Can air pollution negate the health benefits of cycling and walking?

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Highlights

- Air pollution (AP) may reduce the health benefits of active travel (AT).
- We compared risks-benefit tradeoff of AP and physical activity (PA) due to AT.
- In most urban environments benefits of PA outweighed risks of AP.
- If cycling replaces driving, the trade-off would be even more beneficial.

Abstract

Active travel (cycling, walking) is beneficial for health due to increased physical activity (PA). However, active travel may increase the intake of air pollution, leading to negative health consequences. We examined the risk-benefit balance between active travel related PA and exposure to air pollution across a range of air pollution and PA scenarios. The health effects of active travel and air pollution were estimated through changes in all-cause mortality for different levels of active travel and air pollution. Air pollution exposure was estimated through changes in background concentrations of fine particulate matter (PM2.5), ranging from 5 to 200 μg/m3. For active travel exposure, we estimated cycling and walking from 0 up to 16 hours per day, respectively. These refer to long-term average levels of active travel and PM2.5 exposure. For the global average urban background PM2.5 concentration (22 μg/m3) benefits of PA by far outweigh risks from air pollution even under the most extreme levels of active travel. In areas with PM2.5 concentrations of 100 μg/m3, harms would exceed benefits after 1h 30 min of cycling per day or more than 10 h of walking per day. If the counterfactual was driving, rather than staying at home, the benefits of PA would exceed harms from air pollution up to 3 h 30 min of cycling per day. The results were sensitive to dose-response function (DRF) assumptions for PM2.5 and PA. PA benefits of active travel outweighed the harm caused by air pollution in all but the most extreme air pollution concentrations.

Keywords

Physical activity; air pollution; bicycling; walking; mortality; Health Impact Assessment; Risk-Benefit Assessment.

Introduction

Several Health Impact Modelling (HIM) studies have estimated health benefits and risks of active travel (cycling, walking) in different geographical areas[1,2]. In most of these studies, the health benefits due to physical activity (PA) from increased active travel are significantly larger than the health risks caused by increases in exposure to air pollution.

Most of the existing active travel HIM studies have been carried out in cities in high income countries with relatively low air pollution levels[1,2]. This raises the question on the risk-benefit balance in highly polluted environments. Health risks of air pollution are usually thought to increase linearly with increased exposure for low to moderate levels of air pollution, whereas the benefits of PA increase curvy-linearly with increasing dose [3,4]. Thus, at a certain level of background air pollution and of active travel, risks could outweigh benefits, which would directly imply that, from a public health perspective, active travel could not be always recommended.

In this study we compare the health risks of air pollution with the PA-related health benefits from active travel across a wide range of possible air pollution concentrations and active travel levels. We use two thresholds to compare PA benefits and air pollution risks (Figure 1): At the "*tipping point*" an incremental increase in active travel will no longer lead to an increase in health benefits (i.e. max. benefits have been reached). Increasing active travel even more could lead to the "*break-even point*", where risk from air pollution start outweighing benefits of PA (i.e. there are no longer net benefits, compared to not engaging in active travel).

Methods

Our approach followed a general active travel HIM method[1,2]. Air pollution exposures due to active travel were quantified by estimating differences in inhaled dose of fine particulate matter (PM2.5) air pollution. We selected PM2.5 because it is a commonly used indicator of air pollution in active travel HIM studies[1,2], and because of the large health burden caused by PM2.5[5]. For both air pollution and PA we used all-cause mortality as the health outcome because there is strong evidence for its association with both long-term exposure to PM2.5[6] and long-term PA behaviour[3].

The reduction in all-cause mortality from active travel was estimated by converting the time spent cycling or walking to Metabolically Equivalent of Task (METs) and calculating the risk reduction using dose-response functions (DRFs) adapted from Kelly et al.'s[3] meta-analysis. From the different DRFs reported in Kelly et al.[3] we chose the one with "0.50 power transformation" as a compromise between linear and extremely non-linear DRFs. Non-linearity in a DRF means that the health benefits of increased active travel would level out sooner and tipping point would be reached earlier than with more linear DRFs. See supplementary material for sensitivity analysis with different DRFs. To convert cycling and walking time to PA we used values of 4.0 METs for walking and 6.8 METs for cycling, based on Compendium of Physical Activities[7]. The walking and cycling levels used in this study are assumed to reflect long-term average behaviour.

The health risks of PM2.5 were estimated by converting background PM2.5 concentrations to travel mode specific exposure concentrations, and by taking into account ventilation rate while being active. For background PM2.5 we used values between 5 and 200 µg/m3 with 5 µg/m3 intervals. We also estimated tipping points and break-even points for the average and most polluted cities in each region included in the World Health Organization (WHO) Ambient Air Pollution Database[8], which contains measured and estimated background PM2.5 concentrations for 1622 cities around the world.

The mode specific exposure concentrations were estimated by multiplying background PM2.5 concentration by 2.0 for cycling or 1.1 for walking, based on a review of studies [9]. The counterfactual scenario for the time spent cycling or walking was assumed to be staying at home (i.e. in background concentration of PM2.5). See supplementary file for sensitivity analysis with counterfactual scenarios where cycling time would replace motorized transport time. The ventilation rates differences while at sleep, rest, cycling and walking were taken into account when converting exposure to inhaled dose. For sleep, rest, walking and cycling we used ventilation rates of 0.27, 0.61, 1.37 and 2.55, respectively[10,11]. Sleep time was assumed to be 8h in all scenarios and resting time was 16h minus the time for active travel.

For the PM2.5 DRF we used a relative risk (RR) value of 1.07 per 10 µg/m3 change in exposure[4]. We assumed that DRF is linear from zero to maximum inhaled dose. As a sensitivity analysis we used non-linear integrated risk function from Burnett et al.[12] (see supplementary material for details).

The model used for all calculations is provided in Lumina Decision Systems Analytica format in supplementary file 2 (readable with Analytica Free 101, http://www.lumina.com/products/free101/), and a simplified model containing main results is provided in Microsoft Excel format in supplementary file 3.

<u>Results</u>

The tipping point and break-even point for different average cycling times and background PM2.5 concentrations are shown in Figure 2. For half an hour of cycling every day, background PM2.5 concentration would need to be 95 µg/m3 to reach the tipping point. In the WHO Ambient Air Pollution Database less than 1% of cities have PM2.5 annual concentrations above that level[8]. The break-even point for half an hour of cycling every day was at 160 µg/m3 (Figure 2). For half an hour of walking the tipping point and break-even point appear at a background concentration level above 200 µg/m3 (Figure S3, supplementary file). For the average urban background PM2.5 concentration (22 µg/m3) in the WHO database, the tipping point would only be reached after 7 hours of cycling and 16 hours of walking per day.

Tables S2 and S3 (supplementary file) shows the tipping point for cycling and walking, respectively, in different regions of the world. In the most polluted city in the database (Delhi, India, background concentration of 153 µg/m3), the tipping and break-even points were 30 and 45 minutes of cycling per day, respectively (Table S2, supplementary file). In most global regions the tipping points for the most polluted cities (44 µg/m3 to 153 µg/m3) varied between 30 and 120 minutes per day for cycling, and 90 minutes to 6h 15 minutes per day for walking (Table S3, supplementary material).

When we assumed that time spend cycling would replace time driving a car, benefits always exceeded the risks in the background air pollution concentrations below 80 µg/m3, a concentration exceeded in only 2% of cities[8]. Other sensitivity analyses showed that the results are sensitive to the shape of the DRF functions. With the linear DRF for active travel the break-even point would be reached with background PM2.5 concentrations of 170 µg/m3 regardless of the active travel time (Figure S4, supplementary material); a level not currently found in any of the cities in the WHO air pollution database[8]. With the most curved DRF (0.25 power) the PM2.5 concentration where harms exceed benefits for 1h of cycling per day would drop from 150 µg/m3 to 130 µg/m3 (Figure S4, supplementary material), a level currently found only in 9 cities[8]. With a non-linear DRF for PM2.5 the break-even point was not reached in any background PM2.5 concentration when using "power 0.50" DRF for cycling and walking. Other input value modifications had small or insignificant impact to the results.

Discussions

This study indicates that, practically, air pollution risks will not negate the health benefits of active travel in urban areas in the vast majority of settings worldwide. Even in areas with high background PM2.5 concentrations, such as 100 µg/m3, up to 1h 15 min of cycling and 10h 30 min of walking per day will lead to net reduction in all-cause mortality (Figure S5, supplementary material). This result is supported by epidemiological studies that have found statistically significant protective effects of PA even in high air pollution environments[13,14]. However, a small minority engaging in unusually high levels of active travel (i.e. bike messengers) in extremely polluted environments may be exposed to air pollution such that it negates the benefits of PA.

Some considerations of limitations and strengths of our study need to be applied when generalising these findings.

In this analysis we took into account only the long-term health consequences of regular PA and chronic exposure to PM2.5. Impacts of short-term air pollution episodes, where concentrations significantly exceed the average air pollution levels for a few days, may induce additional short term health effects. We have also only worked with all-cause mortality and have, thus, not taken into account morbidity impact.

For the health risks of air pollution we only estimated the increased risk during cycling and walking, not the overall health risk from everyday air pollution. Air pollution causes a large burden of diseases all over the world[12] and reducing air pollution levels would provide additional health benefits. Since transport is an important source of air pollution in urban areas, mode shifts from motorized transport to active travel would not only improve health in active travellers, but also help to reduce air pollution exposures for the whole population[15].

The results are sensitive to assumptions of the linearity of dose-response relationships between active travel-related PA and health benefits, and between PM2.5 and adverse health effects. With linear DRFs for PA the benefits always exceeded the risks at all levels of PM2.5 concentrations. Evidence for a linear DRF for high PM2.5 concentrations is small and, for example, the Global Burden of Disease study applied non-linear, disease specific DRFs for PM2.5[12]. If the risks of PM2.5 level out after PM2.5 concentrations over 100 µg/m3, the health benefits of PA would always exceed the risks of PM2.5.

It should also be taken into account that the results are based on generally representative values without detailed information on local conditions, or from the background PA and disease history of individuals. For individuals highly active in non-transport domains the benefits from active travel will be smaller, and vice versa.

Conclusions

The benefits from active travel generally outweigh health risks from air pollution and therefore should be further encouraged. When weighing long-term health benefits from PA against possible risks from increased exposure to air pollution, our calculations show that promoting cycling and walking is justified in the vast majority of settings, and only in a small number of cities with the highest PM2.5 concentration in the world cycling could lead to increase in risk.

Conflict of interest statement

The authors declare that there are no conflicts of interests.

Author contributions

MT made the calculations and drafted first version of the manuscript. AJN, TG, MJN, SK, THS, DRR and JW participated in designing the scope of the study. AJN and TG helped to clarify the message of the study. All authors contributed to the writing of this paper. All authors approved the final version to be submitted for consideration of publication.

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References

1. Mueller N, Rojas-Rueda D, Cole-Hunter T, et al. Health impact assessment of active transportation: A systematic review. *Prev. Med. (Baltim).* 2015. doi:10.1016/j.ypmed.2015.04.010.
2. Doorley R, Pakrashi V, Ghosh B. Quantifying the Health Impacts of Active Travel: Assessment of Methodologies. *Transp. Rev.* 2015;(July 2015):1-24. doi:10.1080/01441647.2015.1037378.
3. Kelly P, Kahlmeier S, Götschi T, et al. Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. *Int. J. Behav. Nutr. Phys. Act.* 2014;11(1):132. doi:10.1186/s12966-014-0132-x.
4. World Health Organization. *WHO Expert Meeting: Methods and Tools for Assessing the Health Risks of Air Pollution at Local, National and International Level. Meeting Report.* Copenhagen, Denmark; 2014. Available at: http://www.euro.who.int/__data/assets/pdf_file/0010/263629/WHO-Expert-Meeting-Methods-and-tools-for-assessing-the-health-risks-of-air-pollution-at-local,-national-and-international-level.pdf.
5. GBD 2013 Risk Factors Collaborators, Forouzanfar MH, Alexander L, et al. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet (London, England)* 2015;6736(15):1990-2013. doi:10.1016/S0140-6736(15)00128-2.
6. Héroux M-E, Anderson HR, Atkinson R, et al. Quantifying the health impacts of ambient air pollutants: recommendations of a WHO/Europe project. *Int. J. Public Health* 2015:619-627. doi:10.1007/s00038-015-0690-y.
7. Ainsworth BE, Haskell WL, Herrmann SD, et al. 2011 Compendium of Physical Activities: a second update of codes and MET values. *Med. Sci. Sports Exerc.* 2011;43(8):1575-81. doi:10.1249/MSS.0b013e31821ece12.

8. World Health Organization (WHO). Ambient Air Pollution Database. 2014. Available at: http://apps.who.int/gho/data/view.main.AMBIENTCITY2014?lang=en. Accessed August 10, 2015.

9. Kahlmeier S, Schweizer C, Rojas-Rueda D, Nieuwenhuijsen M, Nazelle A de, Bode O. *Development of the Health Economic Assessment Tools (HEAT) for Walking and Cycling - Meeting Background Document*. Bonn. Germany; 2014.

10. de Nazelle A, Rodríguez DA, Crawford-Brown D. The built environment and health: Impacts of pedestrian-friendly designs on air pollution exposure. *Sci. Total Environ.* 2009;407(8):2525-2535. doi:10.1016/j.scitotenv.2009.01.006.

11. Johnson T. *A Guide to Selected Algorithms, Distribution, and Databases Used in Exposure Models Developed by the Office of Air Quality Planning and Standards. U.S. Environmental Protection Agency*.; 2002. Available at: http://www2.epa.gov/sites/production/files/2013-08/documents/report052202.pdf.

12. Burnett RT, Pope CA, Ezzati M, et al. An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure. *Environ. Health Perspect.* 2014;122(4):397-403. doi:10.1289/ehp.1307049.

13. Matthews CE, Jurj AL, Shu XO, et al. Influence of exercise, walking, cycling, and overall nonexercise physical activity on mortality in Chinese women. *Am. J. Epidemiol.* 2007;165(12):1343-1350. doi:10.1093/aje/kwm088.

14. Andersen ZJ, de Nazelle A, Mendez MA, et al. A study of the combined effects of physical activity and air pollution on mortality in elderly urban residents: the danish diet, cancer, and health cohort. *Environ. Health Perspect.* 2015;123(6):557-63. doi:10.1289/ehp.1408698.

15. Johan de Hartog J, Boogaard H, Nijland H, Hoek G. Do the health benefits of cycling outweigh the risks? *Environ. Health Perspect.* 2010;118(8):1109-16. doi:10.1289/ehp.0901747.

Figures

Figure 1: Illustration of tipping point and break-even point as measured by the relative risk (RR) for all-cause mortality (ACM) combining the effects of air pollution (at 50 µg/m^3 $PM_{2.5}$) and physical activity (cycling).

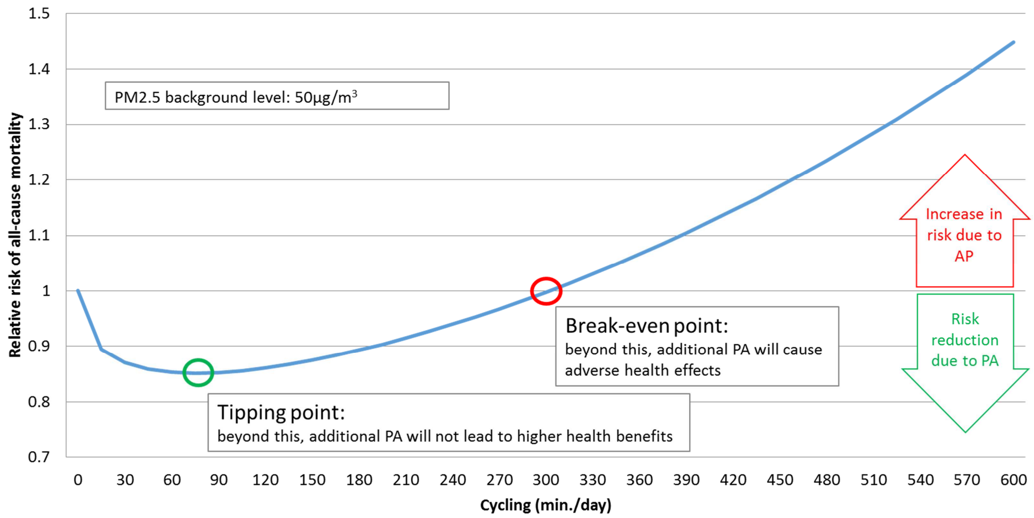
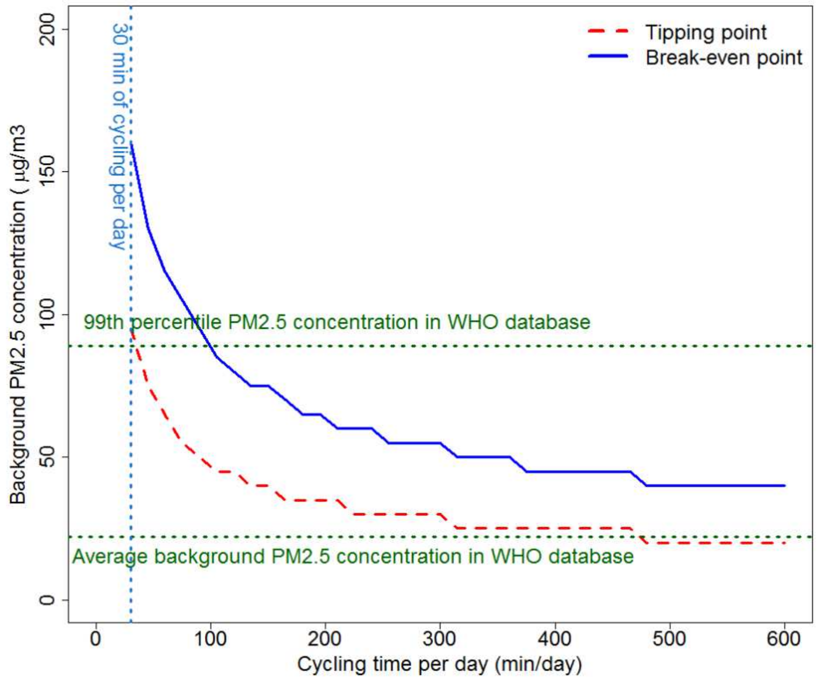


Figure 2: Tipping and break-even points for different levels of cycling (red dashed line and blue solid line, respectively) (minutes per day, x-axis) and for different background PM2.5 concentrations (y-axis). Green lines represent the average and 99th percentile background PM2.5 concentrations in World Health Organization (WHO) Ambient Air Pollution Database[8].



Supplementary data

Tainio et al. Can air pollution negate the health benefits of cycling and walking?

Methods - sensitivity analyses

Shape of dose-response function (DRF) for cycling and walking

In the main analyses we assumed the "power 0.50" shape for DRFs for cycling and walking as a compromise between linear and extremely non-linear DRFs. As a sensitivity analysis we also ran calculations with "log-linear" and "0.25-power transformed" DRFs. See Figure S1 below for illustration of different DRFs for cycling, and their impact to all-cause mortality.

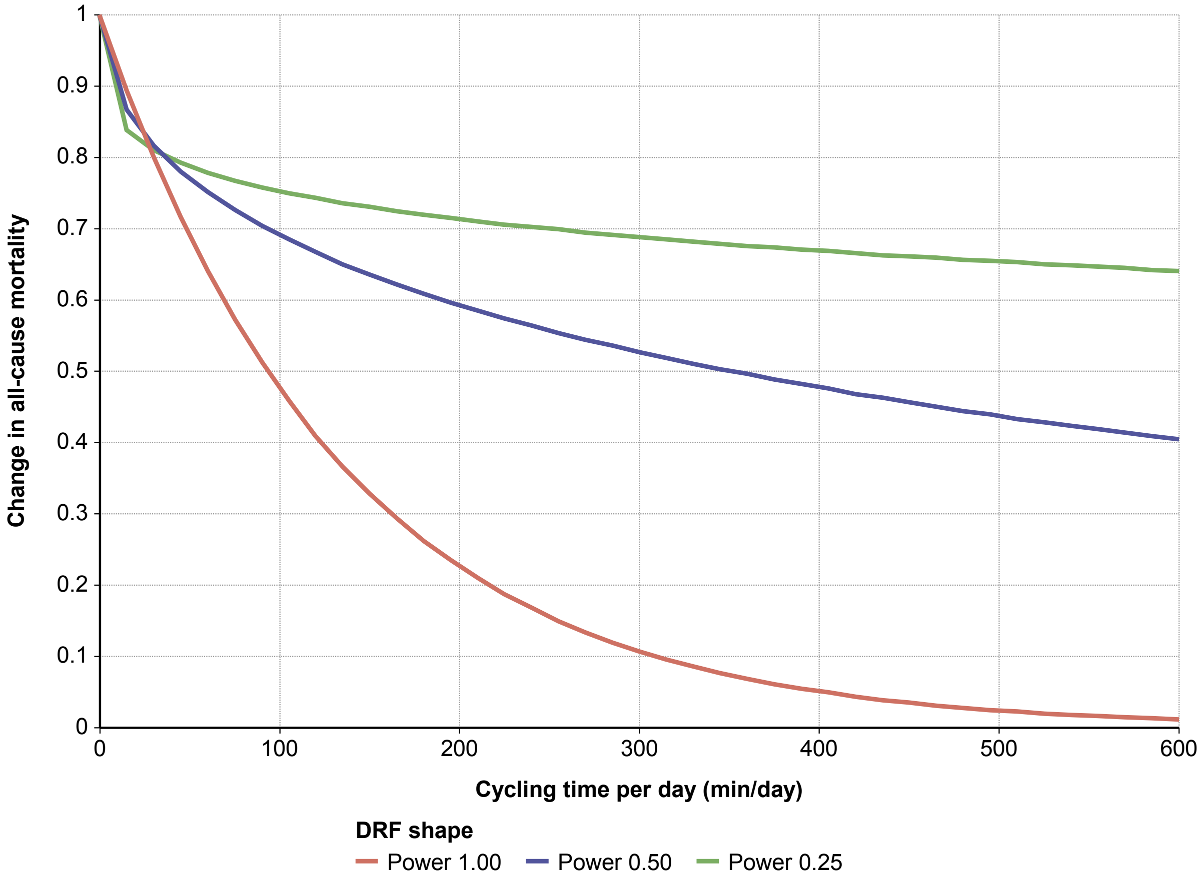


Figure S1: Different transformations for dose-response function (DRF) for cycling. "Power 0.50" was the main DRF used in the analysis. DRFs are adopted from (Kelly et al. 2014).

Air pollution adjusted DRF's

Studies examining the health benefits of physical activity (PA) underestimate the benefits because the participants of these studies are exposed to local air pollution. Kelly et al., previously calculated pooled relative risks for walking and cycling using random-effects meta-analysis of risk estimates at 11.25 MET.hrs/week from included prospective cohort studies. Rojas Rueda (2014 – unpublished work) adjusted the risk estimates for each cohort study by estimating air pollution (PM2.5) exposure in each risk group. We re-calculated an air-pollution adjusted pooled relative risk for walking and cycling using random-effects meta-analysis of these adjusted risk estimates. See Table S1 (below) for comparison of adjusted and non-adjusted DRFs for cycling and walking for log-linear DRFs.

Table S1: RR for cycling and walking with and without adjustment for background air pollution concentrations, based on reanalysis of Kelly et al. (2014) (95% confidence intervals in parenthesis). RR are per 11.25 METh/week change in cycling and walking. Log-linear DRF was assumed in these calculations.

RR	Cycling	Walking
RR	0.903 (0.866-0.943)	0.886 (0.806-0.973)
RR (adjusted)	0.901 (0.863-0.940)	0.884 (0.804-0.971)

Counterfactual scenario from car transport

In the main analyses we assumed that counterfactual scenario for cycling is to stay at home. As a sensitivity analysis we also repeated the calculation assuming that increasing cycling would occur by changing the mode of travel from car to bike. In such scenario we assumed that the exposure concentration would decrease 20% (based on updated review of exposure studies comparing exposure concentration in bicycle and car (Kahlmeier et al. 2014)). In this scenario the exposure to PM2.5 was still assumed to increase because of the ventilation rate differences between car (rest ventilation rate was assumed) and bike. We also assumed that time spent driving and cycling would be same.

Shape of the DRF for PM2.5

In the main analyses the DRF for PM2.5 was assumed to be linear. As a sensitivity analyses we calculated the results by using the DRFs from (Burnett et al. 2014). Burnett et al. predicted non-linear DRF for PM2.5 air pollution for different diseases. The DRF for stroke was the most non-linear with maximum harm reached around 300 µg/m3 concentrations. We used Burnett et al.'s DRF for stroke as a hypothetical non-linear DRF for all-cause mortality to predict how non-linear PM2.5 DRF would change the results. See Figure S2 below for illustration of both DRFs for PM2.5.

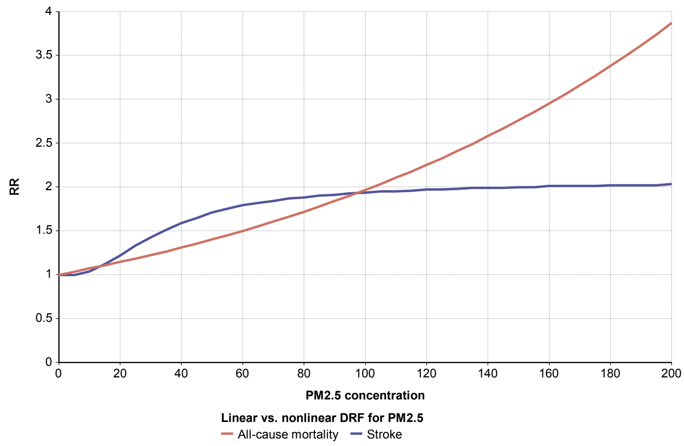


Figure S2: Comparison of linear and nonlinear dose-response function (DRF) for PM2.5 air pollution. Non-linear DRF (Stroke) was obtained from (Burnett et al. 2014).

Results – additional figures and tables

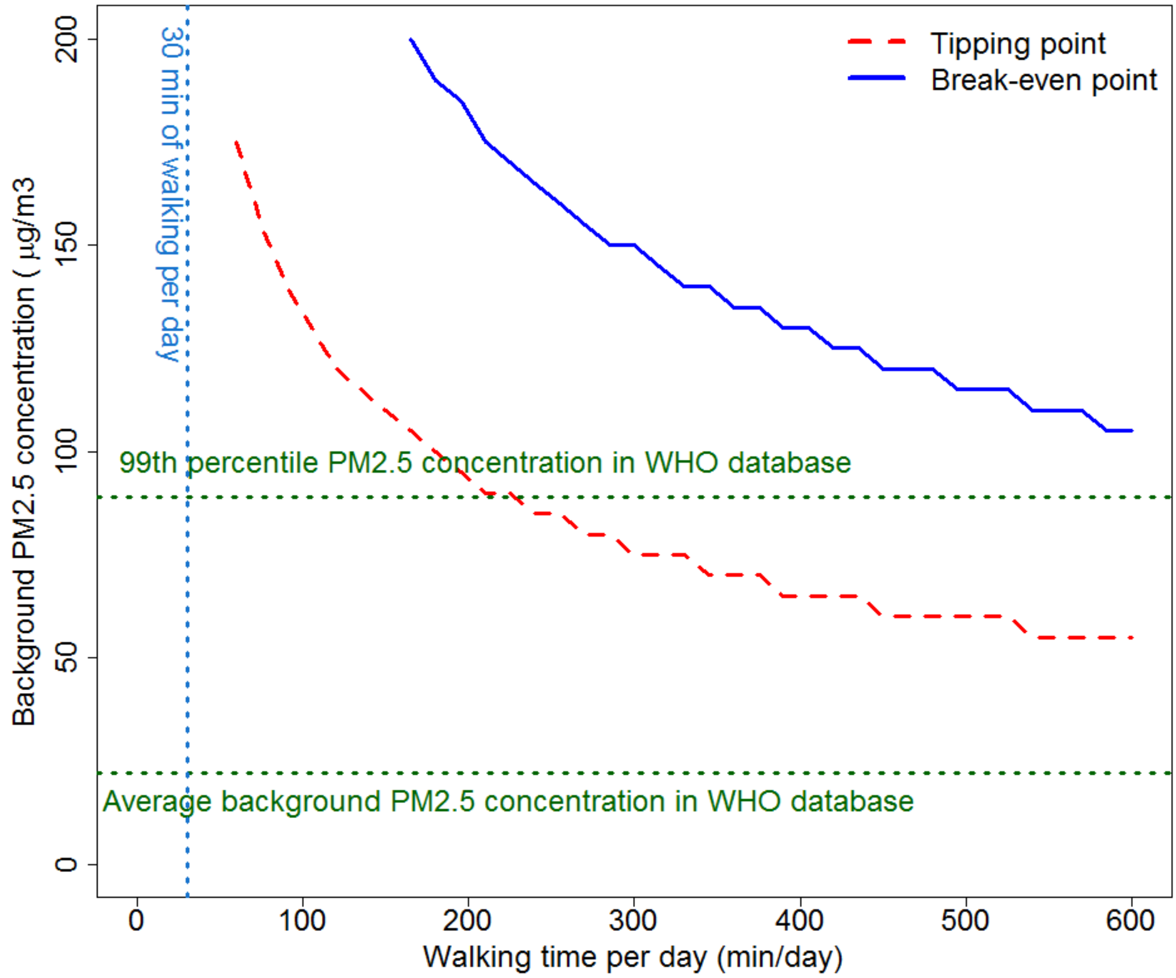


Figure S3: Tipping and break-even points for different levels of walking (red dashed line and blue solid line, respectively) (minutes per day, x-axis) and for different background PM2.5 concentrations (y-axis). Green lines represent the average and 99th percentile background PM2.5 concentrations in World Health Organization (WHO) Ambient Air Pollution Database (World Health Organization (WHO) 2014).

Table S2: Tipping and break-even points for cycling in different WHO regions (World Health Organization (WHO) 2014). *The average represents the average city in the region and max the city with highest background PM2.5 concentration. PM2.5 concentrations are from WHO* (see article for details).

	Average city			Most polluted city		
Region	PM2.5 (µg/m3)	Tipping point (cycling /day)	Break-event point (cycling /day)	PM2.5 (µg/m3)	Tipping point (cycling /day)	Break-event point (cycling /day)
Africa	26	5h	-	66	1h	3h
Americas	21	7h45min	-	44	2h	6h45min
Eastern Mediterranean	72	45min	2h30min	117	30min	1h
Europe	37	2h30min	9h15min	90	45min	1h45min
South-East Asia	43	2h	7h	153	30min	45min
Western Pacific	39	2h15min	8h30min	80	45min	2h

Table S3: Tipping and break-even points for walking in different WHO regions (World Health Organization (WHO) 2014). *The average represents the average city in the region and max the city with highest background PM2.5 concentration. PM2.5 concentrations are from WHO* (see article for details).

	Average city			Most polluted city		
Region	PM2.5 (µg/m3)	Tipping point (walking /day)	Break-event point (walking /day)	PM2.5 (µg/m3)	Tipping point (walking /day)	Break-event point (walking /day)
Africa	26	-	-	66	6h15min	-
Americas	21	-	-	44	14h	-
Eastern Mediterranean	72	5h30min	-	117	2h15min	7h45min
Europe	37	-	-	90	3h30min	13h15min
South-East Asia	43	14h45min	-	153	1h30min	4h45min
Western Pacific	39	-	-	80	4h30min	-

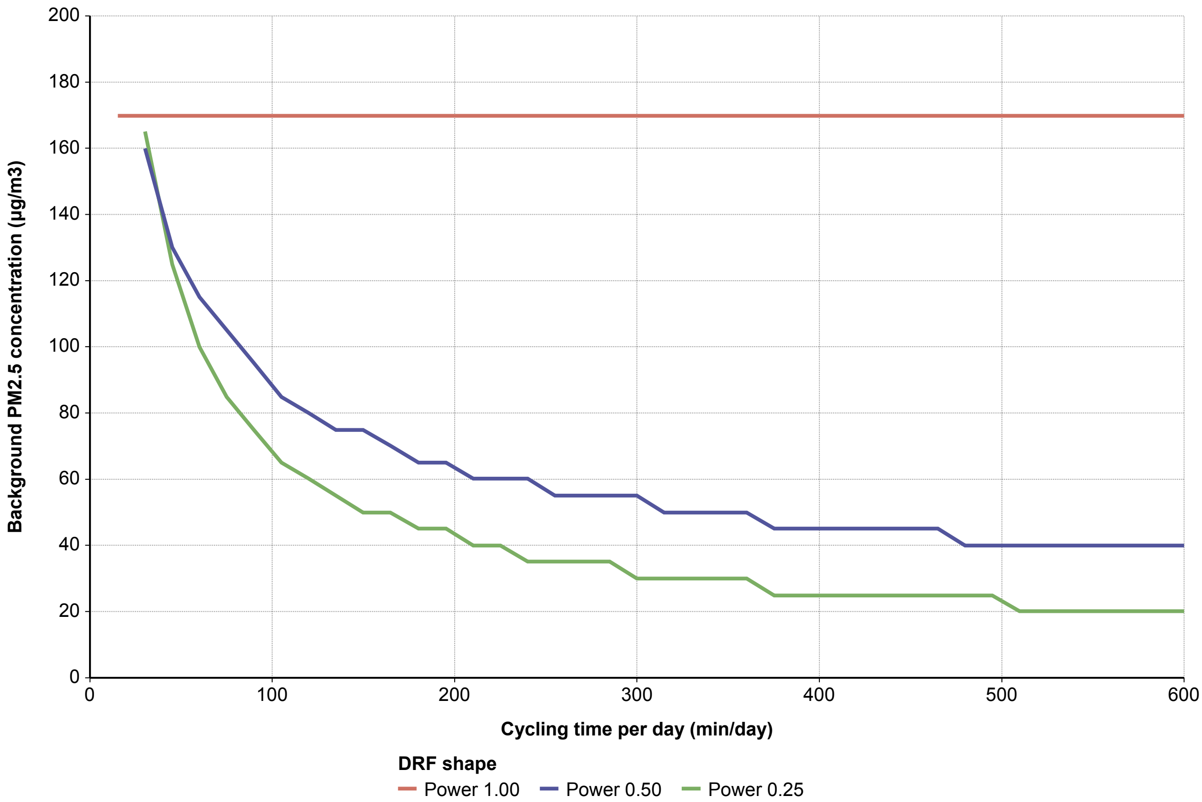


Figure S4: Break-even point for different DRFs for cycling (see Figure S1). Blue line represent the main analysis, green line break-even point "power 0.25" DRF for cycling and brown line break-even point "power 1.00" DRF for cycling. With the log-linear DRF (power 1.00) the risk of air pollution was always higher than physical activity benefits with the background PM2.5 concentration of 170 µg/m3.

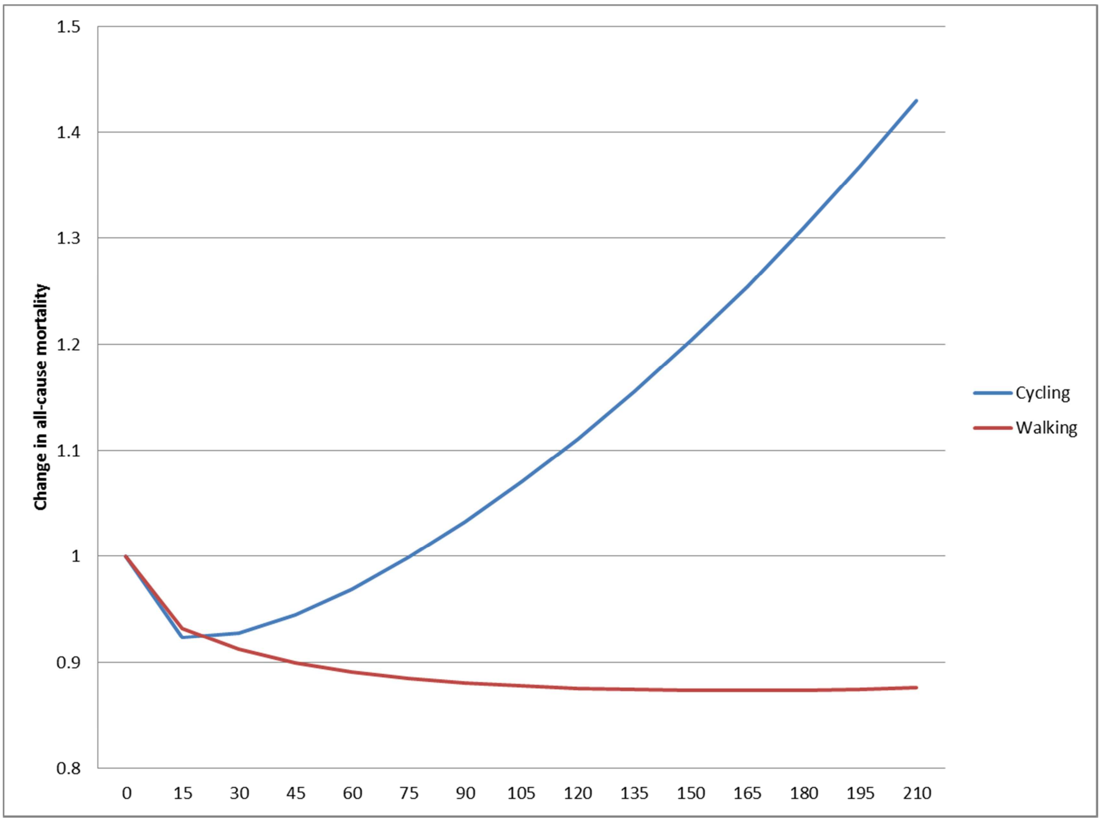


Figure S5: The change in all-cause mortality for cycling and walking for the background PM2.5 concentration of 100 µg/m3. The x-axis represent cycling and walking time per day (min) and y-axis change in all-cause mortality when both physical activity benefits and air pollution risks were taken into account.

References

Burnett, Richard T, C Arden Pope, Majid Ezzati, Casey Olives, Stephen S Lim, Sumi Mehta, Hwashin H Shin, et al. 2014. "An Integrated Risk Function for Estimating the Global Burden of Disease Attributable to Ambient Fine Particulate Matter Exposure." *Environmental Health Perspectives* 122 (4): 397–403. doi:10.1289/ehp.1307049.

Kahlmeier, Sonja, Christian Schweizer, David Rojas-Rueda, Mark Nieuwenhuijsen, Audrey de Nazelle, and Olivier Bode. 2014. *Development of the Health Economic Assessment Tools (HEAT) for Walking and Cycling - Meeting Background Document*. Bonn. Germany.

Kelly, Paul, Sonja Kahlmeier, Thomas Götschi, Nicola Orsini, Justin Richards, Nia Roberts, Peter Scarborough, and Charlie Foster. 2014. "Systematic Review and Meta-Analysis of Reduction in All-Cause Mortality from Walking and Cycling and Shape of Dose Response Relationship." *The International Journal of Behavioral Nutrition and Physical Activity* 11 (1): 132. doi:10.1186/s12966-014-0132-x.

World Health Organization (WHO). 2014. "Ambient Air Pollution Database." http://apps.who.int/gho/data/view.main.AMBIENTCITY2014?lang=en.