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Brief Original Report

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

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ABSTRACT

Active travel (cycling, walking) is beneficial for the 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 ($PM_{2.5}$), ranging from 5 to 200 μg/m3. For active travel exposure, we estimated cycling and walking from 0 up to 16 h per day, respectively. These refer to long-term average levels of active travel and $PM_{2.5}$ exposure.

For the global average urban background $PM_{2.5}$ 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 $PM_{2.5}$ concentrations of 100 μg/m3, harms would exceed benefits after 1 h 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 $PM_{2.5}$ and PA.

PA benefits of active travel outweighed the harm caused by air pollution in all but the most extreme air pollution concentrations.

Introduction

Several health impact modelling (HIM) studies have estimated the health benefits and risks of active travel (cycling, walking) in different geographical areas (Mueller et al., 2015; Doorley et al., 2015). 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 (Mueller et al., 2015; Doorley et al., 2015). 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 (Kelly et al., 2014; World Health Organization, 2014). 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 (Fig. 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 starts outweighing the benefits of PA (i.e. there are no longer net benefits, compared to not engaging in active travel).

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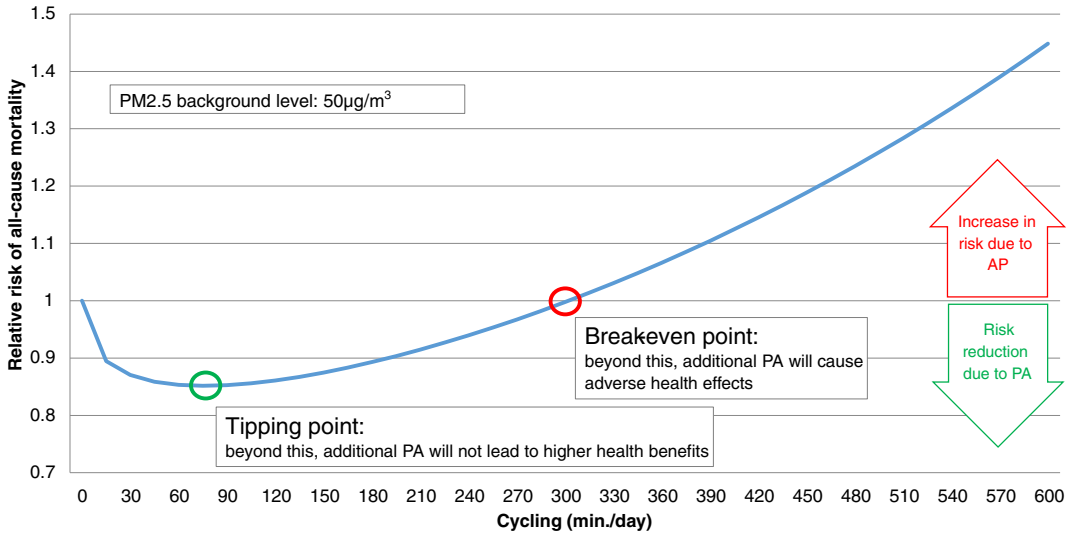

Fig. 1. Illustration of tipping point and break-even point as measured by the relative risk (RR) for all-cause mortality (ACM) combining the effects of air pollution (at 50 µg/m^3 $PM_{2.5}$) and physical activity (cycling).

Methods

Our approach followed a general active travel HIM method (Mueller et al., 2015; Doorley et al., 2015). Air pollution exposures due to active travel were quantified by estimating the differences in the inhaled dose of fine particulate matter ($PM_{2.5}$) air pollution. We selected $PM_{2.5}$ because it is a commonly used indicator of air pollution in active travel HIM studies (Mueller et al., 2015; Doorley et al., 2015), and because of the large health burden caused by $PM_{2.5}$ (GBD 2013 Risk Factors Collaborators et al., 2015). 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 $PM_{2.5}$ (Héroux et al., 2015) and long-term PA behaviour (Kelly et al., 2014).

The reduction in all-cause mortality from active travel was estimated by converting the time spent cycling or walking to metabolically equivalent of task (MET) 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. (2014) we chose the one with the "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 a tipping point would be reached earlier than with more linear DRFs. See supplementary material for the sensitivity analysis with different DRFs. To convert cycling and walking time to PA we used the values of 4.0 METs for walking and 6.8 METs for cycling, based on the Compendium of Physical Activities (Ainsworth et al., 2011). The walking and cycling levels used in this study are assumed to reflect long-term average behaviour.

The health risks of $PM_{2.5}$ were estimated by converting background $PM_{2.5}$ concentrations to travel mode specific exposure concentrations, and by taking into account ventilation rate whilst being active. For background $PM_{2.5}$ 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 (World Health Organization (WHO), 2014), which contains measured and estimated background $PM_{2.5}$ concentrations for 1622 cities around the world.

The mode specific exposure concentrations were estimated by multiplying background $PM_{2.5}$ concentration by 2.0 for cycling or 1.1 for walking, based on a review of studies (Kahlmeier et al., 2014). The counterfactual scenario for the time spent cycling or walking was assumed to be staying at home (i.e. in background concentration of $PM_{2.5}$). See supplementary file for the sensitivity analysis with counterfactual scenarios where cycling time would replace motorised transport time. The ventilation rates differences whilst 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 (de Nazelle et al., 2009; Johnson, 2002). The sleep time was assumed to be 8 h in all scenarios and the resting time was 16 h minus the time for active travel.

For the $PM_{2.5}$ DRF we used a relative risk (RR) value of 1.07 per 10 µg/m3 change in exposure (World Health Organization, 2014). 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. (2014) (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 the main results is provided in Microsoft Excel format in supplementary file 3.

Results

The tipping point and break-even point for different average cycling times and background $PM_{2.5}$ concentrations are shown in Fig. 2. For half an hour of cycling every day, the background $PM_{2.5}$ 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 $PM_{2.5}$ annual concentrations above that level (World Health Organization (WHO), 2014). The break-even point for half an hour of cycling every day was at 160 µg/m3 (Fig. 2). For half an hour of walking the tipping point and break-even point appear at a background concentration level above 200 µg/m3 (Fig. S3, supplementary file). For the average urban background $PM_{2.5}$ concentration (22 µg/m3) in the WHO database, the tipping point would only be reached after 7 h of cycling and 16 h of walking per day.

Tables S2 and S3 (supplementary file) show 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 min 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 min per day for cycling, and 90 min to 6 h 15 min per day for walking (Table S3, supplementary material).

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