Waltham Forest study of life expectancy benefits of increased physical activity from walking and cycling

For: Waltham Forest local authority

By: David Dajnak and Heather Walton

Address: Environmental Research Group, School of Analytical, Environmental and Forensic Sciences , King's College London, Franklin-Wilkins Building, 150 Stamford Street, London, SE1 9NH, United Kingdom.

Tel: +44 207 848 4012, **email:** david.dajnak@kcl.ac.uk

Web: https://www.kcl.ac.uk/lsm/research/divisions/aes/research/ERG/index.aspx

London monitoring: http://www.londonair.org.uk/LondonAir/Default.aspx

Executive Summary and Key results

Waltham Forest (WF) commissioned King's College London (King's) to look at the beneficial effects of cycling and increased pedestrianism on health in terms of calorie expenditure, as well as changes in knowledge, attitudes and practices of residents and visitors resulting from changes to the area.

There are many studies showing links between increased physical activity and reduced risks of all-cause mortality (mainly via reduced risks of cardiovascular mortality). This report is the second (of two[1]) describing the benefits of reduced mortality from increased physical activity in Waltham Forest. This was done by incorporating physical activity data into the King's College London lifetable tool for the first time. More specifically it covers:

- Health benefits of physical activity such as cycling/walking in Waltham Forest
- Health benefits of physical activity from the school run

For general trends in physical activity, King's obtained London Travel Demand Survey (LTDS) data on numbers and duration of Waltham Forest walking and cycling trips from Transport for London which, when combined with relationships between physical activity and mortality, was used to calculate the gains in life-expectancy from the increases in walking and cycling in Waltham Forest.

The school run calculations were similar but the physical activity associated with the school run used Sustainable Travel: Active, Responsible, Safe (STARS) survey data. School run trends over time were derived from estimates of potential increases in walking or cycling journeys to school provided by the Enjoy Waltham Forest team based on existing trends and speculative scenarios considered to be broadly achievable.

Health Impact Assessment (HIA) of physical activity in Waltham Forest

In this study, for the first time, King's have developed a method to quantify the effects of physical activity from walking and cycling on health outcomes in Waltham Forest.

Mortality impact results for physical activity in Waltham Forest are all expressed in terms of life years – the most appropriate metric for the health impact of physical activity changes over time. Calculations are given for walking and cycling separately in the main body of this report but the end results have simply been added up in the text below.

Overall benefits of routine walking and cycling activity (taking into account recent increases)
The population in Waltham Forest is estimated to gain around 204,000 life years (a life year is one person living for one year) over a lifetime from the projected level of combined walking and cycling activity between 2006 to 2016 (2016 levels then maintained). This can also be represented as a gain in average life expectancy from birth in 2006 of around 7 to 9 months.

Proportion of above benefits resulting from increased activity between 2006 and 2016

[1] King's first report covered Waltham Forest air quality modelling, Emissions impacts of the School run, Air quality exposure whilst cycling and walking and, Air Quality Health Impact Assessment. https://drive.google.com/file/d/1MGyThE5H9lgrzhCkjQlKKg7vhuW6pGMR/view

The above figure includes an estimation for the population in Waltham Forest of around 36,000 life years gained over a lifetime, and an increase in average life expectancy from birth in 2006 of around 1.5 months, if the combined walking and cycling levels improve as projected to 2016, compared with remaining at 2006 levels. If the 2006 walking and cycling level remained unchanged for 115 years, around 162,000 life years would be gained across WF's population over that period.

HIA of physical activity from School run and a modal shift

In this report, King's also looked at the school run and concentrated on the physical activity benefits for the adults accompanying the pupils walking, scooting or cycling to primary school. Furthermore, King's calculated the potential improvements of a modal change from doing the school run by cars switching to walking, scooting or cycling.

There is evidence that physical activity in childhood increases the likelihood of maintaining physical activity in adulthood but this is hard to quantify exactly. If this was taken into account, the health benefit estimated in this section could be up to twice as much.

The health benefits have been be calculated in a similar manner to the previous section.

Overall benefits associated with the school run walking and cycling activity (taking into account recent increases)
The population in Waltham Forest is estimated to gain around 13,000 to 17,000 life years over a lifetime from the projected level of walking and cycling activity during the school run between 2013 to 2020 (2020 levels then maintained). This can also be represented as a gain in average life expectancy from birth in 2013 of around 2 to 3 weeks.

Proportion of above benefits resulting from increased school run activity between 2013 and 2020
The population in Waltham Forest will gain around 2,000 to 6,000 life years over a lifetime, and increase average life expectancy from birth in 2013 by around 2 to 5 days, if the school run walking and cycling levels improve as projected to 2020, compared with remaining at 2013 levels. If the 2013 walking and cycling level remained unchanged for 112 years, around 10,900 life years would be gained across WF's population over that period.

Limitations

The main report presents a wider range of uncertainty around the results for the gains in life years.

The input data is based on reports of travel activity on a single day distributed across different days and different people. It may not fully capture less frequent episodes of walking or cycling that are more intense or of longer duration and it does not capture non-travel activities such as cycling or running in the gym (which was not an intended focus of the study).

The benefits of a given increase in physical activity are greater in those that were previously inactive and lower in those that were already moderately active. It was not possible to analyse the data in this way in this study, as the input data did not include information on prior levels of physical activity. Further work on this aspect is recommended.

Table of Contents

1 Approach

Other health benefits beyond air quality, most notably physical activity, could be important for active travel policies. Metabolic Equivalent Task (MET) is a measure of calorie expenditure (sitting is a MET of 1). Kelly et al (2014) reviewed studies on walking and cycling, scaled them to a common scale of metabolic equivalent (MET)-hours per week and pooled the studies to give a response function between walking and cycling and all-cause mortality. This response function can be put into life-tables in the same way as is done for air pollution concentration-response functions (assumptions would need to be made about the age distribution in a small area, provided an area is large enough to have a full range of age groups). There are also online tools to do this such as the WHO HEAT tool (WHO, 2017a) that are designed to be straightforward so are not ideal in some respects; expert commentary on the interpretation of using simpler methods such as the HEAT tool (WHO, 2017b) have been provided in the appendix.

King's investigated how walking and cycling data collected in Waltham Forest can be best converted to MET-hours per week, taking into account the number of people affected. King's collected data from several reports (personal communication with Enjoy Waltham Forest Team and Transport for London) such as

- Waltham Forest Travel survey (2017) (personal communication with Enjoy Waltham Forest Team): provided a wide range of data including minutes of walking or cycling per week but no information on trends over time in the minutes per week.
- London Borough of Waltham Forest Walthamstow Village Review (2017): provided some measurements of bicycle count data on some roads. It shows increased cycling traffic on some more attractive routes and also a reduction on some back road streets. Cycle counts do not give any indication of the duration of journeys as needed for conversion to MET hours per week so this data was not suitable for the purpose of this analysis.
- Enjoy Waltham Forest Walking and Cycling account (2017) and London Borough of Waltham Forest 2020 Vision "Cycling in the London borough of Waltham Forest 2015-2020": cycle training data shows a sharp increase in individual, group and child training. This data clearly shows evidence that there is an increased interest in learning how to ride a bike but this data could not be used to estimate minutes of cycling activity per week.
- Waltham Forest Health and Wellbeing Strategy 2016-2020: data shows that people using outside space for exercise/health reasons has increased more sharply in Waltham Forest when compared with London overall between 2011 and 2014. Again this data could not be used to estimate a change in walking and cycling quantitatively in Waltham Forest.
- The Enjoy Waltham Forest Team provided cycling counts as monthly averages on a few roads for some of the months in 2016/2017 and demographic data on the cycling training sessions. Again, while this provided contextual information it was not suitable for conversion to MET hours per week.
- Public Health England outcome framework website (Public Health England[2]): shows indicators on numbers following CMO (Chief Medical Officer) recommendations for physical activity such as the percentage of the Waltham Forest population meeting 150+, 30-149 minutes or less than 30 minutes of moderate intensity equivalent minutes per week. Due to a change in methodology, this data was only available for the year 2015/2016 and 2016/2017. King's recommend that this type of data could be used in future work to

[2] https://fingertips.phe.org.uk/search/physical%20activity#page/3/gid/1/pat/6/par/E12000007/ati/102/are/E09000031/iid/93014/age/298/sex/4 (based on Active Lives, Sport England)

build a more complex method taking into account physical activity categorisation using an incremental change in risk for each (MET)-hours per week increase in walking or cycling for moving between the different activity categories. Kelly et al, 2014 showed that the same increment of additional physical activity may be of more benefit in those that were previously inactive.

- London Travel Demand Survey (LTDS): provides a picture of travel by London's residents[3]. The LTDS survey captures information from around 8,000 households (age 5 plus) per year on the trips that those people make on a specific day. LTDS provides mode and duration of trips including walking and cycling over many years ranging from 2006 to 2016 and it is designed to enable statistically-robust representative estimates of travel patterns and demand in London. It was concluded that this was a good source of data for this project.

King's established that the best approach in the time available was the following method steps

- Obtain information on minutes per week of walking or cycling specific to Waltham Forest from LTDS survey (STARS survey for the school run analysis in section 4).
- Define a trend from 2006-2016 (2013 to 2020 for the school run analysis in section 4).
- Convert the trend in minutes per week to MET-hours per week (a measure of physical effort and duration).
- Convert the change in MET-hours per week of physical activity to a change in mortality using information on this relationship from several previous studies in the literature pooled by Kelly et al (2014).
- Adapt King's air quality life-table tool by keeping the life-table part that is directly applicable but by modifying the interface and input mechanisms (i.e. by replacing the air quality part of the tool by walking and cycling physical activity input data and a specific physical activity and mortality response function).
- Estimate changes in life expectancy using lifetables.

[3] https://tfl.gov.uk/corporate/about-tfl/how-we-work/planning-for-the-future/consultations-and-surveys/london-travel-demand-survey (accessed August 2018)

2 Analysis of LTDS data

For walking and cycling physical activity (PA) specific data in Waltham Forest, we used yearly Waltham Forest residents' Active travel data between 2006 and 2016 from the London Transport Demand Survey (LTDS) (personal communication with Hannah Groot at TfL).
LTDS data gives an average level of walking and cycling across the whole of the Waltham Forest population age 5+. The total life years saved across the population will be a reasonable estimate using this method, but it has to be borne in mind that the benefits are not in fact evenly distributed (see Appendix section for more details). The LTDS yearly data were used to calculate a trend line using a simple linear regression model as shown in Figure 1 and Figure 2 for walking and cycling, respectively. The statistical analyses were conducted using STATA 12[4]. The 95% confidence and prediction intervals were constructed based on the fitted values and the corresponding standard errors. Figure 1 and Figure 2 show the change in physical activity from walking and cycling between 2006 and 2016 as expressed in minutes per day per person age 5 plus in Waltham Forest.

Waltham Forest walking and cycling trend lines were further scaled[5] by gender and age group (see Table 1) using all London residents' active travel data between 2006 and 2016 from the LTDS dataset (personal communication with Hannah Groot at TfL). Table 1 shows the London mean ratio of yearly walking and cycling physical activity between 2006 and 2016 by gender and age group to the mean yearly walking and cycling for all genders and all ages above 5.

Table 1 Mean walking and cycling ratio by age group and gender between 2006 and 2016 in London

Age group	Gender	Walking Ratio to all ages	Cycling Ratio to all ages
05-16	Male	0.817	0.719
05-16	Female	0.908	0.395
17-24	Male	1.009	1.128
17-24	Female	1.207	0.410
25-44	Male	1.024	1.984
25-44	Female	1.236	0.832
45-59	Male	0.877	1.640
45-59	Female	0.997	0.689
60-64	Male	0.835	1.054
60-64	Female	0.930	0.417
65-74	Male	0.933	0.573
65-74	Female	0.956	0.233
75-84	Male	0.678	0.458
75-84	Female	0.694	0.212
85Plus	Male	0.405	0.336
85Plus	Female	0.415	0.189

LTDS age group data were expanded from 65Plus to further age groups such as 65-74, 75-84 and 85Plus using the Active Lives Adults Survey (2018).

[4] StataCorp. 2011. Stata Statistical Software: Release 12. College Station, TX: StataCorp LP.
[5] The LTDS do not provide this information directly by local authority as survey numbers are too small in some age groups. It is assumed that the age distribution of walking and cycling in WF matches the robust London data.

The original LTDS data was given in minutes per person (age 5 plus) per day. This was converted to hours per week and then to MET hours per week using the metabolic equivalent data values for 'cycling to/from work/self-selected pace' and 'walking to work or class'[6] from the 2011 Compendium of Physical Activities (Ainsworth *et al,* 2011). The LTDS covers travel rather than leisure activity that does not involve a journey (e.g. cycling or running in the gym).

Waltham Forest and London's LTDS walking and cycling yearly data are available upon request to the authors, subject to discussion with Transport for London who own the original data.

[6] 6.8 and 4, respectively.

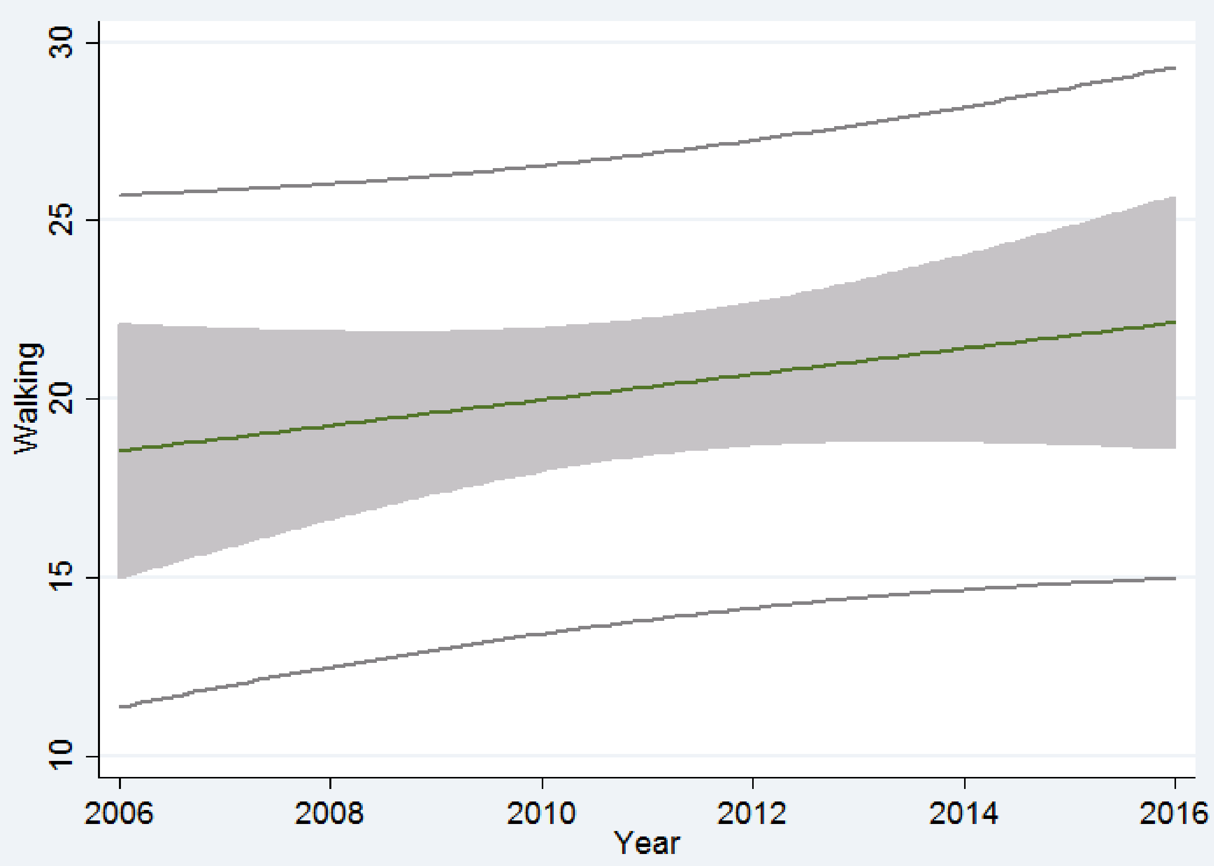

Figure 1 Walking (minutes per person per day) trend in Waltham Forest between 2006 and 2016 with 95% confidence interval and wider prediction interval lines

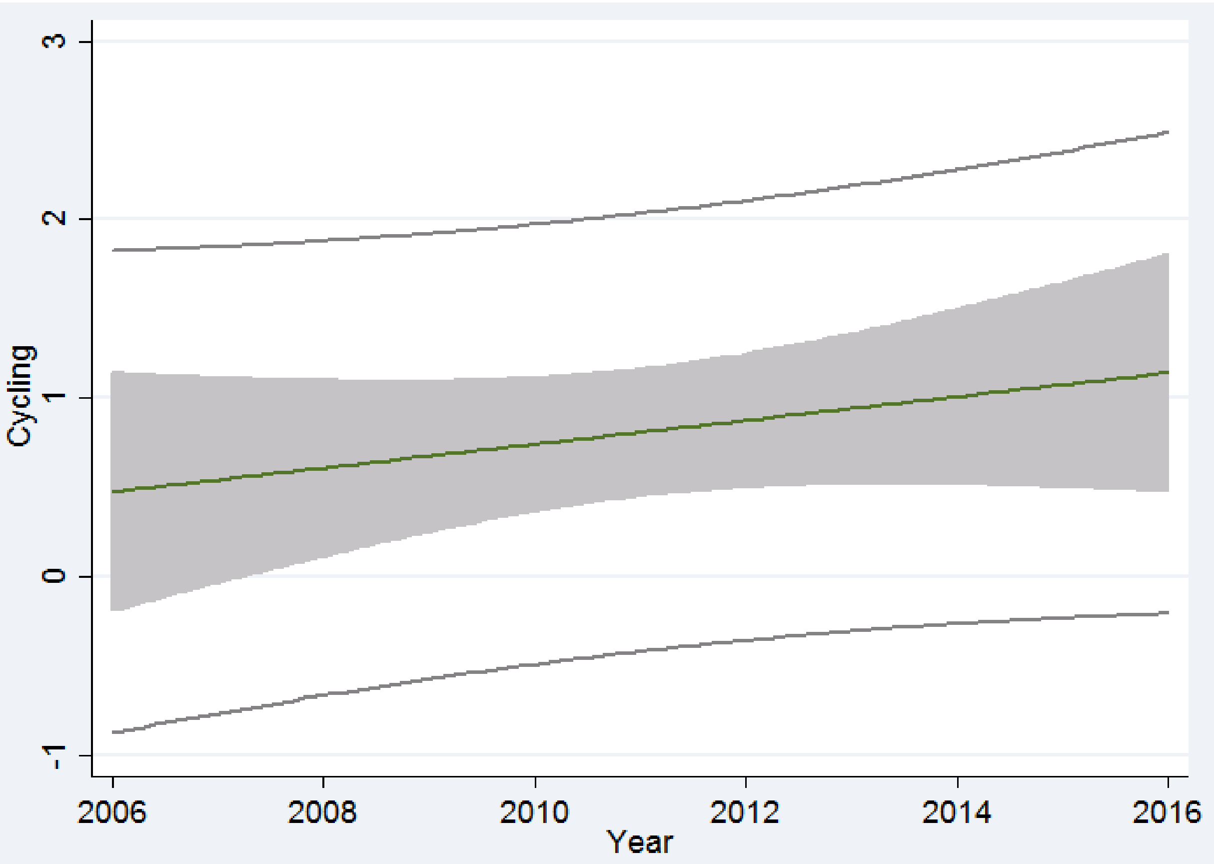

Figure 2 Cycling (minutes per person per day) trend in Waltham Forest between 2006 and 2016 with 95% confidence interval and wider prediction interval lines

3 Health Impact Assessment (HIA) of Physical Activity in Waltham Forest

HIA for PA methods

The health impact assessment from physical activity methodology has been covered in detail in the appendix (as well as in section 1 and 2 above) and can be summarised as follow

- Physical activity for walking and cycling was converted to hours per week and then to MET hours per week using the metabolic equivalent data values for cycling and walking[7] (see Table 2).
- A response function (hazard ratio)[8] between walking and cycling and all-cause mortality derived from Kelly et al (2014) and a common scale of 11.25 metabolic equivalents (MET)-hours per week was used (see Table 2).
- The walking and cycling Hazard Ratio (HR) of 0.90 at 11.25 MET hours per week was used (see Table 2 for confidence interval).
- The equation used was: $HR(x) = 0.90^{(x/11.25)}$ where x is the MET hours per week of interest[9].
- The hazard ratio (HR) per 11.25 MET hours per week was scaled to a new relative risk for the appropriate MET hours per week for each gender and age group in Waltham Forest for each scenario and year (taking into account the lag, see below).
- This HR was put into life-tables in the same way as was done for air pollution concentration-response functions.
- Age distribution and gender was taken into account.
- The changes in life expectancy using lifetables were estimated for the population ranging from 20 to 90 years of age (see Table 2).
- The total life years saved were calculated based on the average level of walking and cycling across the whole population. This method was a reasonable estimate, but it has to be borne in mind that the benefits are not in fact evenly distributed (see Appendix section for more details).
- A lag was used to allow for a delay between exposure and effect.
- Projected changes in birth rates and improvements in baseline mortality rates were included.
- The life years saved for the 2006 level of walking and cycling, assuming this was maintained over time, were used as the counterfactual scenario.
- The life years saved for the increasing trend in walking and cycling between 2006 and 2016, maintained over a lifetime were also calculated.
- The time period for both scenarios was 2006 to 2120, i.e. 105 years after 2016 (as mortality rates are higher in the elderly and the benefits of physical activity occur over time (rather than instantly as a result of one-off physical activity) it is important to follow-up the benefits over an extended period).

---

[7] 6.8 and 4, respectively.

[8] A hazard ratio is the ratio of the hazard in a particular age group with a given level of risk relative to a baseline. It is similar to a relative risk.

[9] X is positive for an increase, negative for a decrease in physical activity. (Positive in this work (see Appendix).

Table 2 Physical activity-response functions (PARFs) for mortality

	Input	Source	Comment
Response function	HR% (Hazard Ratio) increase for a change from inactive to 11.25 MET hours per week	Kelly *et al* (2014)	
Walking HR%	0.90 CI (0.85-0.95))	Kelly *et al* (2014)	
Cycling HR%	0.90 CI (0.89-0.94))	Kelly *et al* (2014)	
Conversion hours per week to MET hours per week	Walking: 4 MET	Kelly *et al* (2014)	Kelly *et al* in turn obtained these from Ainsworth *et al* (2011)
	Cycling: 6.8 MET	Kelly *et al* (2014)	
Population at risk	20 plus Up to 90	Kelly *et al* (2014)	Studies in Kelly et al meta-analysis used various age groups, some elderly, but several had a minimum age of 20. The review did not cover effects under 20. King's made a judgement that the data above the age of 90 was less reliable (fewer survey responses) and the averaged physical activity was assumed to be minimal above the age of 90.
Lag	30% of the effect in the first year, 12.5% in each of years 2-5 and 20% spread over years 5-20	Blair *et al* (1995), analogy with air pollution, discussion with Marko Tainio	As for air pollution, effects are dominated by changes in cardiovascular mortality with a probable small contribution from changes in cancer mortality with a longer lag. See Appendix.

<u>Estimates of the mortality impact of physical activity results</u>

The results from the life table calculations assuming that the physical activity (PA) does not reduce from 2006 levels and assuming the predicted physical activity between 2006 and 2016 (PA was modelled at 2006 and 2016 but also interpolated for the intervening years) are shown in Table 3, for walking and cycling. As discussed in the appendix, King's considered it was reasonable to calculate the reduction in mortality benefits of the 2006 level of walking and cycling as if it was an increase over baseline levels of physical activity as the level of walking and cycling in 2006 was already in the context of an upward trend (see Appendix for more details).

The life years gained gives a large number because the life years (one person living for one year) is summed over the whole population in Waltham Forest over 115 years. For context, the total life years lived with baseline mortality rates is around 42 million, so these gains in life years involve about 0.4% of total life years lived.

If the 2006 walking level remained unchanged for 115 years, around 162,000 life years would be gained across WF's population over that period. This improves to around 191,000 life years gained with the predicted walking level between 2006 and 2016 changes examined here.

If the 2006 cycling level remained unchanged for 115 years, around 5,700 life years would be gained across WF's population over that period. This improves to around 13,200 life years gained with the cycling between 2006 and 2016 changes examined here. The average across the population looks small because it is generated by only the proportion of the population that cycle as discussed in the appendix.

As the activity was averaged across the Waltham Forest population and assumed to be approximately linear, it is possible to combine the walking and cycling calculations (see Appendix for further details). We simply added the end results.

So the <u>overall summary</u> for the projected future changes in walking and cycling from 2006 to 2016 would be around <u>204,000 life years gained</u> for the population of Waltham Forest over 115 years.

Table 3 *Total life years gained across WF population for walking and cycling (central and lower-upper estimate)*

Physical Activity	**Scenario**	**Life years gained** **Central (Lower-Upper) estimate**
Walking	Walking does not increase from 2006 levels	161,849 (79,709-246,621)
	Walking level changes between 2006 and 2016	190,736 (94,139-289,973)
Cycling	Cycling does not increase from 2006 levels	5,696 (3,347-8,148)
	Cycling level changes between 2006 and 2016	13,159 (7,739-18,810)

For walking and cycling physical activity assuming no net migration, with projected new births, 2006-2120, compared with life years lived with baseline mortality rates (incorporating mortality improvements over time) with a hazard ratio (HR) of 0.9 per 11.25 MET.hours per week physical activity and with lags assumed to be equivalent to the air pollution lags from the USEPA.

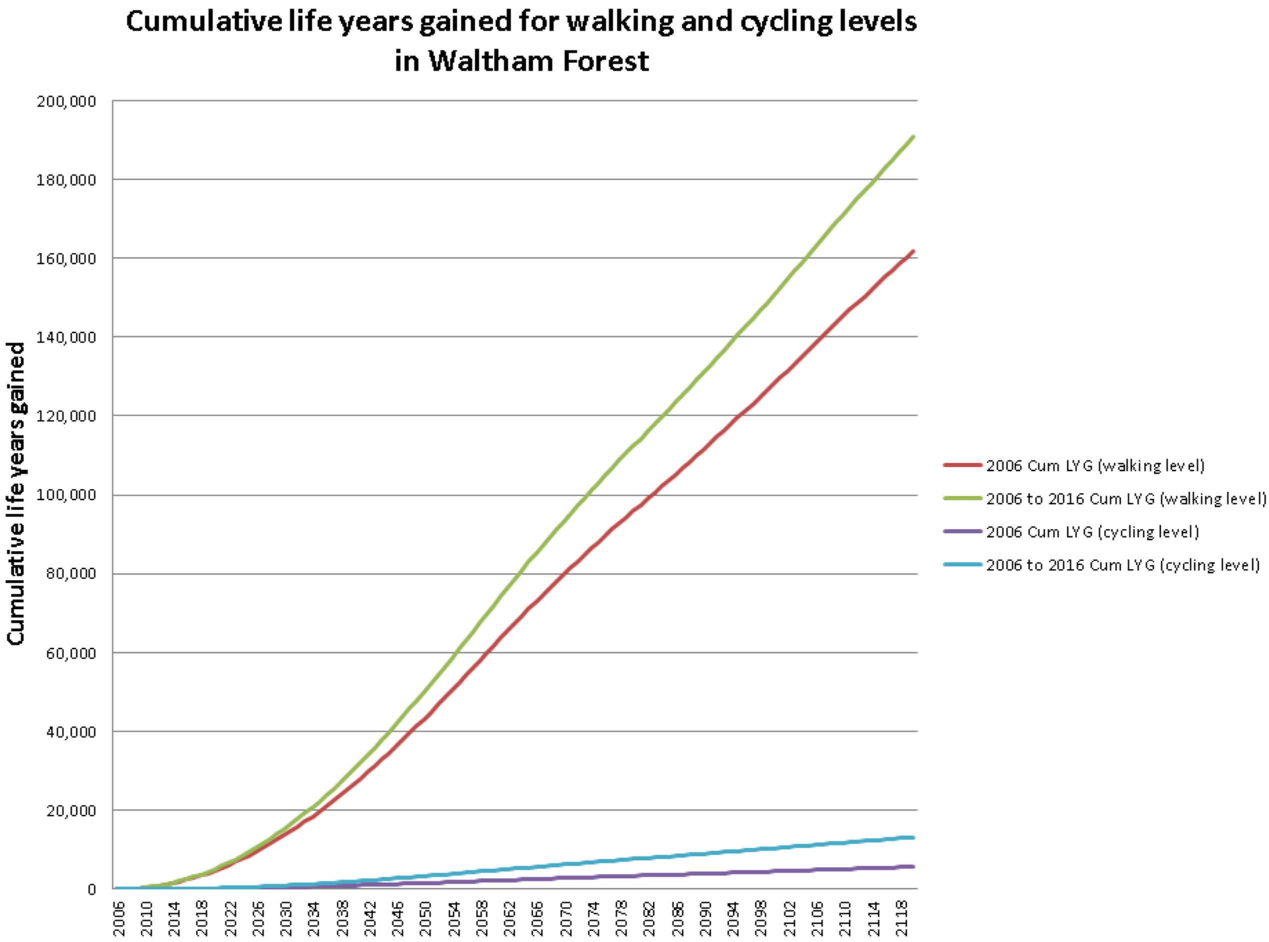

Figure 3 *Cumulative life years gained for walking and cycling assuming the 2006 level remained unchanged and the projected walking and cycling 2006-2016 level across WF population (no migration), with projected new births, compared with life years lived with baseline mortality rates (incorporating mortality improvements over time) 2006-2120. HR 0.9 per 11.25 MET.hours per week for walking and cycling, EPA lag.*

Figure 3 shows that the cumulative life years gained for the walking and cycling change between 2006 and 2016 accumulates more rapidly than the constant 2006 walking and cycling level as a result of the increased walking and cycling level from 2006 to 2016. It is worth remembering that there is a delay before the full benefits of walking and cycling level increases are achieved. This is not just due to a lag between physical activity and effect, but also because the greatest gains occur when both mortality rates and physical activity combined are highest i.e. 55 to 80 years of age.

Table 4 shows the differences between the change of walking and cycling levels between 2006 and 2016 and both walking and cycling remaining constant at 2006 levels. Taking into account the increased walking level between 2006 and 2016, the population in Waltham Forest would gain around 29,000 life years over a lifetime. Similar calculations for cycling show that the population in Waltham Forest would gain around 7,500 life years over a lifetime.

The overall summary would be that taking into account the predicted change of walking and cycling levels between 2006 and 2016, the population in Waltham Forest would gain around 36,000 life years over a lifetime.

Table 4 *Additional life years saved across the WF population for the increased trend in walking and cycling between 2006 and 2016 (maintained to 2120) compared with if walking and cycling was maintained at 2006 levels until 2120*

Physical Activity	**Scenario**	**Total life years saved compared with 2006 Physical Activity maintained Central estimate (Lower-Upper estimate)**
Walking	Predicted walking level between 2006 and 2016	28,887 (14,430-43,352)
Cycling	Predicted Cycling level between 2006 and 2016	7,464 (4,392-10,662)

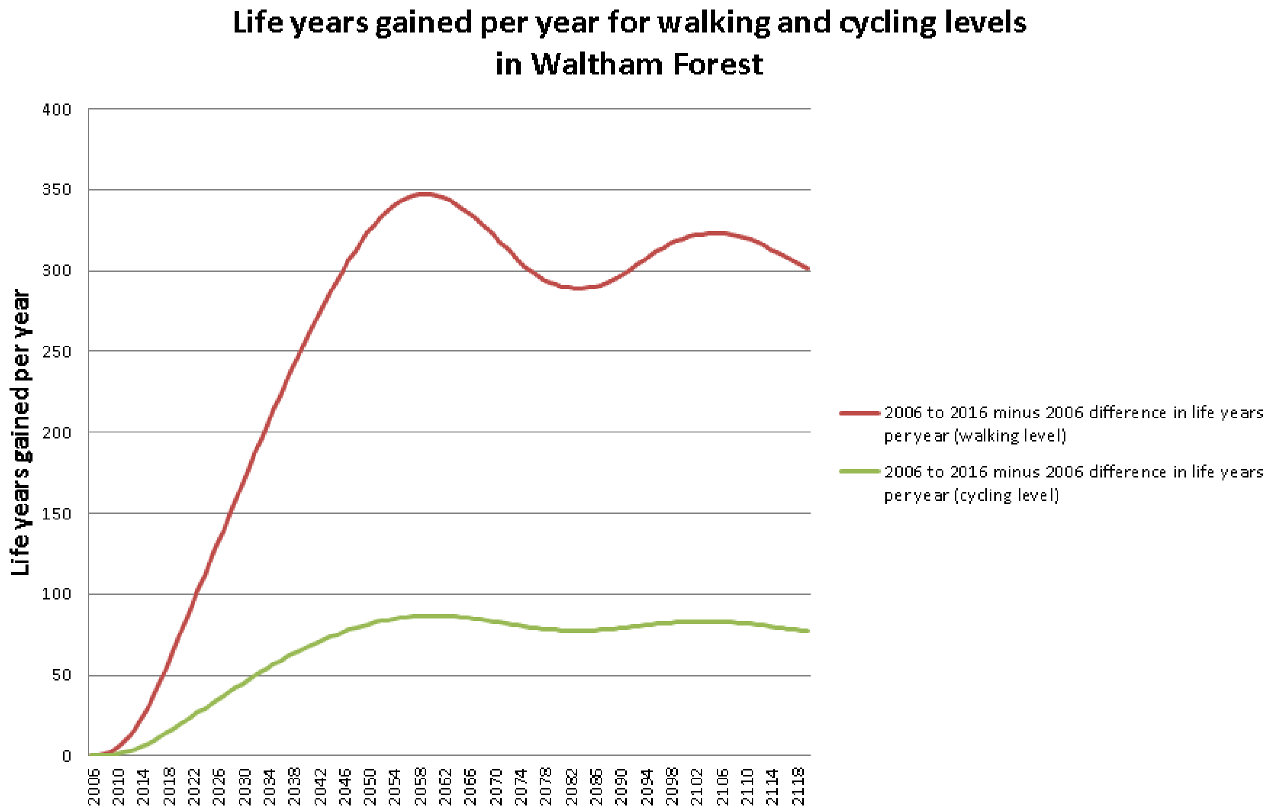

Figure 4 *Life years gained per year from long-term exposure to the improvements in walking and cycling levels from 2006 to 2016 relative to 2006 remaining unchanged.*

Figure 4 shows the effect of the increase in walking and cycling levels from 2006 to 2016 (as seen in Figure 1 and Figure 2 and Table 4).

Life-expectancy from birth in 2006:

Total life years across the population is the most appropriate metric for cost-benefit analysis of policies as it captures effects in the entire population. However, it is a difficult type of metric to communicate as it is difficult to judge what is a 'small' answer or a 'large' answer. Life-expectancy from birth is a more familiar concept for the general public, although it only captures effects on those born on a particular date. Results for life expectancy from birth are shown in Table 5.

This shows that the average gain of life expectancy from birth in WF would be about 31 weeks for males and 23 weeks for females if 2006 walking levels were unchanged but improves to 37 weeks for male and 27.5 weeks for females due to the increased walking level between 2006 and 2016 (an improvement by about 4-6 weeks).

The average gain of life expectancy from birth in WF would be about 1.5 week for males and 0.5 week for females if cycling levels were unchanged from 2006 but improves by about 0.5-2 weeks to 3.5 weeks for males and 1 week for females with projected future changes in cycling physical activity between 2006 and 2016 included.

The overall summary would be that the projected future changes in walking and cycling levels from 2006 to 2016 would be an average gain of life expectancy from birth in 2006 of around 7 to 9 months (29 – 41 weeks) equivalent to an improvement in average life expectancy from birth in 2006 of around 1.5 months (5 – 8 weeks) compared with walking and cycling remaining constant at 2006 levels.

Table 5 Gain in life expectancy by gender across WF from birth in 2006 (followed for 105 years) for walking or cycling maintained at 2006 levels or increased from 2006 and 2016 and maintained at 2016 levels

Physical Activity	**Scenario**	**Gain of life expectancy from birth compared with baseline mortality rates, 2006 birth cohort (in weeks) Central (Lower-Upper) estimate**	
		Male	**Female**
Walking	Walking does not increase from 2006 levels	31.1 (15.3-47.4)	23.3 (11.5-35.4)
	Walking level changes between 2006 and 2016	36.9 (18.2-56.1)	27.6 (13.7-41.9)
Cycling	Cycling does not increase from 2006 levels	1.5 (0.9-2.2)	0.4 (0.2-0.6)
	Cycling level changes between 2006 and 2016	3.6 (2.1-5.1)	1 (0.6-1.5)

It should be noted that the life-expectancy is calculated by dividing the total life years for those born in 2006 by the total number of people in that birth cohort, even though some of them will be less active than the average and some will be more active. For cycling in particular, which is a less common activity than walking, the result will underestimate the gain in life expectancy amongst those born in 2006 who become cyclists. It is not easy to find information on this as most information is on the proportion of the population of any age cycling at a particular point in time. Cycling UK (Cotterell, 2018) estimate that 66% of the population cycle less than once a year or never i.e 34% do some cycling. This may not exactly match the proportion of a birth cohort that will cycle but we used this to construct an illustrative calculation to illustrate the general point that the gain in life expectancy increases when spread across a smaller group of people. If it is assumed that 34% of the population are regular cyclists and that these cyclists increase their activity as described in the scenario then the average gain of life expectancy from birth for this cycling cohort would be about 4.5 weeks for males and 1 week for females if cycling levels were unchanged from 2006 but improves by about 2-6 weeks to 10.5 weeks for males and 3 weeks for females with projected future changes in cycling physical activity between 2006 and 2016 included (Cycling UK's statistics by Cotterell, 2018).

4 School Run Physical Activity and Modal Shift Impacts on Health in Waltham Forest

This section aims to evaluate the health benefit of physical activity from doing the school run by walking, scooting or cycling and the potential improvements of a modal change from doing the school run by cars switching to walking, scooting or cycling. The health benefits have been calculated in a similar manner to the previous section.

School run and modal shift method

Physical activity from school run

Data on the length (in km) of physical activity attributable to the school run were provided by Waltham Forest (personal communication with Enjoy Waltham Forest Team). Data from Sustainable Travel: Active, Responsible, Safe (STARS) survey[10] alongside data identifying the number of pupils attending at each school in the borough was used to estimate the total journeys undertaken by foot, scoot or cycle for pupils. The data for pupils was split between attendees of primary and secondary institutes. Staff data was not provided due to difficulties to clearly define the length and exact pathway of their journeys. The data provided relate to the 2016/2017 school period labelled here as 2016.

Due to time constraints, this analysis only looked at primary school pupils' data. More specifically, the assumption used is that each primary school pupil is accompanied by at least one adult. This analysis calculated the physical activity contribution of each primary school pupils' accompanying adult.

In this report, we are analysing life expectancy benefits that result from reductions in mortality (mainly cardiovascular mortality) in later life. Increased physical activity in children does not have an immediate benefit on reduced mortality because children do not have active cardiovascular disease (apart from a few with rare heart disorders and some indications of an increase in intermediate cardiovascular risk factors (Eisenmann, 2004)). In addition, while possible, demonstrating that physical activity only in childhood leads to reduced mortality in later life would require very long-term studies and is very difficult. There is evidence that physical activity in childhood increases the likelihood of maintaining physical activity in adulthood but this is hard to quantify exactly (Eisenmann, 2004). While with certain assumptions it would be possible to estimate this in future, we concentrated in this report on the physical activity benefits for the adults accompanying the children to school since the evidence on the benefits of increased physical activity on reduced mortality is much stronger for adults than for children.

The data from the Enjoy Waltham Forest team estimated that the primary school pupil's total journey length in 2016 was 6,456,937 Km, 1,024,263 Km and 405,367 Km for walking, scooting and cycling, respectively. It was assumed that an adult walks with a primary pupil walking or scooting to school thus the walking and scooting data were combined into total walking. The accompanying adults total journey length in 2016 was estimated as 7,481,200 Km and 405,367 Km for walking and cycling, respectively.

[10] https://stars.tfl.gov.uk/

Physical activity from the school run modal shift

The first King's report[11] (section 2) evaluated the potential improvements in emissions and air quality resulting from future school run modal change, from using the car to walking, cycling or using public transport. These were as follows:

Scenario 1: the existing trend from 2013 through to 2018 will continue to 2020; an estimated primary school pupil's total journey length will increase between 2013 and 2020 to be 1,079,332 Km and 359,777 Km for walking and cycling, respectively.

Scenario 2: existing trend (scenario 1) and borough interventions will bring about an increase in walking and cycling between 2013 and 2020 estimated to be 1,977,337 Km and 659,112 Km for walking and cycling, respectively.

Scenario 3: existing trend (scenario 1) and further borough interventions will lead to even further increase in walking and cycling between 2013 and 2020 estimated to be 2,849,438 Km and 949,813 Km for walking and cycling, respectively.

Scenario 2 and 3 were speculative scenarios that the Enjoy Waltham Forest team considered might broadly be achievable. It was as much a case of saying "if" this could be achieved, these are the predicted impacts.

The above data was presented as a change while school run absolute data was only available for 2016. Therefore, in order to calculate the absolute values from the change, we evaluated the potential physical activity improvements of a range of modal change scenarios between 2013 and 2020, the school run data in 2016 was then back calculated to 2013 using scenario 2 and furthermore forward calculated using scenario 1, 2 and 3 modal change to produce a range of 2020 walking and cycling indicators as illustrated in Figure 5 (the scooting trend was assumed to follow walking trend between 2013 and 2020).

The original data was given in yearly total journey length in Km. This was converted to hours per week using an average walking and cycling speed[12] and then to MET hours per week using the metabolic equivalent data values for 'cycling to/from work/self-selected pace' and 'walking to work or class'[13] from the 2011 Compendium of Physical Activities (Ainsworth *et al,* 2011). Finally, the MET hours per week were spread over all Waltham Forest residents by calculating the MET hours per week per person (age 16 plus) assuming that any adults accompanying the children to primary school can be aged 16 plus.

The reduction in mortality benefits of the 2013 level of walking and cycling was calculated as if it was an increase over baseline levels of physical activity in adults accompanying their children. The life years saved for the 2013 level of walking and cycling was calculated, assuming this was maintained over time, as the counterfactual scenario. We also calculated the life years saved for the increasing trend in walking and cycling between 2013 and 2020, maintained over a lifetime. The time period for both scenarios was thus 2013 to 2124 (i.e. 105 years after 2020). The reader should refer to the appendix for further methodological details.

[11] https://drive.google.com/file/d/1MGyThE5H9lgrzhCkjQlKKg7vhuW6pGMR/view
[12] 4 and 12Km per hour, respectively.
[13] 6.8 and 4, respectively.

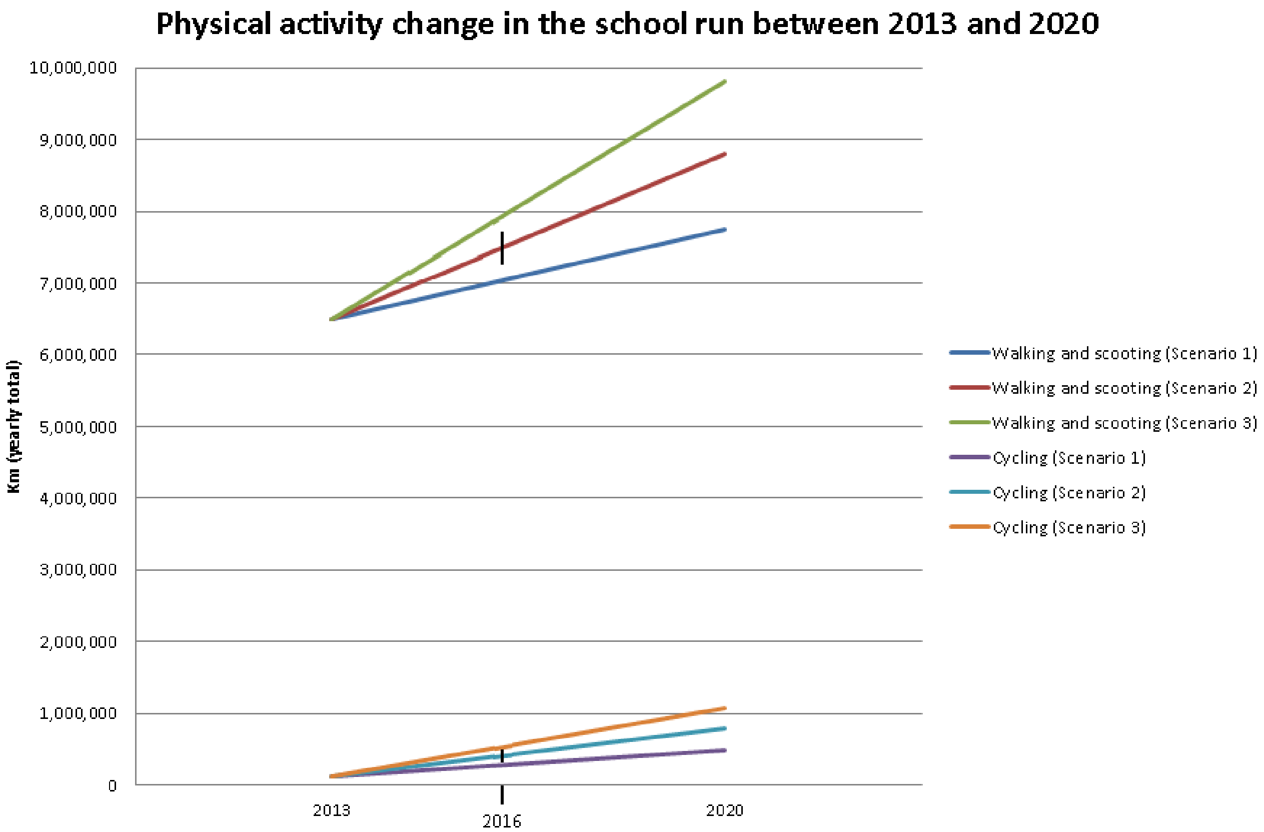

Figure 5 *Total walking (walking and scooting combined) and cycling length in Km from the school run following a range of modal shift scenarios 1, 2 and 3 from 2013 to 2020 (for information, the 2016 original data is marked with dark line crossing scenario 2 trend line)*

School run and modal shift impact results

Calculations are given for walking and cycling separately in Table 6 to Table 8 but for clarity have been added up in the text below.

The results from the life table calculations assuming that the physical activity (PA) does not reduce from 2013 levels and assuming the predicted physical activity between 2013 and 2020 (PA was modelled at 2013 and 2020 but also interpolated for the intervening years) are shown in Table 6, for walking and cycling.

If the 2013 adult school run walking and cycling level remained unchanged for 112 years, around 10,900 life years would be gained across WF's population over that period. This improves to around 13,200, 15,000 and 16,800 life years gained with the predicted physical activity changes between 2013 and 2020 examined here in scenario 1, 2 and 3, respectively.

Table 6 Total life years gained across WF population for adult school run walking and cycling (central and lower-upper estimate) associated with the school run and following a range of modal shift scenarios 1, 2 and 3

<table>
<tr><th>Physical Activity</th><th colspan="2">Scenario</th><th>Life years gained
Central (Lower-Upper) estimate</th></tr>
<tr><td rowspan="4">Walking</td><td colspan="2">Walking does not increase from 2013 levels</td><td>10,828 (5,276-16,687)</td></tr>
<tr><td rowspan="3">Walking level changes between 2013 and 2020</td><td>Scenario 1</td><td>12,831 (6,253-19,770)</td></tr>
<tr><td>Scenario 2</td><td>14,496 (7,065-22,333)</td></tr>
<tr><td>Scenario 3</td><td>16,113 (7,854-24,821)</td></tr>
<tr><td rowspan="4">Cycling</td><td colspan="2">Cycling does not increase from 2013 levels</td><td>87 (51-124)</td></tr>
<tr><td rowspan="3">Cycling level changes between 2013 and 2020</td><td>Scenario 1</td><td>330 (194-472)</td></tr>
<tr><td>Scenario 2</td><td>532 (312-762)</td></tr>
<tr><td>Scenario 3</td><td>728 (428-1,043)</td></tr>
</table>

For adult school run walking and cycling physical activity assuming no net migration, with projected new births, 2013-2124, compared with life years lived with baseline mortality rates (incorporating mortality improvements over time) with a relative risk (RR) of 0.9 per 11.25 MET.hours per week physical activity and with lags assumed to be equivalent to the air pollution lags from the USEPA.

Table 7 shows the differences between the change of adult school run walking and cycling levels between 2013 and 2020 and both walking and cycling staying constant at 2013 levels. Taking into account the increased walking and cycling level between 2013 and 2020, the population in Waltham Forest would gain around 2,200, 4,100 and 5,900 life years over a lifetime from scenarios 1, 2 and 3, respectively.

Table 7 *Additional life years saved associated with adults school run physical activity across the WF population for the increased trend in walking and cycling following a range of modal shift scenarios 1, 2 and 3 between 2013 and 2020 (maintained to 2124) compared with if walking and cycling was maintained at 2013 levels until 2124*

Physical Activity	**Scenario**		**Total life years saved compared with 2013 Physical Activity maintained Central estimate (Lower-Upper estimate)**
Walking	Predicted walking level between 2013 and 2020	Scenario 1	2,003(977-3,083)
		Scenario 2	3,668 (1,790-5,647)
		Scenario 3	5,285 (2,578-8,134)
Cycling	Predicted Cycling level between 2013 and 2020	Scenario 1	243 (143-348)
		Scenario 2	445 (261-637)
		Scenario 3	642 (377-918)

Life-expectancy from birth in 2013:
Results for life expectancy from birth are shown in Table 8.

This shows that the average gain of life expectancy from birth in WF would be about 12 days for males and 10 days for females if 2013 adult school run walking and cycling levels were unchanged but improves to 14, 16 and 18 days for male and 12, 13 and 15 days for females due to the increased walking level between 2013 and 2020 from scenarios 1, 2 and 3, respectively (an improvement by about 2-5 days).

Table 8 *Gain in life expectancy associated with the adult school run by gender across WF from birth in 2013 (followed for 105 years) for walking or cycling maintained at 2013 levels or increased from 2013 and 2020 and maintained at 2020 levels following a range of modal shift scenarios 1, 2 and 3*

Physical Activity	**Scenario**		**Gain of life expectancy from birth compared with baseline mortality rates, 2013 birth cohort (in days) Central (Lower-Upper) estimate**	
			Male	**Female**
Walking	Walking does not increase from 2013 levels		11.5 (5.6-47.4)	9.7 (4.7-35.4)
	Walking level changes between 2013 and 2020	Scenario 1	13.7 (6.7-56.1)	11.6 (5.7-41.9)
		Scenario 2	15.6 (7.6-56.1)	13.1 (6.4-41.9)
		Scenario 3	17.3 (8.5-56.1)	14.7 (7.1-41.9)
Cycling	Cycling does not increase from 2013 levels		0.1 (0.08-0.2)	0.05 (0.03-0.06)
	Cycling level changes between 2013 and 2020	Scenario 1	0.5 (0.3-0.7)	0.2 (0.1-0.3)
		Scenario 2	0.8 (0.5-1.2)	0.3 (0.2-0.4)
		Scenario 3	1.1 (0.7-1.6)	0.4 (0.2-0.6)

5 Discussion

This report has presented some estimates of the life years saved as a result of increasing walking and cycling activity in Waltham Forest. These benefits have not been quantified in this way in this location before although the qualitative benefits of increased physical activity are, of course, clear. Even when averaged across the whole Waltham Forest population, not all of whom undertake the physical activity analysed here, positive benefits on life expectancy can be shown. For a public health measure, showing benefits to the population as a whole is important but it should be remembered that the benefits are greater to those undertaking the activity. This is particularly true for cycling, which is a less common activity than walking.

The physical activity analysed here is only a portion of total physical activity. The LTDS analyses journeys so excludes other types of physical activity such as organised sports and exercises in the gym. The LTDS may capture some leisure cycling and walking (it includes weekend days but this may be diluted by weekdays where people have less time).

Comparison with air pollution: In our first report[14], we analysed the health impacts of air pollution in Waltham Forest. This was for the total amount of air pollution as it changed between 2013 and 2020 while in this report the health impacts looked at a change of physical activity between 2006 and 2016. While the timeline from each report is different, the headlines from both reports are broadly comparable.

The first report showed that Waltham Forest's population would still be losing between 172,000 to 256,000 life years over a lifetime as a result of exposure to air pollution concentrations between 2013 and 2020 (2020 levels then maintained) while this report shows that the same population is estimated to gain around 204,000 life years over a lifetime from the projected level of combined walking and cycling activity between 2006 to 2016 (2016 levels then maintained). This can also be represented as a loss in average life expectancy from birth in 2013 of around 6 to 10 months (report 1) and a gain in average life expectancy from birth in 2006 of around 7 to 9 months (this report).

The first report showed that the population in Waltham Forest will gain around 41,000 life years, and increase life expectancy by around 1.5 months, if air pollution concentrations improve as projected to 2020, compared with remaining at 2013 concentrations. This report estimated that the population in Waltham Forest gained 36,000 life years over a lifetime, equivalent to an increase in average life expectancy from birth in 2006 of around 1.5 months, if the combined walking and cycling level improve as projected to 2016, compared with remaining at 2006 levels.

In summary, the effect on life years and life expectancy from birth for the difference between maintaining the situation in the starting year and having the improvements over time, was of a similar size for physical activity and for air pollution. This may be surprising as physical inactivity is regarded as a more significant risk factor than air pollution. However, this does not take into account differences in the proportion of the population affected. For a group of people who are physically active the benefits would be even greater than for a reduction in air pollution. However, not everyone is physically active but everyone benefits from a reduction in air pollution because exposure is so widespread.

[14] https://drive.google.com/file/d/1MGyThE5H9lgrzhCkjQlKKg7vhuW6pGMR/view

The health benefit associated with the school run physical activity (based on the STARS survey) represent about 6 to 8 % (varying between scenario 1 to 3) of the health benefit from total walking and cycling activity (based on the LTDS survey) in Waltham Forest. The school run analysis estimated the health benefit for a range of modal shift scenarios. King's encourage further measurement and analysis of walking and cycling data in WF to evaluate the validity of the scenarios by 2020.

There is evidence that physical activity in childhood increases the likelihood of maintaining physical activity in adulthood. With certain assumptions, it would be possible to estimate further health benefits using the data for pupils' attendees of secondary institutes in future development. Furthermore, school staff data could be collected and used to estimate further health benefit to complement the school study analysis.

This was the first time King's had developed an analysis of this type. We have presented estimates of the benefits using our initial methodology but this could be developed further. In particular, it would be useful to take into account that the same change in physical activity can have more benefit in those who were inactive beforehand. This does place more demand on the input data that is needed though and would take more time to develop.

We used a different approach from that in the WHO HEAT tool but the underlying evidence used is the same. The WHO HEAT tool presents results in terms of premature deaths – this is reasonable for giving a snapshot estimate in a particular year but less appropriate over the long-term than changes in life-years (everyone dies in the long-term so there is no difference in deaths between scenarios but there is a difference in how long people live).

The HEAT tool excludes the elderly whereas we included them (scaling the amount of physical activity down with increasing age). This turned out to be important because the combination of reasonable amounts of physical activity and higher baseline mortality rates meant that the impacts were potentially greatest in the 55-80 age group. Of course, it may not be the same people maintaining physical activity as those at increased mortality risk but moderate physical activity as analysed here is recommended for those with heart disease, for example. More investigation of this issue would be interesting (walking and cycling activity by age group was inferred from London wide data in the current work).

As described in the approach section there are many sources of data on physical activity in the borough. While these of course have many other purposes, for the specific purpose of calculating life expectancy benefits it would be useful in future to have information on:

- Minutes of walking or cycling per week, averaged across the whole borough population including other types of physical activity such as leisure cycling and walking, organised sports and exercises in the gym covering both weekend and weekdays (the LTDS survey mostly covers journeys as explained toward the start of the discussion section)
- Minutes of walking or cycling per week averaged across those who undertake the activity (more important for cyclists who are a lower proportion of the population)
- Trends in walking or cycling minutes per week by gender and age group (the sample size would have to be increased compared with the LTDS survey)
- The absolute level of walking and cycling activity in minutes per week and the change from a previous level (initially per person, although it could subsequently be aggregated to

preserve anonymity). This is to distinguish groups of people who moved from inactive to active, where the benefits are higher.

Other potential work includes the following:

- A study was published during our analysis that did have information on previous cycling activity in Waltham Forest (2016 vs 2017) within the same individuals (Aldred *et al* 2018). The results were presented in a different form than would be needed as a direct input to our analysis (Aldred *et al* reported results for 2017 differences between mini-Holland boroughs and non mini-Holland boroughs in London adjusted for baseline levels of activity in 2016). Due to this and the timescales involved we did not use this information in this analysis but the use of data such as this could be explored further in the future.

The current report does not include any economic analysis assigning monetary values from people's willingness to pay to avoid small increases in risk but this has been done in previous work using the life table tool in the air pollution context e.g. Williams *et al* 2018a,b; Walton *et al* 2015. But total life-years across the population is the most appropriate metric for analysis of long-term benefits of policies to reduce risks and the monetary value of the benefits can then be incorporated in cost-benefit analysis of such policies. In future work, monetary benefits could be derived from the health impact assessment work done on both the air quality (report 1) and the physical activity changes (this report) to optimize the best policies in comparison with the costs.

In summary this report presents the benefits in terms of total life years across the population of increasing trends in walking and cycling activity as a contribution to assessing progress in achieving public health aims to increase levels of physical activity.

Appendix

Additional Health Assessment Method Information

Set up of scenarios

Points to consider when setting up health impact scenarios include considering both the exact comparisons used to describe the relative risk and the fact that the baseline mortality rates already incorporate a certain level of physical activity.

The relative risk from Kelly *et al* (2014) is described as 0.9 at 11.25 MET hours per week (the equivalent of international recommendations for physical activity of 150 minutes per week of moderate intensity activity). This was pooled from studies that mostly used a non-active comparison group or were scaled to match this. So this is effectively the relative risk for an increase of 11.25 MET hours per week.

The population in Waltham Forest will already have some level of physical activity which will be reflected in the baseline mortality rates. So calculating the baseline level of physical activity as an increase over baseline mortality rates would not be appropriate. However, as we were only considering a component of overall physical activity (routine walking and cycling not sports activity, gardening, housework etc) and the level of walking and cycling in 2006 was already in the context of an upward trend, we considered it was reasonable to calculate the reduction in mortality benefits of the 2006 level of walking and cycling as if it was an increase over baseline levels of physical activity.

We therefore calculated the life years saved for the 2006 level of walking and cycling, assuming this was maintained over time, as the counterfactual scenario. We also calculated the life years saved for the increasing trend in walking and cycling between 2006 and 2016, maintained over a lifetime. The time period for both scenarios was thus 2006 to 2120. (As mortality rates are higher in the elderly and the benefits of physical activity occur over time, rather than instantly as a result of one-off physical activity, it is important to follow-up the benefits over an extended period. It does of course assume that the world does not change drastically in that time, although projected changes in birth rates and improvements in baseline mortality rates are included).

For the school run analysis, the reduction in mortality benefits of the 2013 level of walking and cycling was calculated as if it was an increase over baseline levels of physical activity in adults accompanying their children. The life years saved for the 2013 level of walking and cycling was calculated, assuming this was maintained over time, as the counterfactual scenario. We also calculated the life years saved for the increasing trend in walking and cycling between 2013 and 2020, maintained over a lifetime. The time period for both scenarios was thus 2013 to 2124.

Physical activity input

The studies pooled in the meta-analysis studied groups of people with a particular level of physical activity compared with groups of people with other levels of physical activity. The London Travel Demand Survey on the other hand gives an average level of walking or cycling across the whole population (or across the whole population of a particular gender and age group). However, if it is assumed that the relationship between increased physical activity and reduced mortality is approximately linear[15], then a small average

[15] This is assumed elsewhere such as in the WHO HEAT tool http://www.heatwalkingcycling.org/#homepage. We scaled the risk using a log linear relationship but this is approximately linear for small physical activity

increase for a lot of people is equivalent to the same total activity spread across a smaller number of people. The latter is likely to be more realistic, particularly for cycling. The total life years saved across the population will be a reasonable estimate using this method, but it has to be borne in mind that the benefits are not in fact evenly distributed (see interpretation section).

Mortality Impact

Projections for the baseline life tables before applying physical activity changes
Population data in WF –Population data for Waltham Forest for 2006 was obtained from gender and 1 year age group ONS time series data 2001 to 2017 by local authority (ONS, 2016a). Population data for years beyond 2006 is generated within the lifetable calculations taking into account the effect of physical activity changes on mortality rates in one year on the starting population for the subsequent year.

Deaths data in WF –Deaths data for Waltham Forest was obtained for 2006 from gender and 1 year age group ONS time series data 2001 to 2017 by local authority as above for population data. Deaths for years beyond 2006 was generated within the lifetable calculations.

Natural change – current population size, age distributions and mortality rates will generate future changes in population and age structure in any case. We did not add this separately as it is already taken into account in our life table modelling.

Changes in births over time – actual data on numbers of births in Waltham Forest was used from 2006 – 2010 using ONS time series data 2001 to 2017 by local authority as above for population data (ONS, 2016a) to supplement data previously obtained (Williams *et al* 2018a,b) for 2011-2015 (ONS, 2016b); birth projections by local authority were used from 2016 to 2033 (ONS, 2016c) and the ratio of birth projections to 2039 births for England obtained from national populations projections (ONS, 2015a) was used to scale 2039 births in local authorities to local authority births for 2040 to 2114. No projections were available after 2114 so births were left constant for 2115 to 2120 (2124 for the school run analysis).

Mortality rate improvements were applied to the 2006 all cause hazard rates according to the projected % improvements per year provided by ONS. Percentage improvements for different example ages are provided by the Office for National Statistics (ONS, 2015b); we previously requested the full set of percentage improvements from ONS which have now been published as user requested data (ONS, 2016d).

Migration – predicting migration at the current time post the European referendum is particularly uncertain with both increases and decreases forecast. We did not therefore include this in our first analyses as presented in this report. Over the country as a whole this contribution to overall health impacts is likely to be small. This can be explored further in future work.

Lags
The approach allowed for a delay between exposure and effect. The appropriate value for the lag is not necessarily obvious from the epidemiological studies as it is more common for people to build up or wind down their degree of physical activity slowly over time. Studies such as Blair *et al* (1995) show benefits within a relatively short period (mean follow-up of 5 years). The WHO HEAT tool uses a time period of 5 years for the health benefits to build up. On the other hand, it has been shown that increased physical activity can reduce cancer incidence (Mytton *et al* (2017). If this also results in changes in cancer mortality it seems possible that there would be a longer lag before this was apparent (as mechanisms for tumour formation occur over the long term). For air pollution, this has led to the proposal that a small portion of the effect takes up to 20 years to become apparent (COMEAP, 2010; US EPA, 2004). Discussion with Marko

---

changes. There is some evidence that there are greater benefits moving from inactive to a reasonable degree of physical activity than those that are already very active increasing their activity further. But that is outside the scope of this initial report.

Tainio (University of Cambridge) (and one of the authors of Mytton *et al* (2017)) concluded that, since the dominant disease affected is cardiovascular disease for both air pollution and physical activity, and both have some effect on cancer, it seemed reasonable to use the same lag as used for air pollution i.e. 30% of the effect in the first year, 12.5% in each of years 2-5 and 20% spread over years 5-20.

Calculations

The relative risk (RR) per 11.25 MET hours per week was scaled to a new relative risk for the appropriate MET hours per week for each gender and age group in each local authority for each scenario and year (taking into account the lag, see below). The equation used (for the example coefficient of 0.90) was: $RR(x) = 0.90^{(x/11.25)}$ where x is the MET hours per week of interest (with a positive sign for an increase, negative sign for a reduction). MET hours per week were assumed to increase linearly between 2006 and 2016 according to the trend line derived from the LTDS data or between 2013 and 2020 according to the trend line derived from the Enjoy Waltham Forest data (based on STARS survey) for the school run. The scaled RR was then used to adjust the all cause hazard rates in the life table calculations.
Life table calculations were programmed in SQL based on the methods used in the standard IOMLIFET spreadsheets (IOM, 2013) with the following amendments:

- Extension to 2120 (105 years after 2016) and for the school run analysis extended to 2124 (105 years after 2020)
- Adjustment of the baseline hazard rates over time according to projected mortality rate improvements
- Inclusion of changes in numbers of births over time
- IOMLIFET excludes neonatal deaths. We included neonatal deaths and followed the South East Public Health Observatory life-expectancy calculator (IOM, 2013) and Gowers et al. (2014) in taking into account the uneven distribution of deaths over the course of the first year when calculating the survival probability. (The survival probability (the ratio of the number alive at the end of the year to the number alive at the beginning) is derived by the equivalent of adding half the deaths back onto the mid-year population to give the starting population and subtracting half the deaths from the mid-year population to give the end population, assuming deaths are distributed evenly across the year. This is not the case in the first year where a weighting factor based on 90% of the deaths occurring in the first half of the year and 10% in the second half is used instead. After rearrangement the actual formula is (1- 0.1 x hazard rate)/(1+ 0.9 x hazard rate) rather than the (1- 0.5 x hazard rate)/(1+ 0.5 x hazard rate) used in other years.)

Results for total and annual life years gained were then produced for WF. We also used the life tables to calculate changes in life expectancy.

Adding results of walking and cycling

The LTDS and Enjoy Waltham Forest (for the school run) data as provided to us does not distinguish whether it is the same people or different people doing walking and cycling. It seems likely that cyclists also do some walking, but the proportion of walking activity undertaken by cyclists is unclear. If we were doing calculations specifically in the group of people doing the cycling or walking, this would be a problem. However, as the activity is averaged across the population and assumed to be approximately linear, it is possible to combine the walking and cycling calculations. We simply added the end results. An alternative would be to add walking and cycling MET hours per week at each gender and age group and do a combined lifetable run. This is a more precise way to do it but we suspect since cycling activity is much smaller than walking activity and we are assuming approximate linearity that the answer would not be very different[16]. Nonetheless, if repeating these methods elsewhere, it should always be thought through whether it is appropriate to add the end results.

[16] We tested this for the 2006 sustained results. Putting the combined MET hours per week for walking and cycling for each gender and age through the lifetable gave a result of 167,272 life years gained compared with 167,544 life years gained if adding the end results of calculations for walking and cycling separately. As the difference was only 0.002%, we added the end results throughout.

The life expectancy from birth results are derived from the life year calculations so the same probably applies to the life expectancy results when this is expressed as an average across the population. However, it would not be possible to be sure how this was distributed across walkers and cyclists. Section 3 explained how the average across the population looked small but would be higher across those that cycled. This excluded any walking that the cyclists might do. The key point is more that the life expectancy gains in those that do the given physical activity would be greater than the population average, than the precise value of that gain.

The above two paragraphs assume approximate linearity, as assumed in this initial work. Future work to take into account that those moving from inactive to active have greater gains than additional activity in those that are already active would need information on how walking and cycling combined for each person.

Comparison with the WHO HEAT tool

The WHO HEAT tool also makes assessments of the impact of physical activity changes on mortality. While based on the same general evidence, the approaches are a bit different. We did not pursue a direct comparison of results at this stage because it was difficult to compare like with like in terms of inputs, but the differences could still be explored further than done so far. The table below summarises some of the differences.

Input or method	WHO HEAT tool	This report
Population	Assumes a constant population size and age structure	Takes changes in population size and age structure over time into account
Gender and age group	Excludes children Excludes elderly (75 or over walking; 65 or over cycling) Does not distinguish by gender	Excludes children Includes the elderly by distributing the average physical activity in the population to take into account that younger people are more active than older people (exclude s over 90) Does take difference in activity by gender into account by weighting the population average level of activity.
Duration	Capped at 50 years	Takes the impact of a full lifetime of physical activity into account
Lag	5 years	30% of the effect in the first year, 12.5% in each of years 2-5 and 20% spread over years 5-20
Output	Changes in premature deaths	Changes in life-years Changes in life expectancy from birth

Acknowledgements

The authors would like to thank Hannah Groot (TfL) for providing the LTDS data with some initial analysis; Dimitris Evangelopoulos (KCL) for statistical advice on the analysis of the LTDS data trends, Marko Tainio (University of Cambridge) for discussion of appropriate lags for the effect of increased physical activity on reducing mortality and Enjoy Waltham Forest team for providing data and further discussion.

References

Active Lives Adults Survey (2018). Active Lives Adults Survey November 16/17 report (published March 2018). https://www.sportengland.org/media/13217/v-mass-markets-digital-content-editorial-team-active-lives-march-2018-active-lives-adult-survey-nov-16-17-final.pdf (accessed August 2018).

Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR Jr, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS: Compendium of physical activities: a second update of codes and MET values. Med Sci Sports Exerc 2011, 2011(43):1575–1581.

Aldred, R., J. Croft and A. Goodman (2018). "Impacts of an active travel intervention with a cycling focus in a suburban context: One-year findings from an evaluation of London's in-progress mini-Hollands programme." Transportation Research Part A: Policy and Practice.

Blair, S. N., H. W. Kohl, 3rd, C. E. Barlow, R. S. Paffenbarger, Jr., L. W. Gibbons and C. A. Macera (1995). "Changes in physical fitness and all-cause mortality. A prospective study of healthy and unhealthy men." Jama 273(14): 1093-1098.

COMEAP (Committee on the Medical Effects of Air Pollutants), 2010, The mortality effects of long-term exposure to particulate matter air pollution in the UK, London, UK. Available at http://comeap.org.uk/documents/reports/128-the-mortality-effects-of-long-term-exposure-to-particulate-air-pollution-in-the-uk.html (accessed August 2018).

Cycling UK's statistics, Cotterell A, (2018). https://www.cyclinguk.org/resources/cycling-uk-cycling-statistics#Demographics (accessed August 2018).

Eisenmann, J. C. (2004). "Physical activity and cardiovascular disease risk factors in children and adolescents: an overview." Can J Cardiol 20(3): 295-301.

Enjoy Waltham Forest Walking and Cycling account (2017). https://www.enjoywalthamforest.co.uk/wp-content/uploads/2015/01/Walking-Cycling-Account-2017.pdf (accessed August 2018).

Gowers A, Miller BG, Stedman JR, Estimating the mortality burdens associated with particulate air pollution, Public Health England, Report number PHE-CRCE-010, 2014. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/332854/PHE_CRCE_010.pdf http://www.hpa.org.uk/Publications/Environment/PHECRCEReportSeries/PHECRCE010/ (accessed August 2018).

IOM (2013) IOMLIFET: A Spreadsheet System For Life table Calculations For Health Impact Assessment Available at: http://www.iom-world.org/research/iom-research-disciplines/statistical-services/iomlifet/ (accessed August 2018).

Kelly, P., Kahlmeier, S., Götschi, T., Orsini, N., Richards, J., Roberts, N., Foster, C. (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, 132. https://ijbnpa.biomedcentral.com/articles/10.1186/s12966-014-0132-x (accessed August 2018).

London Borough of Waltham Forest Walthamstow Village Review (2017). https://www.enjoywalthamforest.co.uk/wp-content/uploads/2016/09/2017-08-23-WV-report-FINAL.pdf (accessed August 2018).

London Borough of Waltham Forest 2020 Vision "Cycling in the London borough of Waltham Forest 2015-2020" (2015). https://www.enjoywalthamforest.co.uk/wp-content/uploads/2015/01/018978-Mini-Holland-Cycling-Strategy-v2-FINAL.pdf (accessed August 2018).

ONS - Office for National Statistics (2015a) All data related to national population projections 2014-based statistical bulletin https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/nationalpopulationprojections/2015-10-29/relateddata (accessed August 2018).

ONS - Office for National Statistics (2015b) Compendium: Mortality assumptions (2014-based national population projections) http://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/compendium/nationalpopulationprojections/2015-10-29/mortalityassumptions (accessed August 2018).

ONS - Office for National Statistics (2016a) Select 2001-2017 detailed time series https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland (accessed August 2018).

ONS - Office for National Statistics (2016b) Dataset: Births by mothers' usual area of residence in the UK. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/livebirths/datasets/birthsbyareaofusualresidenceofmotheruk (accessed August 2018).

Office for National Statistics (2016c) Sub-national population projections, local authorities in England SNPP Z1 – 2014 based https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/localauthoritiesinenglandz1 (accessed August 2018)

ONS - Office for National Statistics (2016d) User requested data: Calendar year mortality improvements for 2014 base year projections, UK minus Scotland and Scotland separately https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/adhocs/006400calendaryearmortalityimprovementsfor2014baseyearprojectionsukminusscotlandandukseparately (accessed August 2018)

US EPA (2004). Letter from Advisory Council on Clean Air Compliance Analysis in response to Agency request on Cessation Lag. http://www.epa.gov/sab/pdf/council_ltr_05_001.pdf (accessed August 2018).

Waltham Forest Health and Wellbeing Strategy 2016-2020. http://www.walthamforestccg.nhs.uk/news-items/waltham-forest-joint-health-and-wellbeing-strategy-published/19342 (accessed August 2018).

Walton H, Dajnak D, Beevers SD, Williams ML, Watkiss P, Hunt A, Understanding the Health Impacts of Air Pollution in London, King's College London 2015 available at: https://www.london.gov.uk/sites/default/files/hiainlondon_kingsreport_14072015_final.pdf. (accessed August 2018).

WHO Regional Office for Europe (2017a) Health economic assessment tool (HEAT) for walking and for cycling. HEAT 4.1. http://www.heatwalkingcycling.org/#homepage (accessed August 2018).

WHO Regional Office for Europe (2017b) Health economic assessment tool (HEAT) for walking and for cycling Methods and user guide on physical activity, air pollution, injuries and carbon impact assessments. http://www.euro.who.int/__data/assets/pdf_file/0010/352963/Heat.pdf?ua=1 (accessed August 2018).

Williams ML, Lott MC, Kitwiroon N, Dajnak D, Walton H, Holland M, Pye S, Fecht D, Toledano MB, Beevers SD (2018a) The Lancet Countdown on health benefits from the UK Climate Change Act: a modelling study for Great Britain Lancet Planetary Health 2 (5): e202-e213

Williams ML, Beevers S, Kitwiroon N, Dajnak D, Walton H, Lott MC, et al. (2018b) Public health air pollution impacts of pathway options to meet the 2050 UK Climate Change Act target: a modelling study. Public Health Res 6(7)