2	1080 (8·0%)	3·1
Eastern Mediterranean	453 (6·8%)	2355 (4·4%)	5·2	666 (4·9%)	1·5	1174 (8·7%)	2·6
Europe	848 (12·7%)	11743 (21·8%)	13·9	3829 (28·0%)	4·5	2270 (16·9%)	2·7
Southeast Asia	1858 (27·8%)	936 (1·7%)	0·5	894 (6·5%)	0·5	2699 (20·1%)	1·5
Western Pacific	1819 (27·3%)	9215 (17·1%)	5·1	3509 (25·6%)	1·9	4202 (31·3%)	2·3
By World Bank country income group							
High	1248 (18·7%)	43 484 (80·8%)	34·8	8404 (61·4%)	6·7	3362 (25·0%)	2·6
Upper-middle	2281 (34·1%)	8886 (16·5%)	3·9	3814 (27·8%)	1·7	5581 (41·5%)	2·4
Lower-middle	2422 (36·3%)	1366 (2·5%)	0·6	1350 (9·9%)	0·6	3723 (27·7%)	1·5
Low	723 (10·8%)	75 (0·1%)	0·2	130 (0·9%)	0·2	775 (5·8%)	1·1
Global	6674 (100%)	53 811 (100%)	8·1	13 697 (100%)	2·1	13 441 (100%)	2·0

*The Region of the Americas is further divided into Latin America and Caribbean and North America (Canada and USA only) due to different patterns of disease burden, levels of economic development, and health-care expenditure.

Table 3: **Comparison of mean direct and indirect costs of physical inactivity and lifetime disease burden (measured by disability-adjusted life-years, DALYs) by country income group (2013)**

example, southeast Asia accounts for 20·1% of the DALYs, but only 1·7% of direct costs, while North America accounts for only 8·0% of the DALYs, but nearly half of the direct costs. Noticeably, despite the relatively low economic burden of physical inactivity in middle-income and low-income countries (19% of global direct costs), the disease burden, as measured by DALYs is large (75% of global DALYs; table 3).

After taking into account the upper and lower limits of input variables, we estimated that in 2013 physical inactivity accounted for $14·9–147·6 billion of health-care costs, $3·5–34·5 billion of productivity losses, and 6·4–20·3 million DALYs worldwide (appendix pp 36–44, 49–52).

We re-ran the analysis using unadjusted PAFs, similar to previous studies, and found that the total health-care costs attributable to physical inactivity would be estimated as $123·9 billion ($40·9–291·2), the indirect costs of productivity losses would be

Panel 2: **Strengths and limitations**

Strengths

- Using standard methods and the best global data available, including data from the Global Burden of Disease study, the International Diabetes Federation, the WHO, the World Bank, and the International Labour Organization.
- Applying adjusted population attributable fractions (PAFs) that take into account confounding factors, which are associated with both physical inactivity and health-care costs.
- Accounting for comorbidity, which addresses one of the key limitations identified in previous studies.
- Estimating indirect costs of productivity losses in addition to direct health-care costs.
- Transparent communication; we have provided a full appendix in addition to the methods and results, to present details of the methods and step-by-step intermediate results. This allows for easy replication of our analysis and is a key improvement compared with previous estimates.
- Thorough sensitivity analysis to account for uncertainty, including parameter uncertainty (eg, using the confidence intervals in the adjusted PAFs) and also method or structural uncertainty (eg, applying unadjusted versus adjusted PAFs).
- Through a simple "who pays" analysis, we estimated how the economic burden is apportioned between different sectors.
- Quantifying the lifetime health burden and comparing this with the economic burden to show inequalities at the global level.

Limitations

- Estimates are based on five major non-communicable diseases out of the 22 diseases and conditions documented to be associated with physical inactivity based on moderate to strong evidence. Other outcomes, such as hypertension, metabolic syndrome, and falls,[9] were not considered. This approach underestimates direct health-care costs and disability-adjusted life-years (DALYs) by an unknown amount.
- The PAFs used in this study are based on the counterfactual of the entire population meeting the minimal level of the WHO physical activity recommendations (150 min of moderate-to-vigorous physical activity per week), which does not consider risk reduction from activity levels below the 150 min threshold or further risk reduction beyond this threshold. This could either underestimate or overestimate direct and indirect costs.
- The adjusted relative risks used in the calculation of PAFs are not based on a standard measure or definition of physical inactivity and are not consistently identical to the WHO recommendations. This could lead to either underestimated or overestimated direct and indirect costs.
- Physical activity prevalence was estimated based on self-report only, which considerably underestimated the prevalence of physical inactivity[26] and consequently the economic costs and DALYs.
- Indirect costs only include productivity losses due to premature mortality. Other indirect costs, such as productivity losses due to disability, absenteeism, presenteeism (compromised productivity at work due to ill health), informal care, and other non-medical costs, were not estimated. We did not have sufficient data to extrapolate the EU-27 estimates for these costs to all other countries. Studies in Europe showed that the total indirect costs of cardiovascular disease and cancers could be 2–3 times higher than mortality costs alone,[18,19] which means that the total indirect cost of physical inactivity, if relevant data were available, could be estimated as INT$27–41 billion.
- The data sources used for indirect cost analysis did not take into account the informal economy (and home production), which is often not fully accounted for in country-level national accounts regarding GDP and employment. This could result in underestimated indirect costs.
- Employment data from the International Labour Organization did not provide confidence intervals to allow additional sensitivity analysis.
- The who pays analysis could not be extended to productivity losses to estimate the specific share of GDP lost to the public sector (eg, tax revenue), private sector (eg, profits), and households (eg, net wages), due to a lack of consistent country-level data regarding such proportions.
- An analysis of extremes sensitivity analysis does not inform the likelihood of extreme scenarios. Monte Carlo simulation would be preferable, but there was an absence of information concerning probability distributions of key input variables. Assumptions would have been arbitrary and the resulting confidence intervals might convey a misleading impression. The analysis of extremes approach provided more transparency regarding our limitations, is in common with similar studies, and is consistent with the underlying cost-of-illness studies upon which the global estimates are made.

$21·3 billion ($6·1–47·6), and the DALYs 26·2 million (16·7–32·5).

Overall, the total economic burden of physical inactivity in 2013 was estimated to range from $67·5 billion (18·5–182·1) in a conservative analysis to $145·2 billion (47·0–338·8) in a less conservative analysis.

Discussion

This study provides the first global estimate for the economic burden of physical inactivity. Based on data from 142 countries, representing 93·2% of the world's population, we conservatively estimated that in 2013 the effect of physical inactivity on five major NCDs and all-cause mortality cost the world economy more than

$67·5 billion through health-care expenditure and productivity losses. This is equivalent to the total GDP of Costa Rica (ranked around 80th out of all 193 countries with data) in the same year. The lifetime disease burden associated with physical inactivity for the same five NCDs amounts to 13·4 million DALYs worldwide. Further, sensitivity analysis using less conservative assumptions led to much higher estimates of the economic burden and DALYs lost. Despite imperfect data, this estimate is a key step towards a more comprehensive understanding of the true burden of the pandemic of physical inactivity, and provides useful information for policy making, funding allocation, and benchmarking in global NCD prevention.

The economic burden of physical inactivity is distributed unequally across regions, and disproportionately in relation to the disease burden. This is likely to be driven by differential levels of economic development, and consequentially health-care expenditure. Further, when taking into account the "who pays" analysis, individuals and households from some regions might financially suffer even more, due to the high proportion of out-of-pocket health-care expenditure, such as southeast Asia and Latin America and Caribbean. Generally, the poorer the country, the more the unmet health need, and so it is individuals and households who ultimately pay in the form of premature morbidity and mortality.

In the context of overall health-care expenditure, our estimated direct costs of physical inactivity represent 0·64% of global health expenditure in 2013. Our estimates are lower than most previous national estimates due to several reasons. First, we used PAFs based on maximally adjusted RRs, which is conservative. Applying unadjusted PAFs would double the current estimates (appendix pp 36-48), resulting in estimates that are more comparable with previous national estimates from a few high-income countries.[5] Second, in our estimates, we accounted for comorbidity by subtracting double counting between diabetes and coronary heart disease or stroke, which is a key limitation identified by previous studies. Third, we applied a friction approach for productivity losses, which is conservative and assumes complete replacement within the labour market in 90 days. Fourth, this study relied on estimates of physical inactivity[12] based on the current recommendations,[11] which resulted in lower prevalence estimates of inactivity compared with previous work,[7] which used the older recommendations. Fifth, we estimated the economic burden for 2013 only. Extending the timeframe would involve making increasingly arbitrary assumptions of key input variables, such as PAFs, unit costs, employment rates, and an appropriate discount rate, especially if future generations were to be included in modelling. Additionally, our study had several methodological limitations, such as focusing on the five major NCDs only and using self-reported physical activity prevalence, which have also contributed to our conservative estimates (panel 2).

Future estimates of the economic burden of physical inactivity will benefit from the inclusion of more diseases and adverse events known to be caused by physical inactivity, including emerging areas such as mental health and cognitive function. Improvements and geographical expansion of ongoing physical activity surveillance and disease-specific health expenditure will also help. In 2011, WHO developed a System of Health Accounts to assist countries in reporting expenditure by disease, using a consistent method. As of May 2015, 27 countries had produced preliminary health accounts that are currently being verified by WHO (personal communication, Brindley C, WHO).

Over time, we hope to repeat our economic burden analysis using country-specific estimates of disease-specific health-care costs and a more complete assessment of indirect costs. Finally, there might be a need for future research to more comprehensively investigate the potential inequality between economic effects and health burden. We show that although inactivity is more prevalent in high-income countries, most of the health burden is in low-to-middle-income countries. As such countries develop economically, so will the consequent economic burden, if the pandemic of physical inactivity spreads as expected. It might be important to investigate this further, and especially to consider potential policy responses, such as generating an economic case to invest in a global response to promote physical activity, and perhaps to assist low-income and middle-income countries to promote physical activity to mitigate against future scenarios where the economic burden escalates. Overall, our analysis is a first step in understanding the global economic burden of physical inactivity.

Physical inactivity is a global pandemic that causes not only morbidity and mortality, but also a major economic burden worldwide. Low-income and middle-income countries share the largest disease burden from physical inactivity, but a much smaller proportion of the economic burden. Results from this study could be used to inform global policy and practice in physical activity related areas. It is important to continue to improve the estimates through establishing more robust and consistent methodologies and better epidemiological and economic data, particularly in low-income and middle-income countries. A global pandemic requires global collaboration to fully understand its effect, develop solutions, and mobilise change.

Contributors

DD and TLK-A conducted the literature search. KDL and DD designed the study and other authors provided critical input. DD and TLK-A extracted and managed the data. DD conducted the data analysis. DD and KDL interpreted the data. DD drafted the report. All authors critically reviewed the report.

***Lancet* Physical Activity Series 2 Executive Committee**
Adrian E Bauman (Sydney School of Public Health, Sydney University, Sydney, NSW, Australia), Ding Ding (Sydney School of Public Health, University of Sydney, Sydney, NSW, Australia), Ulf Ekelund (Norwegian School of Sports Sciences, Oslo, Norway, and Medical Research Council Epidemiology Unit, University of Cambridge, Cambridge, UK), Gregory Heath (Department of Health & Human Performance, University of Tennessee, Chattanooga, TN, USA), Pedro C Hallal (Postgraduate Programme in Epidemiology, Federal University of Pelotas, Pelotas, Brazil), Harold W Kohl III (University of Texas School of Public Health, Austin, TX, USA), I-Min Lee (Division of Preventive Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA, and Department of Epidemiology, Harvard T H Chan School of Public Health, Boston, MA, USA), Kenneth E Powell (Atlanta, GA, USA), Michael Pratt (National Center for Chronic Disease Prevention and Health Promotion, Emory University, Atlanta, GA, USA), Rodrigo Reis (Prevention Research Center in St Louis, Brown School, Washington University in St Louis, St Louis, MO, USA, and Urban Management Graduate Program, Pontifical Catholic University of Parana, Curitiba, Brazil), and Jim Sallis (Division of Behavioural Medicine, University of California, San Diego, CA, USA).

Declaration of interests
We declare no competing interests.

Acknowledgments
We thank Jose Leal, Osman Ismail, Nico Pronk, I-Min Lee, Kenneth E Powel, and Shifalika Goenka for contributing to the conceptualisation of the methods. We further thank Joanne Gale for statistical support and Binh Nguyen for research assistance support. In addition, we would like to thank a few people for providing key statistics for calculating the adjustment factor for stroke, including Charles Matthews, Emmanuel Stamatakis, Katrien Wijndaele, Toby Pavey, Xuemei Sui, and I-Min Lee. Further, we would like to thank Klaus Gebel, Justin Richards, Adrian E Bauman, and Dafna Merom, for reviewing previous drafts of the paper and providing critical input. We would like to thank Peter Scarborough and Jorge Mota for formally reviewing the paper prior to the external peer review. Finally, we would like to thank the Institute for Health Metrics and Evaluation and the International Diabetes Federation for data that are fundamental to our analysis.

References
1 Merkur S, Sassi F, McDaid D. Promoting health, preventing disease: is there an economic case? Copenhagen: World Health Organization Regional Office for Europe; 2013 http://www.euro.who.int/__data/assets/pdf_file/0004/235966/e96956.pdf?ua=1 (accessed Nov 6, 2015).
2 Davis JC, Verhagen E, Bryan S, et al. 2014 consensus statement from the first Economics of Physical Inactivity Consensus (EPIC) conference (Vancouver). *Br J Sports Med* 2014; **48:** 947–51.
3 Kohl HW 3rd, Craig CL, Lambert EV, et al. The pandemic of physical inactivity: global action for public health. *Lancet* 2012; **380:** 294–305.
4 Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet* 2012; **380:** 219–29.
5 Pratt M, Norris J, Lobelo F, Roux L, Wang G. The cost of physical inactivity: moving into the 21st century. *Br J Sports Med* 2014; **48:** 171–73.
6 Abegunde DO, Mathers CD, Adam T, Ortegon M, Strong K. The burden and costs of chronic diseases in low-income and middle-income countries. *Lancet* 2007; **370:** 1929–38.
7 Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* 2012; **380:** 247–57.
8 Scarborough P, Bhatnagar P, Wickramasinghe KK, Allender S, Foster C, Rayner M. The economic burden of ill health due to diet, physical inactivity, smoking, alcohol and obesity in the UK: an update to 2006–07 NHS costs. *J Public Health* 2011; **33:** 527–35.
9 Physical Activity Guidelines Advisory Committee. Physical Activity Guidelines Advisory Committee report, 2008. Washington, DC: US Department of Health and Human Services, 2008.
10 Wendel-Vos GC, Schuit AJ, Feskens EJ, et al. Physical activity and stroke. A meta-analysis of observational data. *Int J Epidemiol* 2004; **33:** 787–98.
11 WHO. Global recommendations on physical activity for health. Geneva: World Health Organization, 2010.
12 Sallis JF, Bull F, Guthold R, et al, for the Lancet Physical Activity Series 2 Working Group. Progress in physical activity over the Olympic quadrennium. *Lancet* 2016; published online July 27. http://dx.doi.org/10.1016/S0140-6736(16)30581-5.
13 Global Burden of Disease Study Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2015; **386:** 743–800.
14 Allemani C, Weir HK, Carreira H, et al. Global surveillance of cancer survival 1995-2009: analysis of individual data for 25 676 887 patients from 279 population-based registries in 67 countries (CONCORD-2). *Lancet* 2015; **385:** 977–1010.
15 Daneman D. Type 1 diabetes. *Lancet* 2006; **367:** 847–58.
16 International Diabetes Federation. IDF Diabetes Atlas, 6th edn. Brussels: International Diabetes Federation, 2013.
17 Zhang P, Zhang X, Brown J, et al. Global healthcare expenditure on diabetes for 2010 and 2030. *Diabetes Res Clin Pract* 2010; **87:** 293–301.
18 Luengo-Fernandez R, Leal J, Gray A, Sullivan R. Economic burden of cancer across the European Union: a population-based cost analysis. *Lancet Oncol* 2013; **14:** 1165–74.
19 Leal J, Luengo-Fernandez R, Gray A. Economic Costs. In: Nichols M, Townsend N, Scarborough P, et al. European Cardiovascular Disease Statistics 2012. European Heart Network, Brussels, European Society of Cardiology, Sophia Antipolis.
20 Economist Intelligence Unit. Breakaway: the global burden of cancer–challenges and opportunities, 2009. http://graphics.eiu.com/upload/eb/EIU_LIVESTRONG_Global_Cancer_Burden.pdf (accessed Sept 30, 2015).
21 Bloom DE, Cafiero ET, Jané-Llopis E, et al. The global economic burden of noncommunicable diseases. Geneva: World Economic Forum, 2011.
22 Sarwar N, Gao P, Seshasai SR, et al. Diabetes mellitus, fasting blood glucose concentration, and risk of vascular disease: a collaborative meta-analysis of 102 prospective studies. *Lancet* 2010; **375:** 2215–22.
23 Koopmanschap MA, Rutten FF, van Ineveld BM, van Roijen L. The friction cost method for measuring indirect costs of disease. *J Health Econ* 1995; **14:** 171–89.
24 The World Bank. GDP per capita, PPP (current international $), 2015. http://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD (accessed Sept 30, 2015).
25 Murray CJ, Barber RM, Foreman KJ, et al. Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries, 1990–2013: quantifying the epidemiological transition. *Lancet* 2015; **386:** 2145–91.
26 Craig CL, Marshall AL, Sjöström M, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003; **35:** 1381–95.