All-Cause Mortality Attributable to Sitting Time

Analysis of 54 Countries Worldwide

Leandro Fórnias Machado de Rezende, MSc,[1] Thiago Hérick de Sá, MSc,[2]
Grégore Iven Mielke, MSc,[3] Juliana Yukari Kodaira Viscondi, MSc,[1,4] Juan Pablo Rey-López, PhD,[5]
Leandro Martin Totaro Garcia, MSc[2]

Introduction: Recent studies have shown that sitting time is associated with increased risk of all-cause mortality, independent of moderate to vigorous physical activity. Less is known about the population-attributable fraction for all-cause mortality associated with sitting time, and the gains in life expectancy related to the elimination of this risk factor.

Methods: In November 2015, data were gathered from one published meta-analysis, 54 adult surveys on sitting time distribution (from 2002 to 2011), in conjunction with national statistics on population size, life table, and overall deaths. Population-attributable fraction for all-cause mortality associated with sitting time >3 hours/day was estimated for each country, WHO regions, and worldwide. Gains in life expectancy related to the elimination of sitting time >3 hours/day was estimated using life table analysis.

Results: Sitting time was responsible for 3.8% of all-cause mortality (about 433,000 deaths/year) among those 54 countries. All-cause mortality due to sitting time was higher in the countries from the Western Pacific region, followed by European, Eastern Mediterranean, American, and Southeast Asian countries. Eliminating sitting time would increase life expectancy by 0.20 years in those countries.

Conclusions: Assuming that the effect of sitting time on all-cause mortality risk is independent of physical activity, reducing sitting time plays an important role in active lifestyle promotion, which is an important aspect of premature mortality prevention worldwide.
(Am J Prev Med 2016;▮(▮):▮▮▮–▮▮▮) © 2016 American Journal of Preventive Medicine

Introduction

Physical inactivity is associated with major noncommunicable diseases and all-cause mortality.[1,2] It is estimated that 31% of the global population does not meet current physical activity recommendations.[3] The burden of disease attributable to inactivity was recently estimated to be responsible for 6%–9% of the total deaths worldwide.[2,4] However, the traditional approach for defining physical inactivity is limited because the physiologic benefits of lower-intensity physical activity are overlooked.

In the last decade, some researchers have argued that excessive sitting time (regardless of meeting the recommended moderate to vigorous physical activity guidelines) may be harmful for health.[5–8] Rather than solely focusing on activities of at least moderate intensity, there is emerging evidence that replacing sitting time with standing or light physical activity may also provide substantial public health benefits.[9] Another theoretic advantage is that promoting light physical activity may maximize the likelihood of people increasing their volume of physical activity along the continuum to a higher physical activity level.[10]

Recently, the risks associated with excessive sitting time have been quantified. A meta-analysis of observational studies in adults concluded that for each 1-hour

From the [1]Department of Preventive Medicine, University of Sao Paulo School of Medicine, São Paulo, Brazil; [2]Department of Nutrition, University of Sao Paulo School of Public Health, São Paulo, Brazil; [3]Federal University of Pelotas, Postgraduate Program in Epidemiology, Pelotas, Brazil; [4]Medical Investigation Laboratories (LIM38), Clinics Hospital of Faculty of Medicine, University of São Paulo, São Paulo, Brazil; and [5]Faculty of Health Sciences, University of San Jorge, Zaragoza, Spain

Address correspondence to: Leandro Fórnias Machado de Rezende, MSc, University of Sao Paulo School of Medicine, Department of Preventive Medicine, Sao Paulo, SP, Brazil, Avenida Doutor Arnaldo, 455, Sao Paulo, SP, Brazil 01246-903. E-mail: lerezende@usp.br.
0749-3797/$36.00
http://dx.doi.org/10.1016/j.amepre.2016.01.022

increment in sitting time (>7 hours/day) all-cause mortality risk increased by 5%, even after adjusting for moderate to vigorous physical activity.[11] Furthermore, the population-attributable fraction (PAF) for all-cause mortality due to sitting time in that study was 6%. It is worth noting that this PAF estimation was only based on four high-income countries (Australia, the U.S., Norway, and Japan). Given the differences in sitting time among countries, especially by income level, and its consequences in PAF estimates, more studies are needed to understand the impact of sitting time on all-cause mortality worldwide. Therefore, the objective of this study was to estimate the PAF for all-cause mortality associated with sitting time based on different counterfactual scenarios and the gains in life expectancy related to the elimination of sitting time among 54 countries worldwide.

Methods

The PAF was estimated using the prevalence of sitting time in population-based studies and the relative risk (RR) of all-cause mortality from a meta-analysis through the following equation:

$$PAF = \sum_{i=1}^{2} \frac{P_i(RR_i - 1)}{(RR_i)},$$

where i is the analyzed exposure (i=1 refers to exposure to >3–7 hours/day of sitting, and i=2 refers to exposure to >7 hours/day of sitting); P_i is the prevalence of exposure among individuals who died; and RR_i is the relative risk for all-cause mortality adjusted for confounding variables. This equation has been recommended in situations where confounding exists and adjusted RRs must be used.[12]

Hazard ratios (HRs) were obtained from a recently published meta-analysis.[11] The authors found a nonlinear relationship between sitting time and all-cause mortality: The HRs were 1.02 and 1.05 for every 1-hour increment in sitting time within the intervals of >3–7 hours/day and >7 hours/day, respectively. There was no association between sitting time and all-cause mortality among individuals sitting 0–3 hours/day.

To ensure a conservative PAF estimation, the lowest HR within each stratum was used. In other words, HR=1.02 (related to 4 hours/day) for the stratum >3–7 hours/day and HR=1.13 for >7 hours/day (related to 8 hours/day) were applied. The HRs were adjusted for several covariates, including moderate to vigorous physical activity (the complete list of covariates is described in Appendix Table 1, available online).

Country-level sitting time data were obtained through Eurobarometer,[13] WHO STEPwise approach to Surveillance (STEPS),[14] and the International Prevalence Study.[15] For countries selected from Eurobarometer, data were extracted directly from Bennie et al.[13] Each of the 94 country reports on the STEPS website were read and, when information was not available, the researcher responsible for the survey on that country (or region) was contacted. From the International Prevalence Study, the researchers responsible for the settings were contacted to obtain additional data that were not available in the Eurobarometer and STEPS. Additionally, in October 2015, PubMed, ScienceDirect, and LILACS were searched to detect additional country-level sitting time data (search strategy available in Appendix Table 2 and Appendix Figure 1, available online). Finally, the Sedentary Behaviour Research Network members were contacted to request further published and unpublished references. When countries had overlapping data, the most recent survey was included. In total, information from 54 countries was obtained.

For each country, data on sample size, sitting time mean, and CIs were extracted. Habitual daily sitting time was collected through one self-reported question, using mainly the International Physical Activity Questionnaire and Global Physical Activity Questionnaire. Further details about methodologic issues for each country are described in Appendix Table 3 (available online).

The prevalence of sitting for >3–7 hours/day and >7 hours/day was calculated based on the area under the curve assuming a gamma distribution of population sitting time (using sitting time mean and SD) (Appendix Table 4, available online). Gamma distribution is a continuous probability distribution with two parameters: $\alpha > 0$ and $\beta > 0$, where $\alpha = (\mu/\sigma)^2$ and $\beta = (\sigma^2/\mu)$.[16] These equations are derived from the gamma distribution mean (μ) and SD (σ=square root of sample size X [upper CI – lower CI] / [2 X 1.96]). This assumption was based on previous publications that showed a gamma distribution for sitting time.[17,18]

The cut offs of >3–7 hours/day and >7 hours/day were based on the RR estimates from the meta-analysis of Chau and colleagues.[11] Sensitivity analysis was performed comparing PAF estimation assuming normal distribution (μ and σ) of population sitting time to gamma distribution (Appendix Table 6, available online).

Finally, the PAF equation requires the prevalence of sitting time among cases. Therefore, for each prevalence, an adjustment factor (weighted average case: source prevalence ratio) of 1.11 for >3–7 hours/day and 1.44 for >7 hours/day was applied.[19]

Counterfactual Scenarios

Sitting time PAF was calculated assuming different counterfactual scenarios:

1. theoretical minimum risk: this scenario consists of eliminating the risk factor. For this purpose, the proportion of deaths that would be avoided if the whole population spent <4 hours/day sitting was estimated.
2. plausible minimum risk: plausible scenarios for public health purposes, in which population mean sitting time was reduced in absolute (0.5, 1, and 2 hours/day) and relative terms (10%, 25%, and 50%).

Calculation of Population-Attributable Fraction and Gains in Life Expectancy

The PAFs for all-cause mortality and gains in life expectancy attributed to sitting time for all countries were calculated. Potential gains in life expectancy were calculated using the life tables available from WHO, which provide age-specific death rates worldwide in 2012.[20] Years gained were estimated by reducing the PAF for all-cause mortality at 40–79 years of age. The difference between life expectancies represents the years that would be gained by reducing the risk factors in the population.[21]

Monte Carlo simulation (10,000 simulations) was performed to estimate the 95% CIs for PAF and years gained in life expectancy, assuming gamma distribution of prevalence of sitting time and normal distribution of RR logarithm. The data generated from Monte Carlo simulation have a normal distribution. Therefore, the PAF and 95% CI was estimated using the 2.5th and 97.5th percentiles. In addition, the median and weighted mean PAF globally and by WHO regions were based on the 2005 population size, as it was the average (mean, median, and mode) year of data collection across studies.[22]

Results

The adult population in the 54 countries (1,167,191,000 adults) represented 25% of the global adult population in 2005 (4,694,702,877 adults). Regarding WHO regions, the countries comprised 81% of the American, 62% of European, 21% of Eastern Mediterranean, 4% of Southeast Asian, and 3% of Western Pacific adult populations. The weighted mean sitting time across countries was 4.7 hours/day, ranging from 4.2 hours/day in American countries to 6.2 hours/day in Western Pacific countries (Appendix Table 3, available online). The overall prevalence of sitting for >3 hours/day was 61.5%, ranging from 61.8% in American countries to 64.6% in Western Pacific countries (Figure 1, Appendix Table 4, available online).

Among all the countries, sitting time >3 hours/day was responsible for approximately 433,000 deaths. The weighted mean PAF of sitting time >3 hours/day for all-cause mortality was 3.3% and the median was 3.8%. Weighted mean PAF associated with sitting time >3 hours/day ranged from 2.0% in Southeast Asian countries to 5.7% in Western Pacific countries (Table 1). Removal of sitting time had the largest effect in Lebanon (11.6%, 95% CI=8.9%, 14.1%) and the lowest on Mexico (0.6%, 95% CI=0.1%, 1.1%) (Figure 2; Appendix Table 5, available online).

Eliminating sitting time increased life expectancy by a weighted mean of 0.23 years among the 54 countries, ranging from 0.15 years in Southeast Asian countries to 0.40 years in Eastern Mediterranean countries (Table 1).

Different counterfactual scenarios based on reductions of 10%, 25%, and 50% in mean sitting time indicated that total weighted mean PAF for all-cause mortality could be reduced by 0.6, 1.3, and 2.3 percentage points, respectively. Reductions of 0.5, 1, and 2 hours/day in the mean sitting time would decrease the total weighted mean PAF for all-cause mortality by 0.6, 1.1, and 1.9 percentage points, respectively (Table 2).

In addition, PAF was calculated assuming gamma and normal distributions. In 96% of the countries, the sitting time PAF estimated using the gamma distribution produced more-conservative values (mean difference, –1.2; SD=1.5; range, –6.0 to 0.2). Furthermore, 85% of PAF CIs based on gamma and normal distributions overlapped (Appendix Table 6, available online).

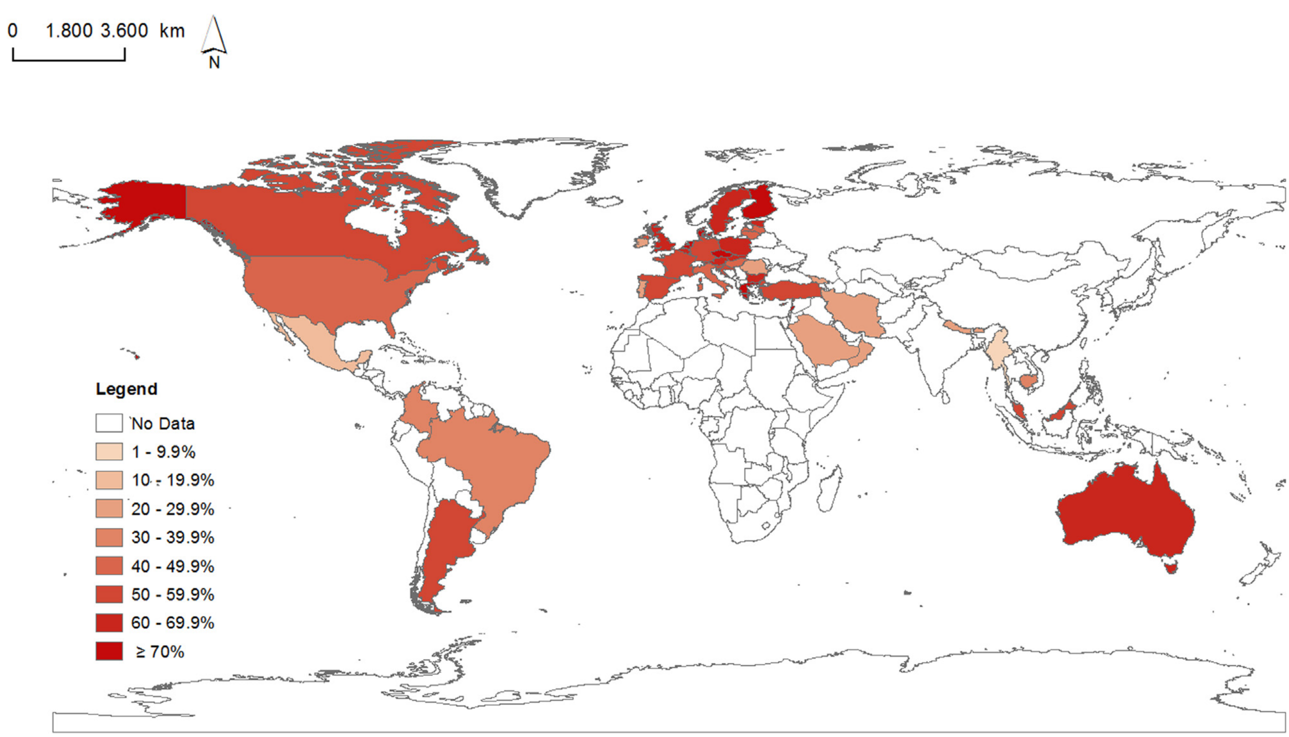

Figure 1. Prevalence of sitting time (>3 hours/day). Data of 54 countries from 2002 to 2011.

Table 1. Gain in Life Expectancy and Deaths Preventable Associated With Sitting Time (>3 hours/day)

Regions and countries	GLE (95% CI)	Deaths (×1,000)
All countries		
Total		433.4
Weighted mean	0.23	
Median	0.29	
America		
Argentina	0.36 (0.24, 0.47)	13.0
Brazil	0.20 (0.12, 0.27)	23.9
British Virgin Islands	–[a]	–[a]
Canada	0.28 (0.20, 0.36)	11.9
Colombia	0.30 (0.22, 0.37)	6.5
Mexico	0.05 (0.01, 0.09)	2.9
Saint Kitts and Nevis	0.12 (0.09, 0.15)	–[a]
U.S.	0.13 (0.00, 0.33)	106.2
Total		163.53
Weighted mean	0.17	
Median	0.20	
Western Pacific		
Australia	0.35 (0.26, 0.45)	9.6
Cambodia	0.30 (0.22, 0.38)	1.9
Cook Islands	0.34 (0.26, 0.42)	–[a]
Kiribati	0.14 (0.08, 0.21)	0.0
Malaysia	0.48 (0.37, 0.59)	7.0
Micronesia (Chuuk)	0.26 (0.19, 0.33)	0.0
Tonga	0.24 (0.18, 0.31)	0.0
Vanuatu	0.15 (0.11, 0.19)	0.0
Total		18.7
Weighted mean	0.40	
Median	0.28	
Southeast Asia		
Bhutan	0.14 (0.08, 0.20)	0.0
Myanmar	0.10 (0.08, 0.12)	4.0
Nepal	0.28 (0.22, 0.35)	3.5
Total		7.6
Weighted mean	0.15	
Median	0.14	

(continued)

Table 1 *(continued)*

Regions and countries	GLE (95% CI)	Deaths (×1,000)
Eastern Mediterranean		
Iran	0.20 (0.15, 0.25)	7.9
Lebanon	0.71 (0.55, 0.88)	2.0
Oman	0.15 (0.09, 0.21)	0.1
Saudi Arabia	0.22 (0.17, 0.27)	1.8
Total		11.8
Weighted mean	0.22	
Median	0.21	
Europe		
Austria	0.26 (0.17, 0.36)	3.3
Belgium	0.35 (0.24, 0.45)	6.0
Bulgaria	0.30 (0.17, 0.43)	4.2
Croatia	0.34 (0.23, 0.45)	2.3
Cyprus (Republic)	0.31 (0.22, 0.41)	0.3
Czech Republic	0.48 (0.34, 0.62)	6.9
Denmark	0.47 (0.33, 0.61)	3.8
Estonia	0.84 (0.56, 1.12)	0.8
Finland	0.30 (0.18, 0.43)	2.4
France	0.23 (0.15, 0.31)	21.0
Georgia	0.20 (0.14, 0.25)	1.2
Germany	0.30 (0.21, 0.39)	40.8
Great Britain	0.31 (0.21, 0.41)	29.6
Greece	0.39 (0.27, 0.52)	8.1
Hungary	0.29 (0.18, 0.40)	4.3
Ireland	0.20 (0.15, 0.25)	1.0
Italy	0.18 (0.11, 0.25)	19.9
Latvia	0.31 (0.20, 0.42)	1.0
Lithuania	0.30 (0.20, 0.41)	1.3
Luxembourg	0.30 (0.20, 0.40)	0.2
Malta	0.15 (0.08, 0.21)	0.1
Netherlands	0.45 (0.33, 0.57)	10.4
Northern Ireland	0.26 (0.16, 0.37)	–[a]
Poland	0.43 (0.29, 0.56)	19.2
Portugal	0.13 (0.08, 0.18)	2.1
Romania	0.18 (0.12, 0.25)	5.5

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Table 1. Gain in Life Expectancy and Deaths Preventable Associated With Sitting Time (>3 hours/day) *(continued)*

Regions and countries	GLE (95% CI)	Deaths (×1,000)
Slovakia	0.72 (0.46, 0.98)	2.4
Slovenia	0.30 (0.20, 0.40)	0.9
Spain	0.21 (0.13, 0.29)	14.6
Sweden	0.30 (0.21, 0.40)	4.9
Turkey	0.28 (0.18, 0.38)	12.7
Total		230.9
Weighted mean	0.29	
Median	0.30	

Note: Weighted mean considering the adult population (aged ≥15 years) in 2005.
[a]No result because of incomplete data for calculation.
GLE, gain in life expectancy (in years).

Discussion

This study is the first to investigate the PAF of sitting time among a large number of countries worldwide. PAF is a measure of association used by epidemiologists to quantify and summarize the public health burden due to one risk factor and describes how much an outcome (in this study, all-cause mortality) may be reduced by eliminating an exposure (in this case, sitting time).[12] Sitting time was responsible for 3.8% of all-cause mortality (approximately 433,000 deaths) in 54 countries worldwide.

This study also estimated the percentage of all-cause mortality that could be avoided if sitting time was reduced at different levels. It was observed that even modest reductions, such as a 10% reduction in the mean sitting time or a 30-minute absolute decrease of sitting time per day, could have an instant impact in all-cause mortality (0.6%) in the 54 evaluated countries, whereas bolder changes (for instance, 50% decrease or 2 hours fewer) would represent at least three times fewer deaths versus the 10% or 30-minute reduction scenarios.

Recent studies have reinforced the importance of considering the entire physical activity continuum in research and physical activity recommendations.[9,23] In other words, incorporating not only moderate to vigorous physical activities but also light-intensity physical activities to replace sedentary time (when applicable) is a more realistic and extensive way to promote active lifestyles worldwide. Considering this scenario, if sitting time plus physical inactivity were removed, about 14% of all deaths per year (more than 1.5 million deaths in these countries) could be avoided (Appendix Text 1, Appendix Figure 2, Appendix Table 7, available online). Importantly, these estimates assume that there is independence between physical inactivity and sitting time, which still requires further research. The present findings support the importance of promoting active lifestyles (more physical activity and less sitting) as an important aspect for premature mortality prevention worldwide, and therefore the need for global action to reduce this risk factor.

Nonetheless, changing population levels of sedentary behavior is challenging. Although sitting is an intrinsic part of human nature, excessive sitting is very common in modern societies. Sedentary behavior is determined by individual, social, and environmental factors, all strongly influenced by the current economic system, including a greater number of labor-saving devices for commuting, at home and work,[24] and urban environment inequalities that force people to travel longer distances and live in areas that lack support for active lifestyles.[25] Though some individual-focused interventions (i.e., sedentary workers sitting >7 hours/day) have shown positive results but small to moderate impact (e.g., individualized motivational counseling, Internet-delivered programs, pedometer-based control, structured group exercise, breaks from sitting),[26,27] only interventions aimed at tackling the macro determinants of sedentary behavior will be able to achieve the bolder scenarios assumed in the analysis.[28] Some examples of this approach were recently highlighted by WHO, such as a strategic health communication to promote physical activity in women in Tonga, a bicycle sharing scheme implemented in Iran, and a sustainable transport system developed in Germany.[29]

Compared with previous studies, worldwide PAF estimates associated with sitting time (4% of all deaths) show lower impact on all-cause mortality than those reported in Australia (7% of all deaths)[30] and four high-income countries (Australia, the U.S., Norway, and Japan —6%).[11] Such differences are probably due to different levels of exposure among countries or methodologic heterogeneity among studies (e.g., different equations, sitting time cut offs, or RR estimates). In the U.S., another study estimated that 27% of all deaths are attributable to sitting ≥2 hours/day,[19] but such a different cut off makes comparisons difficult. In addition, it was found that eliminating sitting time would increase life expectancy for an individual by 0.23 years on average. This benefit is smaller than those gained by eliminating physical inactivity (0.68 years)[3]; obesity (0.73 years for women and 0.98 years for men)[31]; and tobacco smoking (2.4 years in men and 1 year in women).[32] Although sitting time represents a smaller impact compared with other risk factors, reducing sitting time might be an important

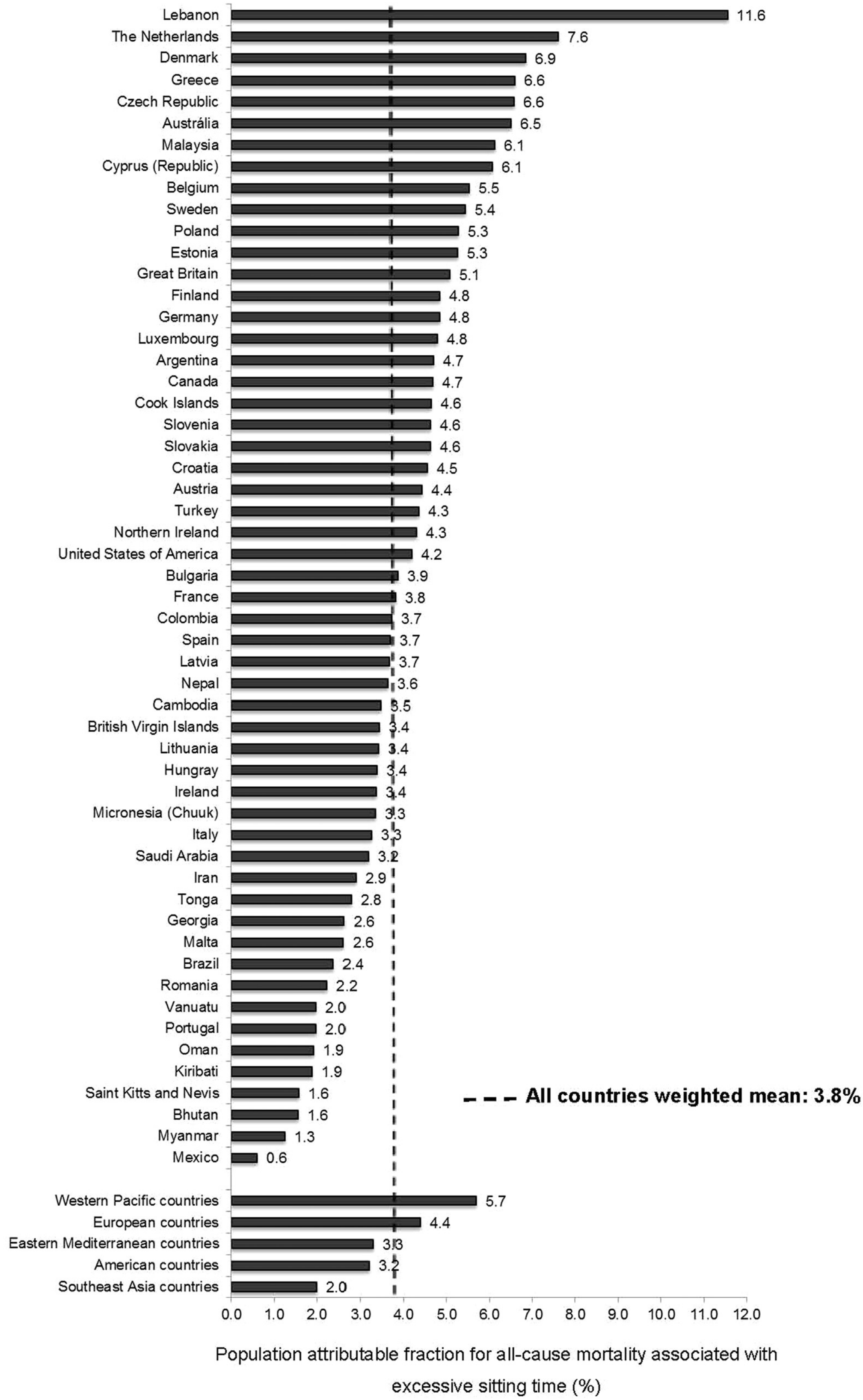

Figure 2. Population-attributable fraction for all-cause mortality associated with prolonged sitting time (> 3 hours/day). Data of 54 countries from 2002 to 2011.

Table 2. Population-Attributable Fraction for All-Cause Mortality According to Relative and Absolute Reductions in Sitting Time

	Relative reduction (%)			Absolute reduction (hours/day)		
Regions and countries	**−10 (95% CI)**	**−25 (95% CI)**	**−50 (95% CI)**	**−0.5 (95% CI)**	**−1 (95% CI)**	**−2 (95% CI)**
All 54 countries						
Weighted mean	0.6	1.3	2.3	0.6	1.1	1.9
Median	0.6	1.4	2.4	0.6	1.2	2.1
America						
Argentina	0.8 (0.2, 1.5)	1.8 (1.0, 2.6)	2.9 (1.9, 4.0)	0.8 (0.1, 1.4)	1.4 (0.7, 2.1)	2.5 (1.5, 3.4)
Brazil	0.3 (0.0, 0.7)	0.8 (0.3, 1.2)	1.3 (0.7, 1.9)	0.5 (0.1, 0.8)	0.8 (0.4, 1.3)	1.4 (0.7, 2.0)
British Virgin Islands	0.4 (−0.1, 1.0)	1.0 (0.4, 1.7)	1.9 (1.1, 2.6)	0.5 (0.0, 1.1)	1.0 (0.4, 1.6)	1.8 (1.1, 2.6)
Canada	0.7 (0.4, 1.1)	1.6 (1.1, 2.2)	2.8 (2.0, 3.7)	0.7 (0.4, 1.1)	1.3 (0.9, 1.8)	2.3 (1.6, 3.1)
Colombia	0.5 (0.1, 0.9)	1.1 (0.7, 1.6)	2.1 (1.4, 2.8)	0.5 (0.1, 0.9)	1.0 (0.6, 1.5)	1.9 (1.3, 2.6)
Mexico	0.1 (0.0, 0.2)	0.2 (0.0, 0.4)	0.3 (0.0, 0.6)	0.2 (0.0, 0.3)	0.2 (0.0, 0.5)	0.3 (−0.1, 0.7)
Saint Kitts and Nevis	0.2 (−0.1, 0.6)	0.6 (0.2, 1.0)	1.1 (0.6, 1.5)	0.3 (−0.1, 0.6)	0.5 (0.2, 0.9)	1.0 (0.6, 1.4)
U.S.	0.5 (0.3, 0.8)	1.3 (0.9, 1.7)	2.3 (1.7, 3.0)	0.6 (0.3, 0.9)	1.1 (0.7, 1.5)	2.0 (1.4, 2.6)
Weighted mean	0.4	1.0	1.8	0.5	0.9	1.7
Median	0.4	1.1	2.0	0.5	1.0	1.9
Western Pacific						
Australia	1.1 (0.7, 1.4)	2.4 (1.8, 3.1)	4.1 (3.0, 5.2)	0.9 (0.5, 1.2)	1.6 (1.2, 2.1)	3.0 (2.2, 3.8)
Cambodia	0.4 (0.2, 0.7)	1.0 (0.7, 1.4)	1.9 (1.3, 2.5)	0.5 (0.2, 0.8)	1.0 (0.6, 1.4)	1.9 (1.3, 2.4)
Cook Islands	0.6 (0.1, 1.1)	1.4 (0.9, 2.0)	2.7 (1.9, 3.5)	0.5 (0.0, 1.0)	1.0 (0.5, 1.6)	2.0 (1.4, 2.7)
Kiribati	0.2 (−0.3, 0.8)	0.5 (0.0, 1.2)	0.9 (0.3, 1.6)	0.4 (−0.2, 1.0)	0.7 (0.1, 1.3)	1.1 (0.4, 1.9)
Malaysia	0.8 (0.3, 1.3)	1.9 (1.3, 2.5)	3.6 (2.7, 4.5)	0.5 (0.1, 1.0)	1.1 (0.6, 1.6)	2.1 (1.5, 2.7)
Micronesia (Chuuk)	0.4 (0.0, 0.9)	1.0 (0.5, 1.5)	1.8 (1.2, 2.5)	0.5 (0.1, 1.0)	1.0 (0.5, 1.5)	1.8 (1.2, 2.5)
Tonga	0.3 (−0.2, 1.0)	0.8 (0.2, 1.5)	1.6 (1.0, 2.3)	0.5 (−0.1, 1.1)	0.9 (0.3, 1.6)	1.8 (1.1, 2.6)
Vanuatu	0.2 (0.0, 0.5)	0.5 (0.3, 0.8)	1.1 (0.8, 1.5)	0.4 (0.2, 0.7)	0.9 (0.6, 1.2)	1.7 (1.2, 2.2)
Weighted mean	0.8	1.9	3.4	0.7	1.3	2.4
Median	0.4	1.0	1.9	0.5	1.0	1.8
Southeast Asia						
Bhutan	0.2 (−0.1, 0.5)	0.4 (0.1, 0.7)	0.7 (0.3, 1.2)	0.3 (0.0, 0.6)	0.5 (0.2, 0.9)	1.0 (0.4, 1.5)
Myanmar	0.2 (0.1, 0.3)	0.5 (0.3, 0.6)	0.8 (0.6, 1.1)	0.3 (0.1, 0.4)	0.5 (0.3, 0.7)	0.9 (0.7, 1.2)
Nepal	0.5 (0.2, 0.8)	1.3 (0.9, 1.7)	2.4 (1.8, 3.0)	0.3 (0.0, 0.6)	0.5 (0.3, 0.9)	1.1 (0.7, 1.5)
Weighted mean	0.3	0.7	1.3	0.3	0.5	1.0
Median	0.2	0.5	0.8	0.3	0.5	1.0
Eastern Mediterranean						
Iran	0.4 (0.3, 0.5)	0.9 (0.7, 1.2)	1.8 (1.4, 2.2)	0.4 (0.3, 0.6)	0.8 (0.6, 1.1)	1.6 (1.2, 2.0)
Lebanon	1.5 (0.9, 2.1)	3.8 (2.8, 4.8)	7.2 (5.5, 8.8)	0.7 (0.2, 1.3)	1.5 (0.9, 2.2)	3.1 (2.2, 4.0)
Oman	0.2 (−0.1, 0.6)	0.6 (0.1, 1.0)	1.0 (0.4, 1.5)	0.4 (0.0, 0.8)	0.7 (0.2, 1.2)	1.1 (0.5, 1.8)

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Table 2. Population-Attributable Fraction for All-Cause Mortality According to Relative and Absolute Reductions in Sitting Time *(continued)*

	Relative reduction (%)			Absolute reduction (hours/day)		
Regions and countries	**−10 (95% CI)**	**−25 (95% CI)**	**−50 (95% CI)**	**−0.5 (95% CI)**	**−1 (95% CI)**	**−2 (95% CI)**
Saudi Arabia	0.4 (0.1, 0.7)	1.0 (0.7, 1.4)	2.0 (1.5, 2.5)	0.4 (0.1, 0.7)	0.8 (0.5, 1.2)	1.6 (1.2, 2.1)
Weighted mean	0.4	1.1	2.0	0.4	0.9	1.7
Median	0.4	1.0	1.9	0.4	0.8	1.6
Europe						
Austria	0.8 (0.2, 1.5)	1.8 (1.0, 2.7)	2.9 (1.8, 4.1)	0.8 (0.2, 1.5)	1.5 (0.8, 2.3)	2.5 (1.5, 3.6)
Belgium	1.0 (0.3, 1.7)	2.2 (1.4, 3.1)	3.6 (2.4, 4.9)	0.9 (0.2, 1.6)	1.6 (0.9, 2.4)	2.9 (1.9, 3.9)
Bulgaria	0.8 (0.2, 1.5)	1.7 (0.9, 2.6)	2.7 (1.5, 3.9)	0.8 (0.2, 1.5)	1.5 (0.7, 2.3)	2.4 (1.3, 3.5)
Croatia	0.8 (0.1, 1.5)	1.7 (1.0, 2.6)	2.9 (1.8, 4.0)	0.8 (0.1, 1.4)	1.4 (0.7, 2.2)	2.4 (1.5, 3.5)
Cyprus (Republic)	1.1 (0.0, 2.2)	2.4 (1.3, 3.7)	4.0 (2.6, 5.5)	0.9 (−0.1, 2.0)	1.7 (0.7, 2.9)	3.0 (1.8, 4.4)
Czech Republic	1.2 (0.4, 1.9)	2.6 (1.7, 3.6)	4.4 (3.1, 5.7)	0.9 (0.2, 1.7)	1.8 (1.0, 2.7)	3.2 (2.2, 4.3)
Denmark	1.2 (0.5, 2.1)	2.8 (1.9, 3.8)	4.6 (3.3, 6.0)	1.0 (0.2, 1.8)	1.9 (1.1, 2.7)	3.3 (2.3, 4.5)
Estonia	1.0 (0.3, 1.7)	2.2 (1.3, 3.1)	3.5 (2.3, 4.8)	0.9 (0.2, 1.6)	1.6 (0.9, 2.5)	2.8 (1.8, 3.9)
Finland	1.2 (0.5, 1.9)	2.5 (1.6, 3.5)	3.8 (2.3, 5.3)	1.1 (0.4, 1.7)	1.9 (1.2, 2.8)	3.2 (2.0, 4.4)
France	0.6 (0.0, 1.3)	1.4 (0.7, 2.2)	2.3 (1.4, 3.4)	0.7 (0.1, 1.3)	1.3 (0.6, 2.0)	2.1 (1.2, 3.1)
Georgia	0.3 (0.1, 0.5)	0.7 (0.4, 1.0)	1.4 (0.9, 1.8)	0.4 (0.2, 0.7)	0.9 (0.5, 1.2)	1.6 (1.1, 2.2)
Germany	0.8 (0.3, 1.3)	1.8 (1.2, 2.5)	3.0 (2.1, 4.1)	0.8 (0.3, 1.3)	1.4 (0.9, 2.1)	2.5 (1.7, 3.4)
Great Britain	0.9 (0.2, 1.6)	2.0 (1.1, 2.9)	3.2 (2.1, 4.4)	0.8 (0.1, 1.5)	1.5 (0.8, 2.3)	2.6 (1.7, 3.7)
Greece	1.3 (0.6, 2.1)	2.9 (2.0, 4.0)	4.7 (3.3, 6.2)	1.1 (0.3, 1.8)	2.0 (1.2, 2.9)	3.6 (2.5, 4.7)
Hungary	0.6 (0.0, 1.2)	1.3 (0.6, 2.0)	2.1 (1.1, 3.0)	0.6 (0.0, 1.2)	1.2 (0.5, 1.9)	1.9 (1.0, 2.8)
Ireland	0.4 (−0.2, 1.1)	1.1 (0.4, 1.7)	2.0 (1.3, 2.8)	0.5 (−0.2, 1.1)	0.9 (0.3, 1.6)	1.7 (1.0, 2.5)
Italy	0.6 (0.0, 1.2)	1.3 (0.6, 2.0)	2.0 (1.1, 3.0)	0.6 (0.1, 1.3)	1.2 (0.5, 1.9)	1.9 (1.0, 2.9)
Latvia	0.6 (0.0, 1.2)	1.3 (0.6, 2.0)	2.2 (1.3, 3.1)	0.6 (0.1, 1.3)	1.2 (0.5, 1.9)	2.0 (1.1, 2.9)
Lithuania	0.5 (−0.1, 1.2)	1.2 (0.5, 2.0)	2.0 (1.1, 3.0)	0.6 (0.0, 1.3)	1.1 (0.5, 1.9)	1.9 (1.0, 2.8)
Luxembourg	0.8 (−0.1, 1.8)	1.8 (0.8, 2.9)	3.0 (1.8, 4.4)	0.8 (−0.1, 1.7)	1.5 (0.5, 2.5)	2.5 (1.4, 3.7)
Malta	0.4 (−0.3, 1.2)	0.9 (0.1, 1.8)	1.5 (0.6, 2.5)	0.5 (−0.2, 1.3)	0.9 (0.1, 1.8)	1.5 (0.6, 2.5)
Netherlands	1.3 (0.6, 2.1)	3.0 (2.1, 4.1)	5.1 (3.7, 6.6)	1.0 (0.2, 1.8)	1.9 (1.1, 2.8)	3.5 (2.5, 4.6)
Northern Ireland	0.8 (−0.3, 2.0)	1.7 (0.5, 3.0)	2.8 (1.4, 4.3)	0.8 (−0.4, 2.0)	1.4 (0.3, 2.7)	2.4 (1.1, 3.8)
Poland	0.9 (0.2, 1.7)	2.1 (1.2, 3.0)	3.4 (2.2, 4.6)	0.8 (0.2, 1.6)	1.6 (0.8, 2.4)	2.7 (1.7, 3.8)
Portugal	0.3 (−0.2, 0.7)	0.6 (0.1, 1.1)	1.0 (0.4, 1.6)	0.4 (−0.1, 0.9)	0.7 (0.2, 1.2)	1.2 (0.5, 1.9)
Romania	0.3 (−0.2, 0.8)	0.6 (0.1, 1.2)	1.1 (0.5, 1.8)	0.4 (−0.1, 0.9)	0.7 (0.2, 1.3)	1.4 (0.7, 2.1)
Slovakia	0.9 (0.2, 1.6)	1.9 (1.1, 2.8)	3.0 (1.9, 4.2)	0.8 (0.2, 1.5)	1.5 (0.8, 2.3)	2.6 (1.6, 3.6)
Slovenia	0.8 (0.2, 1.5)	1.8 (1.0, 2.7)	3.0 (1.8, 4.1)	0.8 (0.1, 1.5)	1.5 (0.7, 2.3)	2.5 (1.5, 3.5)
Spain	0.7 (0.1, 1.3)	1.5 (0.8, 2.3)	2.4 (1.3, 3.5)	0.7 (0.1, 1.4)	1.3 (0.6, 2.0)	2.2 (1.2, 3.2)
Sweden	1.0 (0.3, 1.7)	2.3 (1.4, 3.2)	3.7 (2.4, 4.9)	0.9 (0.2, 1.6)	1.7 (0.9, 2.5)	2.9 (1.9, 4.0)

(continued on next page)

Table 2. Population-Attributable Fraction for All-Cause Mortality According to Relative and Absolute Reductions in Sitting Time *(continued)*

	Relative reduction (%)			Absolute reduction (hours/day)		
Regions and countries	**−10 (95% CI)**	**−25 (95% CI)**	**−50 (95% CI)**	**−0.5 (95% CI)**	**−1 (95% CI)**	**−2 (95% CI)**
Turkey	0.8 (0.1, 1.5)	1.8 (1.0, 2.6)	2.8 (1.7, 4.0)	0.8 (0.1, 1.5)	1.4 (0.7, 2.3)	2.5 (1.5, 3.5)
Weighted mean	0.8	1.7	2.8	0.7	1.1	1.9
Median	0.8	1.8	2.9	0.8	1.2	2.0

Note: Weighted mean considering the adult population (aged ≥15 years) in 2005.

aspect for active lifestyle promotion, especially among people with lower physical activity levels. In other words, reducing sitting time would help people increase their volumes of physical activity along the continuum to higher physical activity levels.

Regardless of the true attributable fraction of total deaths related to sitting time, it is important to highlight that PAF estimates assume that there is a causal relationship between exposure and outcomes, which is still a matter of debate in the sedentary behavior literature.[33] On the other hand, there are many observational[12,34,35] and clinical[6,7] studies that support the adverse effect of excessive sitting time on human health. Epidemiologic studies have reported that sitting time is associated with all-cause mortality,[12] but also with metabolic syndrome and non-communicable diseases such as Type 2 diabetes, fatal and non-fatal cardiovascular diseases,[34,35] and some cancers.[34] In addition, for sitting time >3 hours/day, there is a dose–response relationship between sitting time and all-cause mortality,[11] which strengthens the claim of causation. The mechanisms explaining the detrimental effect of sitting time might be related to lower expression of endothelial nitric oxide synthase (related to increased vascular oxidative stress and impaired endothelial function)[6] and reduction in glucose transporter type 4; lipase lipoprotein (importantly related to triglyceride catabolism, high-density lipoprotein cholesterol, and other metabolic risk factors); and glucose uptake.[7] The accumulated results of sitting time research have mobilized international organizations such as the International Agency for Research on Cancer,[36] U.S. DHHS,[37] Australian Department of Health,[38] and others to reduce the prevalence of this emerging risk factor.

The PAF estimates calculated in this study are likely conservative. First, for sitting time use, the lowest RR within 3–7 hours/day and >7 hours/day strata was used. Second, the pooled measures of association used for PAF calculation might not reveal the total effect of sitting time on all-cause mortality. In fact, cohort studies included in the meta-analysis adjusted by mediators, such as BMI and cardiometabolic profile, provide only the potential direct effect. Third, the RR used in this study might be underestimated, given that self-reported sitting time may produce a non-differential measurement error. Fourth, to estimate preventable absolute deaths and gains in life expectancy, mortality attributable to sitting time was assumed only for people aged 40–79 years.

Limitations

Several limitations of this study should be considered. First, the same pooled RR was applied to estimate PAF for all countries, which was based on cohort studies carried out in high-income countries (Australia, the U.S., Norway, and Japan). Such RR "portability" from other populations has been extensively used elsewhere.[3,5] The possibility of reverse causality and residual confounding in these RR estimates cannot be excluded. However, three cohorts with relatively short follow-up included in the meta-analysis of Chau and colleagues[11] excluded people who died in the first year of follow-up and found similar associations. Indeed, there is heterogeneity between covariates considered in each cohort study included in that meta-analysis, which would be possible to partially overcome using individual participant meta-analysis. Second, an adjustment factor obtained from the Canadian and U.S. populations (the only one available in the literature) was applied for all 54 countries; how applicable this adjustment factor might be to other countries is still unclear and is a potential area for future investigation. The adjustment factor was applied to use a PAF equation that is valid for adjusted RR.[13] Third, although an extensive literature search was conducted and 54 countries worldwide were included, it was not possible to find total sitting time estimates for any African country, which limits the generalization of the results to that region. This lack of data in some countries may reflect the actual scenario of worldwide sitting time surveillance. Lastly, the heterogeneity for sitting time data among countries should also be taken into account, both in terms of source (Eurobarometer, International Prevalence Study, STEPS, and literature search) and year (mode, 2005; range, 2002–2011).

However, it is important to note that all studies used International Physical Activity Questionnaire or Global Physical Activity Questionnaire questions about habitual daily sitting time, which are very similar. Additionally, a previous analysis suggests that the International Physical Activity Questionnaire and Global Physical Activity Questionnaire have acceptable measurement properties for population-based monitoring of sedentary time.[39]

Despite these acceptable measurement properties, these questionnaires are not capable of detecting fidgeting[40] while sitting and breaks in sedentary time,[41] which might reduce the risk of all-cause mortality and cardiometabolic biomarkers associated with sitting time, respectively. In addition, it was not possible to specify the domain of sitting (e.g., leisure, work, or commute), which are associated with different health outcomes and magnitude of association.[33]

Despite these limitations, these estimates might still be helpful, especially for policymakers, to understand the impact of sedentary behavior on public health. In the future, studies with better measures of exposure will help to gain insight about the current inconsistencies in the literature; provide more accurate information about the exposure variable (sitting time); and therefore will produce more-robust estimations of global mortality attributed to sitting time. Additionally, future studies about PAF for all-cause mortality associated with sitting time could include more countries, subgroup populations, and non-communicable diseases in the analysis.

Conclusions

Available data suggest that sitting time is responsible for 3.8% of all deaths. Population prevention strategies focused on upstream determinants of the entire continuum of daily activities might be an effective approach to reduce millions of deaths worldwide.

LFMdR, THdS, GIM, JPR-L, and LMTG contributed to literature search, study design, analysis, and wrote the first draft of the report. JYKV contributed to data analysis, interpretation, and wrote the first draft. All authors read and approved the final report.

LFMR acknowledge PhD scholarship: grant #2014/25614-4, São Paulo Research Foundation (FAPESP). THS PhD is supported by the Sao Paulo Research Foundation (FAPESP, process number: 2012/08565-4). LMTG acknowledges PhD scholarship from the Federal Agency for Support and Evaluation of Graduate Education (CAPES). GIM received PhD scholarship from Brazilian Federal Agency for Support and Evaluation of Graduate Educacional.

The authors thank Nicholas Schroeder and Diana Parra for technical assistance with the English revision of the paper.

No financial disclosures were reported by the authors of this paper.

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Appendix

Supplementary data

Supplementary data associated with this article can be found at http://dx.doi.org/10.1016/j.amepre.2016.01.022.