Quantifying the health and economic benefits of active commuting in Scotland

Citation for published version:
Baker, G, Pillinger, R, Kelly, P & Whyte, B 2021, 'Quantifying the health and economic benefits of active commuting in Scotland', *Journal of Transport and Health*, vol. 22, 101111.
https://doi.org/10.1016/j.jth.2021.101111

Digital Object Identifier (DOI):
10.1016/j.jth.2021.101111

Published In:
Journal of Transport and Health

Journal of Transport & Health 22 (2021) 101111

Contents lists available at ScienceDirect

Journal of Transport & Health

journal homepage: www.elsevier.com/locate/jth

Quantifying the health and economic benefits of active commuting in scotland

Graham Baker[a,*], Rebecca Pillinger[a,1], Paul Kelly[a], Bruce Whyte[b]

[a] Physical Activity for Health Research Centre, Moray House School of Education and Sport, University of Edinburgh, Edinburgh, EH8 8AQ, UK

[b] Glasgow Centre for Population Health, Bridgeton Cross, Glasgow, G40 2QH, UK

ARTICLE INFO

Keywords:
Walking
Cycling
Active commuting
HEAT
Economic
Health

ABSTRACT

Background: Despite the substantial evidence base for the health and economic benefits of walking and cycling, there remains a lack of published findings on the levels and benefits of active commuting at a national level. This study aimed to quantify the proportion of active commuters who met a daily equivalent of weekly physical activity recommendations through their commuting journeys, and the economic value of health benefits associated with active commuting in Scotland.

Methods: A repeat cross-sectional analysis of the 2001 and 2011 waves of the Scottish Census was conducted. We analysed data from approximately 250,000 respondents aged 16–74 at each time-point who selected walking or cycling for their usual journey to work. A count was taken of walkers and cyclists whose daily commuting time was at least 30 min. The Health Economic Assessment Tool was used to estimate the number of deaths averted by active commuting, and the associated economic value of walking and cycling annually and over a 10-year period.

Results: Active modes of commuting accounted for a modal share of 13.5% ($n = 244{,}009$) in 2001, and 14.5% ($n = 286{,}145$) in 2011. In 2001, 46.5% of all active commuters met a daily target of 30 min of moderate intensity activity rising to 50.2% in 2011. In Scotland, the annual health economic benefit of commuting to work by walking was estimated to be approximately EUR 700.2 million, and EUR 79.8 million for cycling to work.

Conclusion: This study provides clear evidence of the substantial health and economic benefits that active commuting makes at a population level. These findings support the case for further investment to increase levels of walking and cycling.

1. Introduction

1.1. The case for promoting walking and cycling

The benefits of a physically active lifestyle are wide-reaching and irrefutable (Lee et al., 2012). It is estimated that physical activity (PA) prevents 3.9 million premature deaths globally each year (Strain et al., 2020). Recent publications of PA guidelines from several

* Corresponding author.

E-mail addresses: graham.baker@ed.ac.uk (G. Baker), rebecca.pillinger@ed.ac.uk (R. Pillinger), p.kelly@ed.ac.uk (P. Kelly), Bruce.Whyte@glasgow.ac.uk (B. Whyte).

[1] Present affiliation: Moray House School of Education and Sport, University of Edinburgh, Edinburgh, EH8 8AQ.

https://doi.org/10.1016/j.jth.2021.101111

Received 23 July 2020; Received in revised form 7 May 2021; Accepted 2 June 2021

Available online 20 June 2021

countries recommend that adults (aged 19–64 years) accumulate a minimum of 150 min of moderate, or 75 min of vigorous intensity PA over the course of a week (Department of Health & Social Care, 2019; Physical Activity Guidelines Advisory Committee, 2018). The global prevalence of insufficient PA is estimated to be 27.5%, with trend data indicating that current global targets for the reduction in levels of inactivity (to 10% by 2025) will not be met (Guthold et al., 2018).

Walking has been proposed to be "*the most likely way all adults can achieve the recommended levels of physical activity*" (NICE Public Health Guidance, 2012) (p28). The potential to increase population-levels of PA through the promotion of cycling has also been highlighted, given the capability of most adults to cycle short trips but the currently reported low levels of this activity in several countries (NICE Public Health Guidance, 2012; Strain et al., 2016). The population-level health benefits of walking and cycling, as forms of transport or as leisure activities, are well-established (Laird et al., 2018). A systematic review and meta-analysis found significant reductions in the risk of all-cause mortality (11% for walking and 10% for cycling) for individuals achieving current PA recommendations through walking and cycling, independent of other forms of activity (Kelly et al., 2014).

Active travel (predominantly walking and cycling for purposeful journeys) has been described by the Global Advocacy for Physical Activity (GAPA) as *"the most practical and sustainable way to increase physical activity on a daily basis"* (Global advocacy for physical activity (GAPA), 2012) (p710). The potential health benefits of active travel are substantial (Laird et al., 2018; Saunders et al., 2013). For example, a recently published prospective cohort study, using data from 263,450 individuals involved in the United Kingdom (UK) Biobank study, found associations with a lower risk of cardiovascular disease for walking and cycling journeys to work (i.e., active commuting), and with cancer and all-cause mortality for cycling commuting (Celis-Morales et al., 2017). There are positive associations between psychological well-being and active travel, which are also evident in those who change from car travel to active travel (Martin et al., 2014). Whilst commuting by bicycle may be associated with a higher risk of hospital admissions from injury in comparison to non-active commuting modes (Welsh et al., 2020), the beneficial impacts on health for individuals who shift from using the car to bicycle for short daily trips have been shown to outweigh any potential adverse effects such as increased exposure to air pollution and injuries (Laird et al., 2018; Hartog et al., 2010).

1.2. Quantifying the health and economic benefits

Several reports have highlighted the contribution of walking and cycling to overall levels of PA (Cavill et al., 2019). Walking in particular has been noted to be a major contributor to total moderate to vigorous PA (regardless of meeting PA guidelines), in men and women and across age categories (Strain et al., 2016). Active commuters report more leisure time activity (Foley et al., 2015) and are more physically active overall than those who commute by other modes (Yang et al., 2012; Donaire-Gonzalez et al., 2015; Sahlqvist et al., 2012). However, research which specifically aims to quantify the potential contribution that active commuting can make to achieving PA guidelines is more limited. Stewart and colleagues (2015) performed a cross-sectional analysis of the English Active People Survey and found that individuals who perform utility cycling (purposeful cycling as a means of transport) are four times more likely to achieve PA guidelines than those who do not, with some evidence of variation by geographical locality (Stewart et al., 2017). An evaluation over a 9-year period of several thousand individuals involved in a workplace transport plan in England found that approximately two-thirds of active commuters met over 80% of the recommended amount of PA (Brockman and Fox, 2011). Another study in England, conducted on a small-scale involving approximately 100 individuals, found that walking to work contributed to almost half of all moderate to vigorous PA accumulated on working days (Audrey et al., 2014).

There is consistent evidence of the health and economic benefits of walking and cycling, supporting the premise that investment in infrastructure and policies which facilitate these behaviours can play a critical role in preventing deaths and enhancing positive health benefits (Davis, 2010; Cavill et al., 2008; Mueller et al., 2015). Analyses have been conducted using a multitude of modelling approaches, with some studies critiqued over the quality and reporting of methods used to calculate the benefits (Davis, 2010; Cavill et al., 2008). One commonly used, robust and nationally endorsed approach is the World Health Organization's (WHO) Health and Economic Assessment Tool (HEAT). The HEAT tool has been used in assessments of small-scale interventions or programmes such as a Bike Share scheme (Babagoli et al., 2019), the implementation of new cycling infrastructure (Deenihan and Caulfield, 2014), and evaluations of city-wide changes in walking and cycling (Pérez et al., 2017). Population-level studies are less common (Mueller et al., 2015), although one study from the Netherlands has estimated that over 6500 deaths in Holland were prevented by cycling annually, with a total economic benefit of 19 billion EUR per year (Fishman et al., 2015). However, this study examined only cycling and further, made no distinction between cycling for leisure and cycling for transport or commuting purposes. One study used HEAT to estimate an annual economic benefit of £1.75 billion for walking in natural environments in England (White et al., 2016). There remains a lack of published findings on the economic benefit of active commuting at a national level.

1.3. Aims and objectives

This study was designed to contribute to the evidence base on quantifying the health and economic benefits of walking and cycling. Specifically, we aimed to expand on the existing literature by utilising a nationally representative data-set at multiple time-points (2001 and 2011 waves of the Scottish Census) to investigate the health and economic benefits of walking and cycling for commuting purposes at a national level.

The specific research objectives were as follows:

1. Establish levels and trends of active commuting (walking and cycling) to work and study in Scotland, UK.

2. Estimate the proportion of these active commuters who walk or cycle a minimum of 30 min per day (meeting a daily equivalent of the weekly target for moderate intensity physical activity).
3. Quantify population-level economic values of the health benefits associated with these levels of commuter walking and cycling.

2. Methods

2.1. Setting and data source

This study utilises data from the Scottish Census, which takes place every 10 years and is the official Government assessment of all individuals and households in Scotland (https://www.scotlandscensus.gov.uk/what-census). Scotland is a small country with an estimated population of 5,463,300 as of 2019 (National Records of Scotland, 2020). Scotland is situated in the northern half of Britain, part of the UK, but with a devolved government since 1999 which controls most aspects of transport in Scotland, including the active travel budget. Within Scotland, there are 32 Local Authority (LA) areas, who are mainly funded through, but operate independently of, central government and are responsible for local service provision such as roads and transport.

Questions in the Scottish Census are asked about key topics such as education, health and transport, in addition to a wide range of sociodemographic factors such as age, gender and employment status. For this study, we analysed data from the 2001 and 2011 waves of the Scottish Census (accessed through the Administrative Data Network; https://www.adruk.org/) using a repeat cross-sectional design. Analyses were conducted at both a national level, and for each of the 32 LAs separately.

2.2. Data extracted

Our analysis is based on responses to the Scottish Census question: "*How do you usually travel to your main place of work or study (including school)?*". Respondents are asked to select which mode of travel they use for the longest part, by distance, of their usual journey. We extracted data for respondents who answered either 'On foot' or 'Bicycle' from 10 possible responses (other responses were: driving a car or van; passenger in car or van; Bus, minibus or coach; Train; Underground, subway, metro, light rail or tram; Taxi; Motorcycle, scooter or moped; Other). The question and responses are equivalent in both Census waves. From available Census data we also extracted an estimated distance to work variable, estimated in both waves as the straight-line distance between the home and work addresses reported by the respondent.

2.3. Sample

For examining trends in active travel, and for quantifying the contribution of active commuting to PA guidelines we focused on a working age sample. This included respondents aged 16–74 years who work or study at a fixed address within the UK, excluding those people who work/study mainly at home, in communal establishments or in no fixed place, offshore or outside the UK.

Examination of the modes of transport for respondents in these categories revealed a minority of pedestrian and cycling commuters who appeared to commute implausibly long distances. It also showed improbable patterns of mode of transport for those living very close to their place of work. This suggests that for these respondents there may be an unacceptably high degree of error in the distance variable (due to the imputation procedures used for the Census). Accordingly, we excluded respondents (approximately 30 and 40% for walking, and 9 and 15% for cycling) with distances of less than 500 m or over 40.5 km. Thus, when we talk for example about the '*percentage of commuters*' walking or cycling, what we precisely mean is: *The percentage of commuters aged 16 to 74 who commute for work or study to a fixed place between 500m and 40.*5 km *from their home, which is within the UK and not offshore,* by walking or cycling.

For estimating the economic value of health benefits, we examined a modified age-range of these respondents. Specifically, analysis was conducted on data for respondents in the 20 to 74 age range for walking, while for cycling this was for the 20 to 64 age range. These are specifications found in the published guidelines for generating these economic values using the WHO's HEAT tool for walking and cycling, and are based on the age applicability of the separate epidemiological evidence bases for walking and cycling and also the likelihood of the maintenance of walking and cycling behaviour with increasing age (Kahlmeier et al., 2017).

2.4. Trends in active commuting

The first stage of our analysis was to develop a consistent set of descriptive statistics from both the 2001 and 2011 waves of census allowing comparison between the two waves. We calculated the number of cyclists and walkers (separately), and what proportion these were of those in the dataset (i.e., of people aged 16 to 74, working or studying between 500 m and 40.5 km from home and commuting to a fixed place onshore in the UK) first of all for Scotland as a whole, and then by the respective 32 LAs. We also stratified the national level findings by employment status (full or part-time and students).

2.5. Contribution to PA guidelines

We first identified the daily distance travelled for each respondent classified as a pedestrian or cyclist, by multiplying the straight-line distance to work by two to include both outward and inward journeys. Daily commuting time was calculated by dividing the estimated daily distance commuted by recommended average speeds for walking (4.8 km/h) or cycling (14 km/h) as per those utilised in the assessment of economic benefit (see section 2.6). These are speeds indicative of moderate intensity activity and sufficient to elicit health benefits (Kahlmeier et al., 2017; Ainsworth et al., 2011). We then counted how many walkers and cyclists had daily commuting times of at least 30 min/day. The current PA guidelines are for the accumulation of 150 min of moderate activity over a week (Department of Health & Social Care, 2019; Physical Activity Guidelines Advisory Committee, 2018). However, within the guidelines relevant at the time of data analysis, it is suggested that one way to achieve this weekly target would be to accumulate 30 min of activity on 5 days of the week in bouts of at least 10 min (Chief Medical Office (CMO), 2011). Therefore, our analysis allowed us to examine the potential of active commuting to achieving these guidelines through the accumulation of 30 min of activity on each day that they actively commute.

2.6. Health and economic impact

The WHO Health Economic Assessment Tool (HEAT) for walking and cycling (available at http://www.heatwalkingcycling.org/) is a tool that allows the economic assessment of the health impacts of walking and cycling (Kahlmeier et al., 2017). The "HEAT" works by estimating the reduction in mortality that results from specified amounts of walking and cycling (the counterfactual being zero walking and cycling). The tool implicitly factors in any increases in mortality from collisions and air pollution to give net benefits. It then places a monetary value on the calculated mortality reductions. The HEAT has default parameters that can be adjusted by the user specific situations. For example, in this study we used default values for walking and cycling speeds, but utilised specific mortality rates for Scotland for the years of Census rather than default UK or EU values.

First, for each census wave, data on the number of commuting walkers and cyclists were extracted within the previously defined age ranges (20–74 for walkers, 20–64 for cyclists). Then the average weekly distance (km) of walking or cycling was estimated assuming a five-day working week, and used to calculate number of minutes walking or cycling per week in the same way as when calculating commuting time to see how many people met the daily equivalent of the target. Based on reference values for relative risk (RR) of all-cause mortality (ACM), and assuming a linear dose-response relationship, the RR for ACM based on calculated walking or cycling exposure was computed (Kahlmeier et al., 2017). The reference values were RR = 0.886 for 168 min per week for walking and RR = 0.903 for 100 min per week for cycling. In line with underlying HEAT assumptions, the maximum benefit (risk reduction) were capped at RR = 0.70 for walking and RR = 0.55 for cycling, beyond which additional walking and cycling was assumed to give no further risk reduction benefits. The formula for estimating risk as described in the HEAT user guidance (Kahlmeier et al., 2017) was:

$$\text{Risk} = 1 - RR_{(\text{walk or cycle})} \times (\text{local volume of walking or cycling/ reference volume of walking or cycling})$$

Data on background population mortality rates for adults aged 20–74 (for walking) and 20–64 (for cycling) in Scotland in 2001 and 2011 were calculated based on an extract of mortality data provided by National Records of Scotland. Mortality rate data and calculated RR for ACM were combined to estimate the number of deaths being averted by the walking or cycling annually and over a 10-year period (at assumed stable levels of walking and cycling).

$$\text{Deaths averted} = \text{Mortality rate (per 100,000) x Population size x } (1 - \text{Risk})$$

The numbers of deaths were combined with the Value of Statistical Life (default 2015 value for the UK of EURO 4.04 million) (Kahlmeier et al., 2017) to estimate annual and 10-year economic value of the walking and cycling.[2] The 10-year economic values were discounted at 5% per year. These analyses were repeated for each of the 32 Local Authority areas in Scotland using the mortality rate and walking and cycling data for each area respectively.

3. Results

3.1. Levels and trends in active commuting

The numbers and proportions of active commuters (walking, cycling and overall active commuting) in 2001 and in 2011, at the national level and also for the lowest and highest LAs can be found in Table 1. Overall in Scotland, active modes of commuting accounted for a modal share of between 13% and 15% of all commuters in both 2001 and 2011. A small increase in the proportion of active commuters was found between 2001 (13.5%, n = 244,009) and 2011 (14.5%, n = 286,145). These data demonstrate the low levels of cycling for commuting purposes reported in Scotland which remained relatively unchanged over time: 1.7% of all commuters (n = 29,981) in 2001, and 1.8% of all commuters (n = 35,389) in 2011. Levels of walking commuting were higher than cycling commuting; walkers constituted approximately 88% of all active commuters at each time-point.

The numbers and proportions of individuals actively commuting varied considerably by Local Authority (see Table 1; a full breakdown by LA can be found in Appendix A: Table A1). Active commuting by either mode ranged from 5.4 to 23.8% in 2001 and 5.6–27.7% in 2011. The four major cities (Aberdeen 24.8%, Dundee 24.5%, Edinburgh 27.7% and Glasgow 20.8%) had the highest levels of active commuting in 2011. With the exception of Dundee, the modal share for cycle commuting in 2011 in these cities was also

[2] "Transport appraisal often uses a standard VSL derived using willingness to pay. The willingness to pay shows how much a representative sample of the population would be willing to pay (in monetary terms), for example for a policy that would reduce their annual risk of dying from 3 in 10,000 to 2 in 10,000. Thus, this estimates the overall economic value to society of reduced premature mortality" Source: http://www.euro.who.int/_data/assets/pdf_file/0010/352963/Heat.pdf?ua=1.

Table 1
Numbers (and proportions) of active commuters aged 16–74 in 2001 and 2011, for Scotland and the lowest and highest Local Authority (LA) areas.

	Scotland			Lowest Proportion[a]			Highest Proportion		
	All Active Commuters	Cyclists	Walkers	All Active Commuters	Cyclists	Walkers	All Active Commuters	Cyclists	Walkers
2001	244,009 (13.5)	29,981 (1.7)	214,028 (11.8)	1916 (5.4)	211 (0.6)	1705 (4.8)	45,707 (23.8)	7332 (3.8)	38,375 (20.0)
2011	286,145 (14.5)	35,389 (1.8)	250,756 (12.7)	1981 (5.6)	301 (0.8)	1680 (4.7)	57,436 (27.7)	11,057 (5.3)	46,379 (22.4)

Note: proportion is of commuters aged 16 to 74 who commute for work or study to a fixed place between 500 m and 40.5 km from their home, which is within the UK and not offshore.

[a] The Local Authority (LA) which reported the lowest proportion of all active commuters, was the same LA for cyclists and walkers at each time-point. The same was evident for the highest LA.

above the national average of 1.8% and had increased between census points. A considerable number of the 32 LAs (22 in 2001, 24 in 2011) were below the national average of proportion of cycling commuters at the respective time-points.

By employment status, there was a higher percentage of students who were active commuters (by either mode) at 31.7% in 2001 than for either part-time (15.8%) or full-time workers (9.8%). This has remained relatively consistent over time, with similar proportions found in 2011 for students (32.8%), part-time workers (14.8%) and full-time workers (10.6%). Full-time workers represent the largest group of active commuters (47.5% of all active commuters); this likely reflects the fact that there are more full-time workers commuting overall. A higher proportion of full-time workers (2.0%) and students (1.8%) cycle compared to part-time workers (1.0%).

3.2. *Contribution to PA guidelines*

Table 2 provides the numbers and proportions of active commuters meeting the recommended 30 min of physical activity daily. At a national level, 46.5% (n = 113,392) of all active commuters met the 30 min a day target in 2001. Of those who walk, 48.4% (n = 103,570) met this target as did 32.8% (n = 9822) of cyclists. In 2011, this had increased for both modes of active commuting, and consequently also overall active commuting; 50.2% (n = 143,614) of active commuters met this daily recommended amount of activity, made up of 42.5% (n = 15,027) of cyclists and 51.3% (n = 128,587) of walkers. Overall, active commuters who meet the daily PA target account for approximately 7.3% of all commuters (active or not) in 2011; this proportion has risen slightly since 2001 (from 6.3%).

There was evidence of increases between time-points in the proportion of active commuters meeting activity guidelines for all employment types. For those who commuted by any active mode, full-time workers had the highest proportion meeting the activity guidelines in both 2001 (49.0%, n = 61,115) and 2011 (52.8%, n = 71,845). Students reported the next highest proportion, again at both time-points (46.1%, n = 30,461 in 2001; and 50.4%, n = 44,126 in 2011). Part-time workers who actively commute were less likely to meet the 30 min per day target in both 2001 (41.0%, n = 21,816) and 2011 (44.2%, n = 27,643) than the other groups.

In 2011, a higher proportion of full-time workers who cycled met the daily PA target (46.8%, n = 12,286) compared with part-time workers who cycled (36.5%, n = 1624) at this time-point. However, students who cycle were the group least likely to meet the daily PA target by this mode (23.8%, n = 1117). As reflected in the national level findings, these values represent an increase from 2001 for all employment types (full-time workers; 36.2%, n = 8286; part-time workers 23.8%, n = 828; students 19.6%, n = 708).

There was considerable variation in the proportions of active commuters achieving 30 min of moderate intensity activity per day (by different active modes) in different Local Authority areas (see Table 2 and Appendix A: Table A2). For example, those reaching the target by commuting by any active mode ranged from 33.3% to 59.4% in 2011 which, as expected, was similar to commuting by walking. However, there was even greater variation by local authority area for cycling where the proportion ranged from 21.7% to 86.4% in 2011.

3.3. *Health and economic impact*

Differences in values between time-points or by LA are a function of walking or cycling prevalence, walking or cycling distance, population size and local mortality rate. The values presented in the text below and in Table 3 (for Scotland and the lowest and highest LAs) for number of premature deaths and health economic value (annually and for 10-years) were not adjusted for population size. A full breakdown by LA of these values, and additionally a population size adjusted mortality rate, can be found in Appendix A: Tables A3 and A4.

3.3.1. *Economic impact of walking*

In Scotland, 171,729 people walked an average of 4.7 km/day to work in 2001 and 203,879 people walked an average of 4.1 km/day in 2011. From these data it was estimated that walking commuting in Scotland prevented 211.3 premature deaths per year in 2001 and 173.3 premature deaths per year in 2011. Analysis showed that the annual health economic value of walking commuting in Scotland in 2001 was EUR 853.7 million per year, or EUR 6850.7 million over 10 years (at an annual discount rate of 5%). In 2011 the values were EUR 700.2 million (annual) and EUR 5619.3 million (over 10 years) respectively.

Table 2
Numbers (and proportions) of active commuters aged 16–74 meeting recommended 30 min of daily PA, for Scotland and the lowest and highest Local Authority (LA) areas.

	Scotland			Lowest Proportion[a]			Highest Proportion[b]		
	All Active Commuters	Cyclists	Walkers	All Active Commuters	Cyclists	Walkers	All Active Commuters	Cyclists	Walkers
2001	113,392 (46.5)	9822 (32.8)	103,570 (48.4)	1800 (32.4)	23 (13.7)	1755 (33.8)	6165, 24,856[c] (54.4)	160 (75.8)	22,272 (58.0)
2011	143,614 (50.2)	15,027 (42.5)	128,587 (51.3)	401 (33.3)	30 (21.7)	371 (34.8)	34,130 (59.4)	260 (86.4)	29,138 (62.8)

Note: proportion is of commuters aged 16 to 74 who commute by walking or cycling on the longest leg of the commute for work or study to a fixed place between 500 m and 40.5 km from their home, which is within the UK and not offshore.
[a] There were two LAs represented within the lowest proportions of cyclists, walkers and all active commuters at each time-point.
[b] There were two LAs represented within the highest proportions of cyclists, walkers and all active commuters at each time-point.
[c] There were two LAs who had the same highest proportion of all active commuters (54.4%) in 2001.

Table 3
Deaths averted and annual economic values for walking and cycling commuters for Scotland and the lowest and highest Local Authority (LA) areas (for deaths averted per year).

	Walking				Cycling			
	Population size (aged 20–74)	Deaths averted per year	Annual value (EUR millions)	10 year discounted value (EUR millions)	Population size (aged 20-64	Deaths averted per year	Annual value (EUR millions)	10 year discounted value (EUR millions)
Scotland								
2001	3,481,059	211.3	853.7	6850.7	3,034,417	16.8	68.0	546.0
2011	3,706,733	173.3	700.2	5619.3	3,221,953	19.8	79.8	640.2
Lowest LA[a]								
2001	14,695	0.9	3.7	29.7	13,082	0.02	0.1	0.8
2011	60,007	0.6	2.4	19.1	13,794	0.03	0.1	1.1
Highest LA[b]								
2001	400,500	31.2	125.9	1010.1	284,032	3.2	12.7	102.1
2011	425,482	30.8	124.4	998.4	313,728	4.4	17.8	142.8

[a] The lowest LA for walking was different between 2001 and 2011, but the same for cycling at each time-point. There were different LAs represented for walking and cycling respectively.
[b] The highest LA was the same for walking at each time-point, and also for cycling. There were different LAs represented for walking and cycling respectively.

Across the 32 LAs, there was considerable variation in walking distance (3.2–8.6 km/day in 2001; 3.0–6.3 km/day in 2011). It was estimated that the number of premature deaths prevented by walking commuting per year ranged from 0.9 to 31.2 per year in 2001, and 0.6–30.8 in 2011. And the health economic value of walking commuting at the LA level ranged from EUR 3.7 to 125.9 million per year, and EUR 29.7 million to 1010.1 million over 10 years in 2001. In 2011 this ranged from EUR 2.4 to 124.4 million per year and EUR 19.1 to 998.4 million over 10 years.

3.3.2. *Economic impact of cycling*

In Scotland, 27,966 people cycled an average of 7.7 km/day to work in 2001 and 33,818 people cycled an average of 8.9 km/day in 2011. From these data it was estimated that cycle commuting in Scotland prevented 16.8 premature deaths per year in 2001 and 19.8 premature deaths per year in 2011. Further analysis showed that the annual health economic value of cycle commuting in Scotland in 2001 was EUR 68.0 million per year, or EUR 546.0 million over 10 years (at an annual discount rate of 5%). In 2011 the values were EUR 79.8 million and EUR 640.2 million, respectively.

Across the 32 LAs, there was considerable variation in cycling distance (6.3–14.4 km/day in 2001; 7.1–16.0 km/day in 2011). From these numbers it was estimated that the number of premature deaths prevented by cycling commuting ranged from 0.02 to 3.2 per year in 2001, and 0.03–4.40 in 2011. The health economic value of cycling commuting ranged from EUR 0.1 million to 12.7 million per year, and 0.8 million to 102.1 million over 10 years in 2001. In 2011 this ranged from 0.1 million to 17.8 million per year and EUR 1.1 million to 142.8 million over 10 years.

4. Discussion

4.1. Main findings

This study is the first to use individual-level Census data in Scotland to examine trends in active commuting over time. These findings show that over a 10-year period there was a small increase (approximately 1%) in the proportion of people using walking and cycling as their usual mode of transport to work or study (for the longest part of their journey). Importantly, these data demonstrate that only one in seven people in Scotland chose an active mode of commuting to work or study at these time-points. Perhaps unsurprisingly, the main cities in Scotland have the highest rates of active commuting, although these still represent around only one in four commuters choosing an active mode. These findings provide further evidence of the low levels of cycling in Scotland, where at a national level less than 2% of the population commuted by this mode (although substantial geographic variation was noted). There are relatively few sources of national level data on active travel in Scotland. However, these findings are consistent with more recent data from the Scottish Household Survey (a nationally representative survey based on a sample of the general population in private residences with a detailed travel diary) that demonstrates no substantial changes in walking or cycling commuting from 2009 to 2019, and a low modal share of cycling commuting; 12% walked to work in 2019 and 2.7% cycled (Transport Scotland, 2020).

Despite the relatively low modal shares found, it is evident that there are still substantial health and economic benefits to Scotland as a result of these activities. This study provides clear evidence of the considerable contribution that active commuting to work can make to achieving recommended guidelines for PA. The findings indicate that half of all full-time workers actively commuting would achieve the recommended weekly quantity of PA (150 min of moderate intensity PA) (Department of Health & Social Care, 2019) through active commuting alone. Future research could use these data to explore different durations of activity (e.g., 10 or 20 min daily), as it is likely that a much greater proportion of workers would be achieving these which would still make a valuable contribution to achieving the PA recommendations in combination with other forms of physical activities over the week.

Despite the relatively low levels of active commuting in Scotland, in 2011 it was estimated that close to 200 deaths a year could be prevented through current levels of active commuting. Using the most up-to-date estimates (2015) for Value of Statistical Life (Kahlmeier et al., 2017), this is linked to an economic value of approximately EUR 780 million per year for both modes of active commuting combined. The majority of this (EUR 700 million) is attributable to walking to work due to the higher prevalence of this mode of commuting in comparison to cycling (value of EUR 80 million). Even if there is no change in levels of active commuting between 2011 and the next Scottish Census, this would result in an economic value over 10 years of over EUR 6 billion for both modes of active commuting combined. It is worth noting that the health economic value calculations are based on mortality, and do not factor in reduced morbidity as a result of walking and cycling. Thus, these values are likely to be a substantial underestimation of the true health benefits of active commuting in Scotland.

These values are lower than economic benefits published for some other European countries (Mueller et al., 2015; Cavill and Kahlmeier, 2016), although our findings do not include the additional health economic value of walking or cycling for other purposes. For example, an annual economic benefit of EUR 19 billion for the Netherlands was reported in one study (Fishman et al., 2015). Whilst this study also used the HEAT tool, the economic benefit was estimated using levels of total cycling for all adults aged up to 90 years, thus the results are not directly comparable and not solely due to the considerably higher prevalence of cycling in the Netherlands compared with Scotland.

It is interesting to note the economic value of walking was lower for 2011 than for 2001, despite an increase in the number of pedestrian commuters over time. This difference is attributable to a lower average daily walking distance combined with reductions in background mortality (−115 per 100,000) for this age group between 2001 and 2011. Whilst overall commuting distances in the UK were increasing during this time-period (Le Vine et al., 1988), recent Scottish data suggest a decrease in the percentage of short, all-purpose journeys under 2 miles by walking (Transport Scotland, 2019). These trends may be reflected in our study in that walkers (including new) in 2011 are those who have a shorter commuting journey, and that longer commuting journeys are now more likely to be performed by a different mode.

4.2. Limitations and strengths

There are some limitations to this study. First, it is important to place findings into a temporal context, given that they are generated using data from 2001 to 2011, and therefore may not fully reflect current levels of active commuting in Scotland, in particular geographic variation. Second, applying cut-points for implausible distances leads to an underestimation of the number of active commuters, and consequently of the estimated health economic values. Third, the outcome measure used is a single-item instrument designed to capture the main mode of commuting only and assumes that the return journey home is by the same mode as the journey to work. This limits the available detail of participants' commuting journeys (time, distance and frequency) compared to what could be obtained by other methods such as a travel diary or GPS (Fishman et al., 2015; Le Vine et al., 1988; Ogilvie et al., 2010). Population levels of meaningful active commuting may be underestimated, as some respondents may walk and cycle for shorter parts of a multi-mode journey. Whilst the active commuting question refers to the longest part of a journey, any distance estimation represents the entire commuting journey. Therefore, an overestimation of the distance travelled by walking or cycling is possible. However, individuals who select walking or cycling as their main mode of transport rarely perform this as part of a multi-stage journey so such overestimation is likely to be minor (Transport Scotland, 2019). Alternatively, the straight-line distance estimate used may underestimate the actual commuting distance, since journeys are performed on road networks and off-road cycle path (Stigell and Schantz, 2011).

However, Goodman (2013) compared the corresponding active commuting item in the English and Welsh census with total travel time spent in those modes from the National Travel Survey, concluding that the census item appears to be a reasonable proxy for the proportion of total travel time spent in that mode, at a population level (Goodman, 2013). Therefore, despite the associated limitations, the active commuting measure used in this study is appropriate for the purpose of the investigation (Sattler et al., 2021). The Census is a valuable resource to contribute to the accumulation of evidence on active travel in the Scottish context alongside other sources which may provide more detailed information but not at the same geographical scale.

Finally, it should also be noted that estimating the magnitude of the health economic benefits that are likely to occur is no simple task, and there are a multitude of potential methods (Davis, 2010; Cavill et al., 2008; Mueller et al., 2015). HEAT uses a linear dose-response function so that it can be used in situations where the baseline or underlying physical activity levels of the walking or cycling population are not known. It is understood that this will slightly under-estimate the effect of the walking or cycling in a low active population and slightly over-estimate in a high active population, and leads to some uncertainty in the results presented. However, the HEAT tool is based on the best available evidence and transparent assumptions and is issued and endorsed by the WHO (Kahlmeier et al., 2017). It is considered to be robust, can be used at both national and local level, and was decided to be the most appropriate given the likely audience of these findings. HEAT is promoted, and included in national guidance of several European countries (Cavill and Kahlmeier, 2016). Additionally, other tools often require more detailed data on exposure that could not be obtained from the data source used in this study.

4.3. Relevance to policy makers

Increasing population levels of walking and cycling has multiple health and environmental benefits. The recently published WHO Global Action Plan on Physical Activity 2018–2030 states that *"investing in policies to promote walking and cycling … can contribute directly to achieving many of the 2030 Sustainable Development Goals (SDG)"* such as good health and well-being, climate action and sustainable cities and communities (World Health Organization, 2018) (p7). Impressive benefit to cost ratios have been shown. In one study, the economic benefit of cycling was estimated as almost 20 times that of the economic investment in cycling infrastructure (Fishman et al., 2015). Within the 2020-21 Scottish Budget, the Government committed to raise the Active Travel budget further to £100 million, which equates to £18.30 per head of population, over double the equivalent English figure (Scottish Government, 2020). With this increased investment, which has built up over the last decade, it is plausible that levels of active commuting may increase over time and be reflected in future waves of Census data, resulting in greater economic benefits than those observed in this study. Nevertheless, it is clear from our findings that sustained and substantial investment will be required if Scotland is to achieve the goal of having walking and cycling as the most popular choices for shorter everyday journeys (Transport Scotland, 2014).

At the time of writing of this article, the world is dealing with the outbreak and aftermath of Coronavirus Disease (COVID-19). In Scotland, there is mixed-evidence on the short-term impact on walking and cycling during the period of lockdown. Levels of commuting (by any mode) have substantially decreased with the modal share for cycling reported as less than 2% (Transport Scotland, 2020); however, there is evidence that leisure time cycling has increased (Whyte, 2020). Data from several countries supports an increase in cycling between 2019 and 2020 as a result of Covid-19 (Buehler and Pucher, 2021). The longer-term (and potentially differential) impacts of COVID-19 on walking and cycling, as linked to transport and health, are not yet known. However, it is likely that the aftermath of this outbreak will lead to shifts in future mobility patterns due to changes in work patterns, the use of public transport and participation in leisure activities (Musselwhite et al., 2020) potentially leading to a maintenance in the observed increase in cycling (Buehler and Pucher, 2021). Data from Scotland collected during lockdown cite that 63% of respondents intend to walk or cycle more for travel when restrictions on transport are lifted (Transport Scotland, 2020). Our findings provide supportive evidence of the contribution active travel (specifically commuting) can make to achieving government recommended levels of PA, and for the substantial economic benefits that walking and cycling commuting can make at both national and local authority levels. These findings underline the critically important role of making the case for walking and cycling promotion, particularly during the recovery from COVID-19 (Buehler and Pucher, 2021). These data could be utilised as advocacy tools at the national level, but also within individual local authorities to stress the value of the promotion of active commuting and the need for continued investment.

Finally, we have demonstrated for the first time the potential to utilise this data source to investigate the health and economic benefits of active commuting in Scotland. This data-set has not been made available before now for research purposes in the manner which has been done in this study. Other data sources in Scotland offer more detailed information on commuting journeys, but invariably have small sample sizes (e.g. (Transport Scotland, 2019)). Whilst there is an argument that what is needed is a comprehensive, national monitoring scheme of walking and cycling in Scotland, the data-sets analysed in this study provide local, and national trend data which may be used for comparison when considering the effects of future interventions, programmes or policies that potentially have an impact on active travel.

5. Conclusion

Overall this work shows the important health and economic benefits associated with active commuting at a local and national level. There has been little observed change in active commuting between the 2001 and 2011 waves of the national census, however it is clear that walking and cycle commuting have a substantial economic value to Scotland. These findings form a vital part of advocacy for more walking and cycling promotion, in engaging the wider public, and in justifying further investment in more walkable and cycle friendly environments in Scotland given the multiple co-benefits of moving away from car use to more active modes of travel. The outcomes of this research provide a baseline set of active travel and health metrics which can be used for monitoring and comparison over time.

Funding

Funding for the project was provided by Glasgow Centre for Population Health and the Physical Activity for Health Research Centre, University of Edinburgh.

This funding was used for salary costs of the main researcher Rebecca Pillinger.

Other authors did not receive any specific funding for this work.

Author contributions

GB and BW conceived the study and developed the overarching research goals. All authors contributed to the design of the methodology. Formal analysis of the Census data (including calculation of summary statistics for input to the HEAT analysis) was conducted by RP, with the HEAT analysis conducted by PK. GB wrote the original draft and BW, RP and PK provided critical review and editing during the drafting process. All authors agreed to the final submitted manuscript.

Credit author statement

Graham Baker: Conceptualization, Methodology, Writing – Original Draft, Supervision, Project administration; **Rebecca Pillinger**: Methodology, Formal analysis, Data Curation, Writing – Review & Editing; **Paul Kelly**: Methodology, Formal analysis, Data Curation, Writing – Review & Editing; **Bruce Whyte**: Conceptualization, Methodology, Writing – Review & Editing

Acknowledgements

The authorship team would like to acknowledge Andrew Williams and Chloë Williamson for critical reviews of the Research Narrative and draft manuscript, respectively. We would also like to thank the Administrative Data Network and National Records Scotland for facilitating access to the data used in this study.

Appendix A

Table A.1
Numbers and proportions of active commuters aged 16–74 in 2001 and 2011, for Scotland and stratified by Local Authority area

	2001			2011		
	All Active Commuters	Cyclists	Walkers	All Active Commuters	Cyclists	Walkers
	Number (% of all commuters)					
Scotland	244,009 (13.5)	29,981 (1.7)	214,028 (11.8)	286,145 (14.5)	35,389 (1.79)	250,756 (12.7)
Local Authority						
Aberdeen City	18,525 (20.3)	1895 (2.1)	16,630 (18.2)	25,989 (24.8)	2388 (2.3)	23,601 (22.5)
Aberdeenshire	7374 (9.5)	1123 (1.5)	6251 (8.1)	8129 (8.9)	878 (1.0)	7251 (7.9)
Angus	6056 (16.5)	1034 (2.8)	5022 (13.7)	5816 (14.9)	731 (1.9)	5085 (13.0)
Argyll & Bute	3612 (14.6)	419 (1.7)	3193 (12.9)	3766 (15.2)	425 (1.1)	3341 (13.5)
Clackmannanshire	1496 (9.2)	211 (1.3)	1285 (7.9)	1598 (8.8)	203 (1.1)	1395 (7.7)
Dumfries & Galloway	6611 (15.6)	1078 (2.5)	5533 (13.1)	6916 (15.2)	881 (1.9)	6035 (13.2)
Dundee City	11,325 (21.3)	718 (1.4)	10,607 (19.9)	13,797 (24.5)	890 (1.6)	12,907 (23.0)
East Ayrshire	3927 (9.7)	203 (0.5)	3734 (9.2)	3635 (8.3)	190 (0.4)	3445 (7.9)
East Dunbartonshire	2854 (6.5)	300 (0.7)	2554 (5.8)	2957 (7.1)	407 (1.0)	2550 (6.1)
East Lothian	2815 (8.8)	408 (1.3)	2407 (7.6)	3600 (10.0)	561 (1.6)	3039 (8.5)
East Renfrewshire	1916 (5.4)	211 (0.6)	1705 (4.8)	1981 (5.6)	301 (0.8)	1680 (4.7)
Edinburgh, City of	45,707 (23.8)	7332 (3.8)	38,375 (20.0)	57,436 (27.7)	11,057 (5.3)	46,379 (22.4)
Eilean Siar	628 (8.5)	70 (0.9)	558 (7.5)	723 (8.5)	61 (0.7)	662 (7.8)
Falkirk	5142 (9.3)	855 (1.5)	4287 (7.8)	5160 (8.4)	700 (1.1)	4460 (7.2)
Fife	14,458 (11.4)	1870 (1.5)	12,588 (10.0)	15,215 (11.3)	1888 (1.4)	13,327 (9.9)
Glasgow City	31,896 (16.8)	2489 (1.3)	29,407 (15.5)	46,580 (20.8)	4602 (2.1)	41,978 (18.7)
Highland	10,583 (16.5)	2354 (3.7)	8229 (12.8)	11,998 (16.2)	2499 (3.4)	9499 (12.8)
Inverclyde	2670 (9.0)	78 (0.3)	2592 (8.8)	2734 (9.2)	83 (0.3)	2651 (9.0)
Midlothian	2601 (8.1)	324 (1.0)	2277 (7.1)	2602 (8.0)	370 (1.1)	2232 (6.8)
Moray	5296 (19.6)	1734 (6.4)	3562 (13.2)	5246 (17.4)	961 (3.2)	4285 (14.2)
North Ayrshire	4481 (10.0)	559 (1.3)	3922 (8.8)	4012 (8.8)	371 (0.8)	3641 (8.0)
North Lanarkshire	9328 (7.9)	355 (0.3)	8973 (7.6)	9340 (7.3)	431 (0.3)	8909 (6.9)
Orkney Islands	961 (16.3)	168 (2.9)	793 (13.5)	1205 (16.6)	138 (1.9)	1067 (14.7)
Perth & Kinross	5911 (13.7)	582 (1.3)	5329 (12.4)	7435 (15.1)	728 (1.5)	6707 (13.6)
Renfrewshire	5578 (8.1)	619 (0.9)	4959 (7.2)	6006 (8.7)	624 (0.9)	5382 (7.8)
Scottish Borders	5802 (17.9)	617 (1.9)	5185 (16.0)	5676 (16.3)	499 (1.4)	5177 (14.9)

(*continued on next page*)

Table A.1 (*continued*)

	2001			2011		
	All Active Commuters	Cyclists	Walkers	All Active Commuters	Cyclists	Walkers
	Number (% of all commuters)					
Shetland Islands	681 (8.8)	29 (0.4)	652 (8.4)	756 (8.3)	41 (0.4)	715 (7.8)
South Ayrshire	4141 (11.7)	617 (1.7)	3524 (10.0)	4206 (12.0)	568 (1.6)	3638 (10.4)
South Lanarkshire	9617 (8.6)	482 (0.4)	9135 (8.1)	9334 (7.8)	552 (0.5)	8782 (7.4)
Stirling	3814 (13.2)	459 (1.6)	3355 (11.6)	3942 (12.8)	529 (1.7)	3413 (11.1)
West Dunbartonshire	3264 (9.6)	237 (0.7)	3027 (8.9)	2926 (8.5)	236 (0.7)	2690 (7.9)
West Lothian	4929 (7.6)	551 (0.8)	4378 (6.7)	529 (7.7)	596 (0.8)	4833 (6.8)

Table A.2
Numbers and proportions of active commuters aged 16–74 meeting recommended 30 min of daily PA, for Scotland and stratified by Local Authority area

	2001			2011		
	All Active commuters	Cyclists	Walkers	All Active commuters	Cyclists	Walkers
	Number (% of all using that mode of commuting)					
Scotland	113,392 (46.5)	9822 (32.8)	103,570 (48.4)	143,614 (50.2)	15,027 (42.5)	128,587 (51.3)
Local Authority						
Aberdeen City	9034 (48.8)	605 (31.9)	8429 (50.7)	14,327 (55.1)	1000 (41.9)	13,327 (56.5)
Aberdeenshire	2430 (33.0)	238 (21.2)	2192 (35.1)	2944 (36.2)	297 (33.8)	2647 (36.5)
Angus	2227 (36.8)	171 (16.5)	2056 (40.9)	2407 (41.4)	200 (27.4)	2207 (43.4)
Argyll & Bute	1429 (39.6)	201 (48.0)	1228 (38.5)	1567 (41.6)	208 (48.9)	1359 (40.7)
Clackmannanshire	530 (35.4)	74 (35.1)	456 (35.5)	669 (41.9)	86 (42.4)	583 (41.8)
Dumfries & Galloway	2294 (34.7)	224 (20.8)	2070 (37.4)	2630 (38.0)	215 (24.4)	2415 (40.0)
Dundee City	6165 (54.4)	291 (40.5)	5874 (55.4)	6702 (48.6)	309 (34.7)	6393 (49.5)
East Ayrshire	1768 (44.9)	62 (30.5)	1706 (45.7)	1583 (43.5)	75 (39.5)	1508 (43.8)
East Dunbartonshire	1362 (47.7)	204 (68.0)	1158 (45.3)	1539 (52.0)	318 (78.1)	1221 (47.9)
East Lothian	1028 (36.5)	188 (46.1)	840 (34.9)	1515 (42.1)	340 (60.6)	1175 (38.7)
East Renfrewshire	936 (48.9)	160 (75.8)	776 (45.5)	1071 (54.1)	260 (86.4)	811 (48.3)
Edinburgh, City of	24,856 (54.4)	2584 (35.2)	22,272 (58.0)	34,130 (59.4)	4992 (45.1)	29,138 (62.8)
Eilean Siar	234 (37.3)	20 (28.6)	214 (38.4)	304 (42.0)	16 (26.2)	288 (43.5)
Falkirk	2298 (44.7)	251 (29.4)	2047 (47.7)	2542 (49.3)	282 (40.3)	2260 (50.7)
Fife	6108 (42.2)	503 (26.9)	5605 (44.5)	6463 (42.5)	665 (35.2)	5798 (43.5)
Glasgow City	16,747 (52.5)	980 (39.4)	15,767 (53.6)	24,818 (53.3)	2034 (44.2)	22,784 (54.3)
Highland	3944 (37.3)	494 (21.0)	3450 (41.9)	5013 (41.8)	656 (26.3)	4357 (45.9)
Inverclyde	1082 (40.5)	35 (44.9)	1047 (40.4)	1238 (45.3)	60 (72.3)	1178 (44.4)
Midlothian	1029 (39.6)	172 (53.1)	857 (37.6)	1154 (44.4)	271 (73.2)	883 (39.6)
Moray	1987 (37.5)	558 (32.2)	1429 (40.1)	2274 (43.3)	313 (32.6)	1961 (45.8)
North Ayrshire	1721 (38.4)	173 (30.9)	1548 (39.5)	1710 (42.6)	174 (46.9)	1536 (42.2)
North Lanarkshire	4361 (46.8)	156 (43.9)	4205 (46.9)	4493 (48.1)	250 (58.0)	4243 (47.6)
Orkney Islands	323 (33.6)	23 (13.7)	300 (37.8)	401 (33.3)	30 (21.7)	371 (34.8)
Perth & Kinross	2541 (43.0)	151 (25.9)	2390 (44.8)	3573 (48.1)	291 (40.0)	3282 (48.9)
Renfrewshire	2623 (47.9)	296 (47.8)	2327 (46.9)	2927 (48.7)	356 (57.1)	2571 (47.8)
Scottish Borders	1880 (32.4)	125 (20.3)	1755 (33.8)	2233 (39.3)	171 (34.3)	2062 (39.8)
Shetland Islands	305 (44.8)	11 (37.9)	294 (45.1)	349 (46.2)	15 (36.6)	334 (46.7)
South Ayrshire	1803 (43.5)	190 (30.8)	1613 (45.8)	2091 (49.7)	226 (39.8)	1865 (51.3)
South Lanarkshire	4693 (48.8)	231 (47.9)	4462 (48.8)	4860 (52.1)	340 (61.6)	4520 (51.5)
Stirling	1734 (45.5)	126 (27.5)	1608 (47.9)	1939 (49.2)	168 (31.8)	1406 (51.9)
West Dunbartonshire	1680 (51.5)	101 (42.6)	1579 (52.2)	1524 (52.1)	118 (50.0)	2333 (52.3)
West Lothian	2240 (45.4)	224 (40.7)	2016 (46.0)	2624 (48.3)	291 (48.8)	2436 (48.3)

Table A.3
Deaths averted and annual economic values for walking commuters aged 20–74, for Scotland and stratified by Local Authority area

	2001				2011			
	Population size[a]	Deaths averted per year (population adjusted rate)[b]	Annual value (EUR millions)	10 year discounted value (EUR millions)	Population size[a]	Deaths averted per year (population adjusted rate) [b]	Annual value (EUR millions)	10 year discounted value (EUR millions)
Scotland	3,481,059	211.3 (6.1)	853.7	6850.7	3,706,733	173.3 (4.7)	700.2	5619.3
Local Authority								
Aberdeen City	151,086	1.0 (6.6)	40.3	323.2	162,414	10.6 (6.5)	42.8	343.5
Aberdeenshire	153,866	6.6 (6.6)	26.7	214.6	175,646	5.2 (3.0)	21.2	170.0
Angus	73,884	5.0 (4.3)	20.1	161.3	79,644	4.3 (5.4)	17.4	139.6
Argyll & Bute	62,570	5.0 (6.7)	20.3	162.9	61,750	3.7 (6.0)	14.9	119.5
Clackmannanshire	32,626	1.1 (3.4)	4.5	35.9	36,229	0.7 (2.0)	2.9	23.0

(continued on next page)

Table A.3 (*continued*)

	2001				2011			
	Population size[a]	Deaths averted per year (population adjusted rate)[b]	Annual value (EUR millions)	10 year discounted value (EUR millions)	Population size[a]	Deaths averted per year (population adjusted rate) [b]	Annual value (EUR millions)	10 year discounted value (EUR millions)
Dumfries & Galloway	101,056	7.3 (7.2)	29.6	237.2	104,133	5.3 (5.0)	21.2	170.3
Dundee City	99,729	12.5 (12.5)	50.4	404.7	102,329	7.9 (7.7)	31.9	255.9
East Ayrshire	82,080	5.6 (6.8)	22.6	181.4	85,523	3.1 (3.6)	12.3	99.0
East Dunbartonshire	73,473	1.4 (2.0)	5.8	46.5	71,306	1.1 (1.5)	4.3	34.3
East Lothian	60,308	2.1 (3.5)	8.6	68.8	67,729	2.1 (3.1)	8.4	67.6
East Renfrewshire	59,458	1.2 (2.0)	4.7	37.6	60,007	0.6 (1.0)	2.4	19.1
Edinburgh, City of	320,265	24.2 (7.6)	97.7	784.3	347,942	22.9 (6.6)	92.6	742.7
Eilean Siar	17,838	1.0 (5.6)	4.1	32.5	19,041	0.8 (4.0)	3.1	25.0
Falkirk	100,059	3.7 (3.7)	14.9	119.7	109,001	2.8 (2.5)	11.2	89.7
Fife	237,486	12.5 (5.3)	50.6	405.9	253,495	10.3 (4.1)	41.7	334.7
Glasgow City	400,500	31.2 (7.8)	125.9	1010.1	425,482	30.8 (7.2)	124.4	998.4
Highland	143,299	9.9 (6.9)	39.8	319.2	161,470	7.5 (4.6)	30.1	241.6
Inverclyde	57,257	3.4 (6.0)	13.8	110.7	56,651	2.4 (4.3)	9.8	78.6
Midlothian	54,890	2.0 (3.7)	8.2	65.8	57,509	1.1 (1.9)	4.3	34.9
Moray	59,245	3.7 (6.3)	15.1	120.9	63,947	3.9 (6.1)	15.7	126.0
North Ayrshire	92,252	5.1 (5.5)	20.6	165.0	95,264	3.9 (4.1)	15.6	125.3
North Lanarkshire	220,293	9.1 (4.1)	36.9	296.3	234,282	6.7 (2.8)	26.9	216.2
Orkney Islands	13,048	1.1 (8.3)	4.4	35.3	14,981	0.7 (4.9)	2.3	23.9
Perth & Kinross	91,638	6.9 (7.6)	28.0	224.6	100,764	6.4 (6.4)	25.9	208.1
Renfrewshire	119,629	4.8 (4.0)	19.3	155.0	122,008	3.2 (2.7)	13.1	105.1
Scottish Borders	72,919	5.1 (7.0)	20.6	164.9	78,567	4.1 (5.2)	16.5	132.1
Shetland Islands	14,695	0.9 (6.2)	3.7	29.7	15,947	0.6 (3.9)	2.5	20.1
South Ayrshire	76,833	3.7 (4.9)	15.1	121.2	78,000	2.9 (3.7)	11.5	92.3
South Lanarkshire	207,669	9.6 (4.6)	38.7	310.8	219,027	6.6 (3.0)	26.4	212.2
Stirling	58,977	3.5 (6.0)	14.2	114.0	62,106	2.2 (3.5)	8.9	71.3
West Dunbartonshire	63,199	5.3 (8.3)	21.3	170.9	63,066	2.4 (3.7)	9.5	76.0
West Lothian	108,932	4.4 (4.0)	17.6	141.2	121,473	3.1 (2.5)	12.4	99.8

[a] Population size for walking on individuals aged 20–74 years, and for cycling individuals aged 20–64 years, based on population sizes taken from an extract of mortality data provided by National Records of Scotland.

[b] Population adjusted rate equivalent to death rate/population *100,000.

Table A.4
Deaths averted and annual economic values for cycling commuters aged 20–64, for Scotland and stratified by Local Authority area

	2001				2011			
	Population size[a]	Deaths averted per year (population adjusted rate)[b]	Annual value (EUR millions)	10 year discounted value (EUR millions)	Population size[a]	Deaths averted per year (population adjusted rate)[b]	Annual value (EUR millions)	10 year discounted value (EUR millions)
Scotland	3,034,417	16.8 (0.6)	68.0	546.0	3,221,953	19.8 (0.6)	79.8	640.2
Local Authority								
Aberdeen City	133,380	0.8 (0.6)	3.1	25.1	146,054	1.0 (0.7)	3.9	31.2
Aberdeenshire	135,977	0.4 (0.3)	1.6	13.0	152,752	0.4 (0.3)	1.6	13.1
Angus	63,264	0.4 (0.6)	1.6	13.0	67,248	0.4 (0.5)	1.4	11.5
Argyll & Bute	53,411	0.4 (0.7)	1.5	11.7	50,954	0.3 (0.7)	1.4	11.00
Clackmannanshire	28,761	0.1 (0.4)	0.5	3.8	31,306	0.1 (0.4)	0.5	3.6
Dumfries & Galloway	85,169	0.5 (0.5)	1.8	14.7	86,027	0.4 (0.5)	1.6	12.9
Dundee City	85,775	0.5 (0.6)	2.1	16.9	89,944	0.5 (0.5)	1.9	14.9
East Ayrshire	71,228	0.1 (0.2)	0.6	4.7	73,535	0.1 (0.2)	0.6	4.7
East Dunbartonshire	63,655	0.2 (0.3)	0.8	6.6	60,228	0.3 (0.5)	1.2	9.6
East Lothian	51,949	0.2 (0.5)	1.0	7.9	58,163	0.6 (1.0)	2.2	17.9
East Renfrewshire	51,669	0.2 (0.3)	0.6	5.0	51,618	0.2 (0.4)	0.9	7.5
Edinburgh, City of	284,032	3.2 (1.1)	12.7	102.1	313,728	4.4 (1.4)	17.8	142.8
Eilean Siar	15,132	0.1 (0.4)	0.3	2.0	15,805	0.0 (0.2)	0.2	1.2
Falkirk	87,477	0.4 (0.5)	1.6	13.2	94,851	0.4 (0.4)	1.5	11.9
Fife	206,691	0.9 (0.4)	3.7	29.3	218,031	1.1 (0.5)	4.4	35.1
Glasgow City	350,312	1.9 (0.5)	7.7	61.8	383,156	3.0 (0.8)	11.9	95.6
Highland	123,842	1.1 (0.9)	4.4	35.3	137,395	1.1 (0.8)	4.6	36.8
Inverclyde	49,474	0.1 (0.2)	0.3	2.8	48,677	0.1 (0.2)	0.5	3.7
Midlothian	47,919	0.3 (0.6)	1.1	9.1	49,564	0.3 (0.6)	1.3	10.1
Moray	51,325	1.0 (1.9)	3.8	30.8	54,444	0.4 (0.8)	1.8	14.3
North Ayrshire	77,910	0.4 (0.5)	1.6	12.8	80,603	0.3 (0.4)	1.4	10.9
North Lanarkshire	193,890	0.3 (0.1)	1.2	9.3	205,171	0.4 (0.2)	1.6	13.0
Orkney Islands	11,321	0.1 (0.6)	0.3	2.2	12,511	0.1 (0.5)	0.3	2.1

(continued on next page)

Table A.4 (*continued*)

	2001				2011			
	Population size[a]	Deaths averted per year (population adjusted rate)[b]	Annual value (EUR millions)	10 year discounted value (EUR millions)	Population size[a]	Deaths averted per year (population adjusted rate)[b]	Annual value (EUR millions)	10 year discounted value (EUR millions)
Perth & Kinross	78,155	0.3 (0.4)	1.2	9.6	84,996	0.4 (0.4)	1.5	12.2
Renfrewshire	104,384	0.5 (0.5)	2.1	17.0	105,834	0.5 (0.4)	1.9	15.4
Scottish Borders	62,171	0.3 (0.5)	1.1	9.2	65,509	0.3 (0.4)	1.0	8.4
Shetland Islands	13,082	0.0 (0.2)	0.1	0.8	13,794	0.0 (0.2)	0.1	1.1
South Ayrshire	65,280	0.3 (0.5)	1.4	10.9	64,903	0.3 (0.5)	1.3	10.3
South Lanarkshire	181,166	0.3 (0.2)	1.4	11.1	189,720	0.5 (0.2)	1.9	15.1
Stirling	51,585	0.2 (0.4)	0.9	7.0	53,507	0.2 (0.4)	0.8	6.6
West Dunbartonshire	54,953	0.2 (0.4)	0.9	7.6	54,952	0.2 (0.4)	0.9	7.0
West Lothian	98,078	0.4 (0.4)	1.7	13.6	101,973	0.5 (0.4)	1.8	14.6

[a] Population size for walking on individuals aged 20–74 years, and for cycling individuals aged 20–64 years, based on population sizes taken from an extract of mortality data provided by National Records of Scotland.

[b] Population adjusted rate equivalent to death rate/population *100,000.

References

Ainsworth, B.E., et al., 2011. Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc 43 (8), 1575–1581.

Audrey, S., Procter, S., Cooper, A.R., 2014. The contribution of walking to work to adult physical activity levels: a cross sectional study. Int. J. Behav. Nutr. Phys. Activ. 11 (1), 37.

Babagoli, M.A., et al., 2019. Exploring the health and spatial equity implications of the New York City Bike share system. Journal of Transport & Health 13, 200–209.

Brockman, R., Fox, K.R., 2011. Physical activity by stealth? The potential health benefits of a workplace transport plan. Publ. Health 125 (4), 210–216.

Buehler, R., Pucher, J., 2021. COVID-19 Impacts on Cycling, 2019–2020. Transport Reviews, pp. 1–8.

Cavill, N., Kahlmeier, S., 2016. Turn up the Heat: Recommendations to Increase the Use of the World Organization's Health Economic Assessment Tool for Cycling across Europe. European Cyclists' Federation.

Cavill, N., et al., 2008. Economic analyses of transport infrastructure and policies including health effects related to cycling and walking: a systematic review. Transport Pol. 15 (5), 291–304.

Cavill, N., et al., 2019. Active Travel and Physical Activity Evidence Review. Sport England.

Celis-Morales, C.A., et al., 2017. Association between active commuting and incident cardiovascular disease, cancer, and mortality: prospective cohort study. BMJ 357, j1456.

Chief Medical Office (CMO), UK physical activity guidelines (online). 2011.

Davis, A., 2010. An Economic Assessment of Investment in Walking and Cycling. Department of Health and Government Office of the South West, London.

Deenihan, G., Caulfield, B., 2014. Estimating the health economic benefits of cycling. Journal of Transport & Health 1 (2), 141–149.

Department of Health & Social Care, 2019. UK Chief Medical Officers' Physical Activity Guidelines. Department of Health & Social Care.

Donaire-Gonzalez, D., et al., 2015. The added benefit of bicycle commuting on the regular amount of physical activity performed. Am. J. Prev. Med. 49 (6), 842–849.

Fishman, E., Schepers, P., Kamphuis, C.B., 2015. Dutch cycling: quantifying the health and related economic benefits. Am. J. Publ. Health 105 (8), e13–e15.

Foley, L., et al., 2015. Changes in active commuting and changes in physical activity in adults: a cohort study. Int. J. Behav. Nutr. Phys. Activ. 12, 161.

Global advocacy for physical activity (GAPA) the advocacy council of the international society for physical activity and health (ISPAH), *Investments that Work for physical activity*. Br. J. Sports Med. 46 (10), 2012, 709–712.

Goodman, A., 2013. Walking, cycling and driving to work in the English and Welsh 2011 census: trends, socio-economic patterning and relevance to travel behaviour in general. PloS One 8 (8), e71790.

Guthold, R., et al., 2018. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1.9 million participants. The Lancet Global Health 6 (10), e1077–e1086.

Hartog, J.J., et al., 2010. Do the health benefits of cycling outweigh the risks? Environ. Health Perspect. 118 (8), 1109–1116.

Kahlmeier, S., et al., 2017. Health Economic Assessment Tool (HEAT) for Walking and Cycling. Methods and User Guide on Physical Activity, Air Pollution, Injuries and Carbon Impact Assessments. World Health Organization, Regional Office for Europe, Copenhagen.

Kelly, P., et al., 2014. 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. Activ. 11, 132.

Laird, Y., et al., 2018. Cycling and Walking for Individual and Population Health Benefits: A Rapid Evidence Review for Health and Care System Decision-Makers. Public Health England.

Le Vine, S., Polak, J., Humphrey, A., 2017. *Commuting trends in England 1988 - 2015*. Department for Transport, London.

Lee, I.M., et al., 2012. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 380 (9838), 219–229.

Martin, A., Goryakin, Y., Suhrcke, M., 2014. Does active commuting improve psychological wellbeing? Longitudinal evidence from eighteen waves of the British Household Panel Survey. Prev. Med. 69, 296–303.

Mueller, N., et al., 2015. Health impact assessment of active transportation: a systematic review. Prev. Med. 76, 103–114.

Musselwhite, C., Avineri, E., Susilo, Y., 2020. Editorial JTH 16 -The Coronavirus Disease COVID-19 and implications for transport and health. Journal of Transport & Health 16, 100853-100853.

National Records of Scotland, 2020. Mid-Year Population Estimates Scotland, Mid-2019. National Records Scotland.

Ogilvie, D., et al., 2010. Commuting and health in Cambridge: a study of a 'natural experiment' in the provision of new transport infrastructure. BMC Publ. Health 10, 703.

Pérez, K., et al., 2017. The health and economic benefits of active transport policies in Barcelona. Journal of Transport & Health 4, 316–324.

Physical Activity Guidelines Advisory Committee, *Physical Activity Guidelines Advisory Committee Scientific* Report. 2018, 2018. U.S. Department of Health and Human Services, Washington, DC.

Sahlqvist, S., Song, Y., Ogilvie, D., 2012. Is active travel associated with greater physical activity? The contribution of commuting and non-commuting active travel to total physical activity in adults. Prev. Med. 55 (3), 206–211.

Sattler, MC., Ainsworth, BE., Sattler, LB., et al., 2021. Physical activity self-reports: past or future? Br. J. Sports Med. https://doi.org/10.1136/bjsports-2020-103595. Published Online First: 03 February 2021.

Saunders, L.E., et al., 2013. What are the health benefits of active travel? A systematic review of trials and cohort studies. PloS One 8 (8), e69912.
Scottish government. https://www.gov.scot/news/budget-agreement-reached/, 2020–. (Accessed 1 July 2020).
Stewart, G., Anokye, N.K., Pokhrel, S., 2017. Quantifying the contribution of utility cycling to population levels of physical activity: an analysis of the Active People Survey. J. Public Health 38 (4), 644–652.
Stigell, E., Schantz, P., 2011. Methods for determining route distances in active commuting – their validity and reproducibility. J. Transport Geogr. 19 (4), 563–574.
Strain, T., et al., 2016. Age-related comparisons by sex in the domains of aerobic physical activity for adults in Scotland. Prev Med Rep 3, 90–97.
Strain, T., et al., 2020. Use of the prevented fraction for the population to determine deaths averted by existing prevalence of physical activity: a descriptive study. The Lancet Global Health 8 (7), e920–e930.
Transport Scotland, 2014. A Long-Term Vision for Active Travel in Scotland 2030. Transport Scotland.
Transport Scotland, Transport and Travel in Scotland: Results from the Scottish Household Survey. 2019, 2019. Available from: https://www.transport.gov.scot/media/45852/sct09199889061.pdf. (Accessed 1 June 2020).
Transport Scotland, Transport and Travel in Scotland 2019: Results from the Scottish Household Survey 2020, 2020. Available from: https://www.transport.gov.scot/media/48317/sct09201490081.pdf. (Accessed 12 March 2021).
Transport Scotland, 2020. COVID-19 Public attitudes survey data: Wave 1. Transport Scotland: Available from: https://www.transport.gov.scot/publication/covid-19-public-attitudes-survey-data-wave-1/. (Accessed 1 July 2020).
NICE, Walking and Cycling, 2012. Local measures to promote walking and cycling as forms of travel or recreation. In: NICE public health guidance (PH41).
Welsh, C., et al., 2020. Association of injury related hospital admissions with commuting by bicycle in the UK: prospective population based study. BMJ 368, m336.
White, M.P., et al., 2016. Recreational physical activity in natural environments and implications for health: a population based cross-sectional study in England. Prev. Med. 91, 383–388.
Whyte, B., 2020. Cycling through a Pandemic. https://www.gcph.co.uk/latest/news/942_cycling_through_a_pandemic. (Accessed 1 July 2020).
World Health Organization, 2018. Global Action Plan on Physical Activity 2018-2030: More Active People for a Healthier World. Geneva.
Yang, L., et al., 2012. Associations between active commuting and physical activity in working adults: cross-sectional results from the Commuting and Health in Cambridge study. Prev. Med. 55 (5), 453–457.