International Transport Forum

Exposure-Adjusted Road Fatality Rates for Cycling and Walking in European Countries

Discussion Paper

168

Roundtable

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Table of contents

Introduction

Physical inactivity is a significant public health problem in most regions of the world, which is unlikely to be solved by classical health promotion approaches alone (1). The promotion of active transport (cycling and walking) for everyday physical activity is a win-win approach; it not only promotes health but also has benefits from an urban and transport planning perspective, as well as positive environmental effects, especially if cycling and walking replace short car trips. Cycling and walking are particularly space- and cost-effective transport options that can also be readily integrated into people's busy daily schedules as a practical and feasible form of regular physical activity.

There is large potential for active travel in urban transport, as many trips are short and would often be amenable to being undertaken on foot or by bicycle (2). This, however, requires effective partnerships between involved sectors, such as health and environment and the transport and urban planning sectors, whose policies are driving forces in providing safe and convenient conditions for active transport to thrive. In particular, concerns about traffic safety have been found to be a major barrier to taking up active transport (3). Since 2002, Member States of the World Health Organisation (WHO) European Region are collaborating under the Transport, Health and Environment Pan-European Programme (THE PEP) (4). THE PEP is an inter-sectoral policy platform supported by the WHO and the UNECE, to facilitate dialogue, exchange of experiences and good practices and the establishment of partnerships among representatives of ministries of health, transport and environment, with the ultimate aim of promoting healthy and sustainable transport options. One of the on-going partnerships under THE PEP is the promotion of active mobility and support to the development of policies in this area. In particular, THE PEP is currently supporting the development of a Pan-European master plan for cycling promotion, which is expected to be adopted at the 5th High Level Meeting on Transport, Health and Environment, to take place in Vienna, Austria, in 2019 (5).

Within this framework, coordinated by the WHO/Europe, steered by a core group of multi-disciplinary experts and supported by ad-hoc invited relevant international experts, an open-ended project was started in 2005 to develop the Health Economic Assessment Tool (HEAT) for Walking and Cycling (www.heatwalkingcycling.org) with the aim to foster the integration of the appreciable health benefits of regular physical activity through walking and cycling into economic appraisals in the transport sector (6-8). HEAT calculates: if x people cycle or walk a distance of y on most days, what is the economic value of the resulting reduction in all-cause mortality? HEAT is primarily aimed at transport planners, traffic engineers, economists and special interest groups. Since this audience may not necessarily have ready access to epidemiological and economic expertise and health impact modelling tools, HEAT is intended to be easy to use, yet scientifically robust. It provides an estimate of the health effects of regular walking and cycling (currently on mortality only) based on minimal data input (mainly two input figures only, namely the volume of walking or cycling and the number of population regularly carrying out this behaviour) for use in economic analyses in transport planning, such as cost-benefit analyses of different transport interventions or urban planning approaches. Wherever possible, HEAT provides default values which can be reviewed and changed by the user (as well as non-changeable background data, derived from best-available evidence) (7).

In the past, HEAT has faced some criticism for focusing on benefits from physical activity only, despite the fact that the scientific literature consistently showed that benefits by far outweigh the risks (9-11). Arguably, the use of all-cause mortality as main health outcome inherently included adverse effects from air pollution and traffic crashes; however, such assessments of net benefits of physical activity did not allow explicit weighting of benefits against risks and also did not accurately reflect local conditions. User feedback indicated that being able to communicate risks separately would be preferred to an overall result figure.

Being able to separately quantify crash risks of active transport is crucial for its promotion, in particular for cycling. However, the emphasis needs to be on risks, or crash rates, in contrast to absolute numbers of crashes, as only exposure-adjusted crash rates allow for valid comparisons of how safe or dangerous conditions for active transport are at national, local, or infrastructure level. Thus, comparable crash rates are equally essential for international comparisons and for setting local planning priorities. However, exposure-adjusted crash rates for active transport modes are typically not routinely available, with few exceptions such as the annual report on road casualties by the Department for Transport in the United Kingdom ((12), p. 103).

The role of crash risks of cycling is two-fold: First, injuries and fatalities are immediate and severe health impacts that should be avoided as much as possible. Quantifying objective risks is a pre-requisite for effectively reducing risks. In addition, they can help to place the magnitude of the problem into perspective – in particular where objective risks are much lower than they are perceived to be. Second, the perceived risk of crashing influences behaviour and can deter people from cycling more, or from cycling at all (3), precluding individuals and society from benefiting from (additional) cycling. Both, objective and perceived traffic safety, which in fact are not necessarily correlated (13), have been identified as crucial determinants of the decision to bike (14-15).

In 2017, a new version of HEAT (version 4.0) was launched as part of the Physical Activity through Sustainable Transport Approaches project (PASTA) (16). It enables a separate assessment of the risks from increased exposure to air pollution while walking and cycling and the risk of crashes (currently implemented for cycling only), as well as carbon emissions saved. In addition, a new user interface and the underlying computational platform improve usability and handling of future upgrades and expansions of the tool (7).

HEAT developments follow a generic process in which the project core group identifies key topics, which are then addressed by selected scientists, with the goal to prepare a proposal for implementation of new tool features. Such proposals then proceed through a consensus meeting process whereby external multi-disciplinary experts are invited and changes to the proposal are discussed until there is consensus for implementation, or that further clarifications or evidence are required. Implementation is then handled by members of the core group and/or additional technical experts. Crash risk assessments, like any new HEAT features, were developed according to the same requirements as the rest of tool, namely allowing basic assessment with minimal input data while maintaining scientific robustness.

Based on an initial scoping review and discussions of its findings in light of the available data and evidence as well as HEAT specific requirements within its core group (17), the scope of implementing crash risk assessments in HEAT as part of the PASTA project was defined as follows:

- Prioritisation of the implementation for cycling, road fatalities, and assessments at the national level over walking, injuries and city/sub-city level;
- A basis on active mode exposure only, i.e. ignoring effects on risk due to variations in motorised modes.
- A simplified non-linear relationship between changes in active travel volumes and crash rates (i.e. the effect colloquially referred to as “safety in numbers”).

Expansions to walking, injuries, and city/sub-city level as well as effect of motorized modes were considered of a lower priority mainly based on practical considerations and scarcity of data to derive background rates and/or default values.

This article presents the methodology and findings in gathering datasets of exposure-adjusted crash rates in European countries for both cycling, as part of the development of HEAT version 4.0, and for walking and discusses strengths and weaknesses of the fatality rates used in the HEAT crashes module.

References in this paper are presented in a way which differs from the ITF standard. This is due to the number of references identified by the authors and to the need to include references in compact data tables.

Method

Road fatality data at the national level can be found in compilations by transport departments (e.g. the Transport Department in the United Kingdom (12), statistical agencies e.g. Destatis in Germany (18)), police departments (e.g. Directorate of the Traffic Police Service of the Police Presidium of Czech Republic (19), or in international datasets (e.g. or International Traffic Safety Data and Analysis Group (IRTAD) of the International Transport Forum (ITF) (20) or Global Health Observatory of the World Health Organisation) (21). Such sources normally contain absolute numbers of fatalities per year. The annual report on road casualties of the Transport Department in the United Kingdom, which contains data on exposure-adjusted fatality rates, is an exception (12). Absolute values cannot be used to compare fatality risks across countries or different administrative areas, since more populated areas, and areas with higher levels of active transport are expected to have a higher number of fatalities (even if equally safe). To overcome this limitation, fatality rates have been normalised in some data sets based on units of population (i.e. annual fatalities per 100 000 inhabitants). However, population-adjusted fatality rates fail to account for contrasts in transport patterns, which in particular for active transport modes can be substantial, both across countries or regions as well as over time. Therefore, quantitative risk assessments require exposure-adjusted fatality rates.

None of the reviewed international data sets provided exposure-adjusted fatality rates for active modes (namely walking and cycling). Therefore, fatality data and exposure data were compiled separately to calculate exposure-adjusted fatality rates as shown in Equation 1. In consideration of data quality and required assumptions, the resulting fatality rates were classified by levels of reliability.

Equation 1: Calculation of fatality rate

$$FR = \frac{F}{E}$$

FR = Fatality rate (number of fatalities per travelled km)
F = Yearly number of fatalities by active mode
E = Exposure measured in yearly travel distance (km) by active mode

Fatality data

Regarding fatality data, national sources can provide detailed information of crashes (e.g. by sex, age and transport modes of involved persons), but international data sets facilitate efficient data collection across different countries if aggregated numbers of fatalities are sufficient, as is the case here. Therefore, four international data sets on fatalities in both walking and cycling (20-23) were explored first (Table 1).

Table 1: International data sets on fatalities of pedestrians and cyclists

Source	Year of data	Number of countries
International Transport Forum (ITF) - International Traffic Safety Data and Analysis Group (IRTAD) (20)	2005-2015 Time series	32
World Health Organization (WHO) - Global Health Observatory (GHO) (21)	2013 One-year data	142
European Commission - European Road Safety Observatory (22)	2009:2014[(a)] One-year data	27
United Nations Economic Commission for Europe (UNECE) - Statistical database (23)	1993:2014[(b)] Time series	56

Notes: [(a)] Year depends on country. [(b)] First and last year of the series depends on country

The two main criteria to choose data sets to derive exposure-adjusted fatality rates for HEAT were the following: a) year of the data and b) number of countries. On the one hand, due to the high variability of fatalities across years, time-series data enable more solid values (averages over several years) than one-year data. On the other hand, the number countries included in the data set was a relevant factor in the development of international tools such as HEAT. Thus, to estimate exposure-adjusted fatality rates, the average number of fatalities for each mode from 2011 to 2015[1] was primarily calculated based on data from the ITF-IRTAD data set (20), which reported the most consistent time-series; the available five-year' time series were considered as solid enough to derive valid average values. For countries not included in this data set, one-year data from the WHO-GHO (21) were used, which compiled the most comprehensive list of countries.

Exposure data

Exposure can be measured in travel time or distance of active transport, aside from other, cruder indicators like number of trips or mode shares. Travel distance was found more often in travel surveys and therefore it was used in this data collection effort.

Availability of exposure data was found to be generally poorer than for fatality data, as travel distances of active modes are not systematically collected in all countries ((24), p. 34). Three international datasets on active mode mileage were found in the data search: Two of them were considered outdated (i.e. a report of the European Commission published in 1999 (25) and a report of the EU project WALCYNG published in 1997 (23), respectively). The third data set was a compilation from 2017 by the consulting group COWI, commissioned by the Directorate-General for Mobility and Transport (25). It contains daily travel distances by inhabitant for walking in 12 countries and for cycling in 10 countries[2], which can be converted into total yearly travel distance. Data from the COWI report (26) were compared against the original national source of a number of European countries, where national data was accessible. In total, national sources from 20[3] out of the 53 countries of the WHO European Region were consulted. Annual travel distances were found or estimated based on available information for 14 countries for cycling and for 12 countries for walking.

Depending on the format of exposure of active modes provided by national sources, values required some basic adjustments, such as extrapolation of daily distances to annual values, and extrapolation of average travel distances per person to the country population.

When no exposure data was found from national sources, distance was derived according to Equation 2, based on a dataset of crude mode shares by world regions[4] produced by the Institute for Transportation & Development Policy (ITDP) and the Institute of Transportation Studies (ITS) at University of California, Davis (27) and the following assumptions: a) Trips by all-modes per person and day: 3 (i.e. 1,095 trips per year), based on the WALCYNG report (22) as well as PASTA data[5] (28) and b) average trip lengths of 4 kilometres per bicycle trip and 1 km per walking trip, based on our own analyses of travel data from the United Kingdom and the Netherlands ((29) and (30)), as well as PASTA data (28)[6]

Equation 2: Alternative approach for the estimation of yearly travel distance

$$TD = AMS * TT * TL * Pop * 365$$

TD = Yearly travel distance by active mode (kilometres)
AMS = Active mode share (active mode trips / trips by all modes)
TT = Total number of trips by all modes (trips per person and day)
TL = Average trip length (km per active mode trip)
Pop = Population (inhabitants)

However, the international dataset including cycling mode shares did not provide mode share figures for walking. Exposure estimation based on Equation 2 was therefore not applied for walking.

According to the differences in data quality and the need for as robust assumptions as possible, the resulting fatality rates were categorised into levels of reliability, to provide HEAT users with a sense for the accuracy of their assessment. For the classification of exposure data, the use of national data versus world region mode share estimates (27), as well as the use of assumptions was distinguished. For the classification of fatality data the use of observed versus modelled death records, as well as the use of five years' time-series vs. one single year were distinguished. In combination, the classification of fatality and exposure estimates resulted in six distinct reliability categories for the fatality rates, as shown in Table 2.

Table 2: **Combination of data quality criteria and resulting reliability levels of derived fatality rates, from higher to lower quality**

<table>
<tr><th colspan="2">Exposure data</th><th colspan="2">Fatality data</th><th colspan="2">Fatality rate</th></tr>
<tr><th>Original data</th><th>Used data</th><th>Original data</th><th>Used data</th><th colspan="2">Reliability level</th></tr>
<tr><td rowspan="3">National data</td><td>Original data (or combination thereof) without assumptions</td><td rowspan="5">Observed deaths</td><td rowspan="2">Five year average</td><td>1</td><td>Very high</td></tr>
<tr><td rowspan="5">Estimation with assumption[(a)]</td><td>2</td><td>High</td></tr>
<tr><td>Single year</td><td>3</td><td>Moderate</td></tr>
<tr><td rowspan="3">Mode share estimate for world region based on selected cities</td><td>Five year average</td><td>4</td><td rowspan="3">Low</td></tr>
<tr><td rowspan="2">Single year</td><td>5</td></tr>
<tr><td>Model estimation</td><td>6</td></tr>
</table>

Note: [(a)] Detailed assumptions for each country can be seen in Table 4. Table calculations based on world region mode share estimates are shaded grey due to considerably lower reliability.

Results

In total, fatality rates were derived or estimated in 47 European countries for cycling[7] and 12 for walking (Table 3). Reliability of fatality rates for 14 European countries for cycling and 12 for walking was considered moderate to high. For 33 countries fatality rates for cycling could only be estimated based on world region mode share estimates considered of weak reliability.

Table 3: Frequency of reliability levels of fatality rates for cycling and walking

Reliability level of fatality rate	Cycling	Walking
Very high (1)	6	4
High (2)	7	7
Moderate (3)	1	1
Low (4-6)	33	n.a.[(a)]
Total	*47*	*12*

Note: [(a)] For walking fatality rates were not calculated using world region mode share estimates as published in ITDP-ITS report (27).

Tables 4 and 5 show the estimated fatality rates and their reliability for cycling and walking, respectively. These tables include fatality and exposure figures used to estimate the fatality rates, as well as information about the data sources and handling.

Table 4. **Cycling fatalities, exposure and fatality rate in the WHO European Region by country**

Country (a)	Fatalities (cycling fatalities per year)				Exposure (million km travelled by bicycle per year)				Fatality rate (cycling fatalities per hundred million km)	
	Value	Year	Data	Source	Value	Year	Data	Source	Value	Reliability
Albania	20.0	2013	E, 1y	(21)	260	2015	MS, A[d]	(27), (31)	7.7	Low
Armenia	2.0	2013	E, 1y	(21)	271	2015	MS, A[d]	(27), (31)	0.7	Low
Austria	45.8	2011-2015	O, 5y	(20)	1 898	2014[e]	N, A[f][l]	(32, p. IV)	2.4	High
Azerbaijan	3.0	2013[b]	O[c], 1y	(21)	876	2015	MS, A[d]	(27), (31)	0.3	Low
Belarus	101.0	2013	O, 1y	(21)	853	2015	MS, A[d]	(27), (31)	11.8	Low
Belgium	74.0	2011-2015	O, 5y	(20)	3 033	2009	N, NA	(33, p. 17)	2.4	Very high
Bosnia and Herzegovina	74.0	2013	E, 1y	(21)	342	2015	MS, A[d]	(27), (31)	21.6	Low
Bulgaria	31.0	2013	O, 1y	(21)	642	2015	MS, A[d]	(27), (31)	4.8	Low
Croatia	25.0	2013	O, 1y	(21)	381	2015	MS, A[d]	(27), (31)	6.6	Low
Cyprus	3.0	2013	O[c], 1y	(21)	12	2009	N, A[g][m]	(31), (34, p. 31)	24.8	Moderate
Czech Republic	73.6	2011-2015	O, 5y	(20)	3 313	2015	MS, A[d]	(27), (31)	2.2	Moderate
Denmark	28.2	2011-2015	O, 5y	(20)	3 079	2013[e]	N, A[h][m]	(31), (35, p. 1)	0.9	High
Estonia	10.0	2013	O, 1y	(21)	413	2015	MS, A[d]	(27), (31)	2.4	Low
Finland	23.0	2011-2015	O, 5y	(20)	1 438	2011[e]	N, A[h][m]	(31), (36)	1.6	High
France	152.0	2011-2015	O, 5y	(20)	5 468	2008	N[n]	(37)	2.8	Very high
Georgia	3.0	2013	O, 1y	(21)	359	2015	MS, A[d]	(27), (31)	0.8	Low
Germany	387.6	2011-2015	O, 5y	(20)	35 367	2011-2014	N, NA	(38, pp. 224–226)	1.1	Very high

Country (a)	Fatalities (cycling fatalities per year)				Exposure (million km travelled by bicycle per year)				Fatality rate (cycling fatalities per hundred million km)	
	Value	Year	Data	Source	Value	Year	Data	Source	Value	Reliability
Greece	15.8	2011-2015	O, 5y	(20)	3 443	2015	MS, A(d)	(27), (31)	0.5	Moderate
Hungary	83.6	2011-2015	O, 5y	(20)	3 097	2015	MS, A(d)	(27), (31)	2.7	Moderate
Iceland	0.2	2011-2015	O, 5y	(20)	237	2015	MS, A(d)	(27), (31)	0.1	Moderate
Ireland	8.8	2011-2015	O, 5y	(20)	482	2012-2014	N, A(i)(m)	(31), (39)	1.8	High
Israel	12.8	2011-2015	O, 5y	(20)	1 086	2015	MS, A(d)	(27), (31)	1.2	Moderate
Italy	269.8	2011-2015	O, 5y	(20)	5 294	2011-2015	N, A(j)(l)	(40, pp. 3, 9–10)	5.1	High
Kazakhstan	44.0	2013 (b)	O(c), 1y	(21)	1 583	2015	MS, A(d)	(27), (31)	2.8	Low
Kyrgyzstan	13.0	2013	O, 1y	(21)	533	2015	MS, A(d)	(27), (31)	2.4	Low
Latvia	15.0	2013	O, 1y	(21)	619	2015	MS, A(d)	(27), (31)	2.4	Low
Lithuania	23.4	2011-2015	O, 5y	(20)	258	2015	MS, A(d)	(27), (31)	9.1	Moderate
Luxembourg	0.4	2011-2015	O, 5y	(20)	178	2015	MS, A(d)	(27), (31)	0.2	Moderate
Montenegro	1.0	2013	O, 1y	(21)	56	2015	MS, A(d)	(27), (31)	1.8	Low
Netherlands	125.4	2011-2015	O, 5y	(20)	15 080	2011-2015	N, NA	(30)	0.8	Very high
Norway	11.2	2011-2014	O, 4y	(20)	1 315	2014	N, A(h)(m)	(31), (41, p. 29)	0.9	High
Poland	301.2	2011-2015	O, 5y	(20)	12 134	2015	MS, A(d)	(27), (31)	2.5	Moderate
Portugal	32.6	2011-2015	O, 5y	(20)	3 253	2015	MS, A(d)	(27), (31)	1.0	Moderate
Republic of Moldova	26.0	2013	O, 1y	(21)	365	2015	MS, A(d)	(27), (31)	7.1	Low

Country (a)	Fatalities (cycling fatalities per year)				Exposure (million km travelled by bicycle per year)				Fatality rate (cycling fatalities per hundred million km)	
	Value	Year	Data	Source	Value	Year	Data	Source	Value	Reliability
Romania	160.0	2013	O(c), 1y	(21)	1 752	2015	MS, A(d)	(27), (31)	9.1	Low
Russian Federation	459.0	2013	O(c), 1y	(21)	12 881	2015	MS, A(d)	(27), (31)	3.6	Low
Serbia	67.0	2013	O(c), 1y	(21)	795	2015	MS, A(d)	(27), (31)	8.4	Low
Slovakia	24.0	2013	O, 1y	(21)	1 705	2015	MS, A(d)	(27), (31)	1.4	Low
Slovenia	13.8	2011-2015	O, 5y	(20)	650	2015	MS, A(d)	(27), (31)	2.1	Moderate
Spain	64.6	2011-2015	O, 5y	(20)	14 494	2015	MS, A(d)	(27), (31)	0.4	Moderate
Sweden	22.6	2011-2015	O, 5y	(20)	1 934	2014	N, NA(f)	(42, p. 3)	1.2	Very high
Switzerland	33.8	2011-2015	O, 5y	(20)	2 175	2011-2015	N, NA	(43)	1.6	Very high
Tajikistan	65.0	2013	E, 1y	(21)	762	2015	MS, A(d)	(27), (31)	8.5	Low
TFYR Macedonia	11.0	2013	O, 1y	(21)	187	2015	MS, A(d)	(27), (31)	5.9	Low
Turkey	60.0	2013	O, 1y	(21)	10 595	2015	MS, A(d)	(27), (31)	0.6	Low
Turkmenistan	17.0	2013	E, 1y	(21)	482	2015	MS, A(d)	(27), (31)	3.5	Low
United Kingdom	111.6	2011-2015	O, 5y	(20)	5 221	2011-2015	N, A(k)(m)	(44, p. 16), (45), (46)	2.1	High

Notes: O = Observed deaths, E = Model estimate, 5y = 5-year estimate, 4y = 4-years estimate, 1y = Single year estimate, N = National data from travel survey or similar, MS = Estimation based on world region mode share estimates, NA = No assumptions are required, A= Assumption(s) are required (see details in table footnote)

(a) Monaco, Uzbekistan and Ukraine are missing because no crash data were found. Andorra, Malta and San Marino report 0 fatalities (21); therefore no fatality rate can be estimated.

(b) Data from 2012 (total all-modes fatalities) and 2013 (distribution of fatalities by mode).

(c) In the original source, distribution of total fatalities by mode was expressed as a single value without confidence interval, which means that the value was not obtained by a model estimation (it is then an observation), but a footnote warns that this is projected death registration data.

(d) Exposure was estimated as follows: Population in 2015 (31) * 3 trips per person and day by all modes (assumption based on WALCYNG report (2, p. 13) and PASTA data (28)) * cycling modal share data extrapolated to world regions from municipal data from ITDP-ITS report (27, p. 11) * 4 km per bicycle trip (assumption based on average values in England and Wales (29) and The Netherlands (30) as well as PASTA data (28)) * 365 days per day.

(e) Data were collected for period that covers more than one year; the last year of the period has been assigned to this field.

(f) Exposure was estimated as follows: cycled kilometres per person per day (data from national survey) * 365 days per year.

(g) Exposure was estimated as follows: cycled kilometres by all survey participants per day / number of participants (data from national survey) * population in the corresponding year (31) * 365 days per year.

(h) Exposure was estimated as follows: cycled kilometres per person per day (data from national survey) * population in the corresponding year (31) * 365 days per year.

(i) Exposure was estimated as follows: average km per trip by any mode (data from national survey) * 3 trips per person and day by all modes (assumption based on WALCYNG report (2, p. 13) and PASTA data (28)) * cycling modal share (data from national survey) * population in the corresponding year (31)* 365 days per year.

(j) Exposure was estimated as follows: Population in the corresponding year (31)* share of population travelling on working days (data national survey) * daily trips per travelling inhabitant on work days (national survey) * bicycle modal share on work days (data from national survey) * km per bicycle trip on work days (data national survey) * 365 days.

(k) Exposure was calculated by summing exposure data from Great Britain (in 2015) and Northern Ireland (2012-2014, assigned to the period 2011-2014, and 2013-2015 assigned to 2015). Exposure in Northern Ireland was estimated as follows: km per year and person (44, p. 16) * population (for 2014 using 2012-2014 and for 2015 using 2013-2015 data, respectively) (45).

(l) This estimation assumes same mobility demand on weekends as on work days.

(m) This estimation assumes the same mobility demand for people younger and older than the age group studied in the corresponding national survey (different age range depending on the survey).

(n) Exposure was estimated as follows: cycled kilometres per working day (data from national survey) * working days in a year + cycled kilometres per Saturday (data from national survey) * Saturdays in a year + cycled kilometres per Sunday (data from national survey) * Sundays in a year.

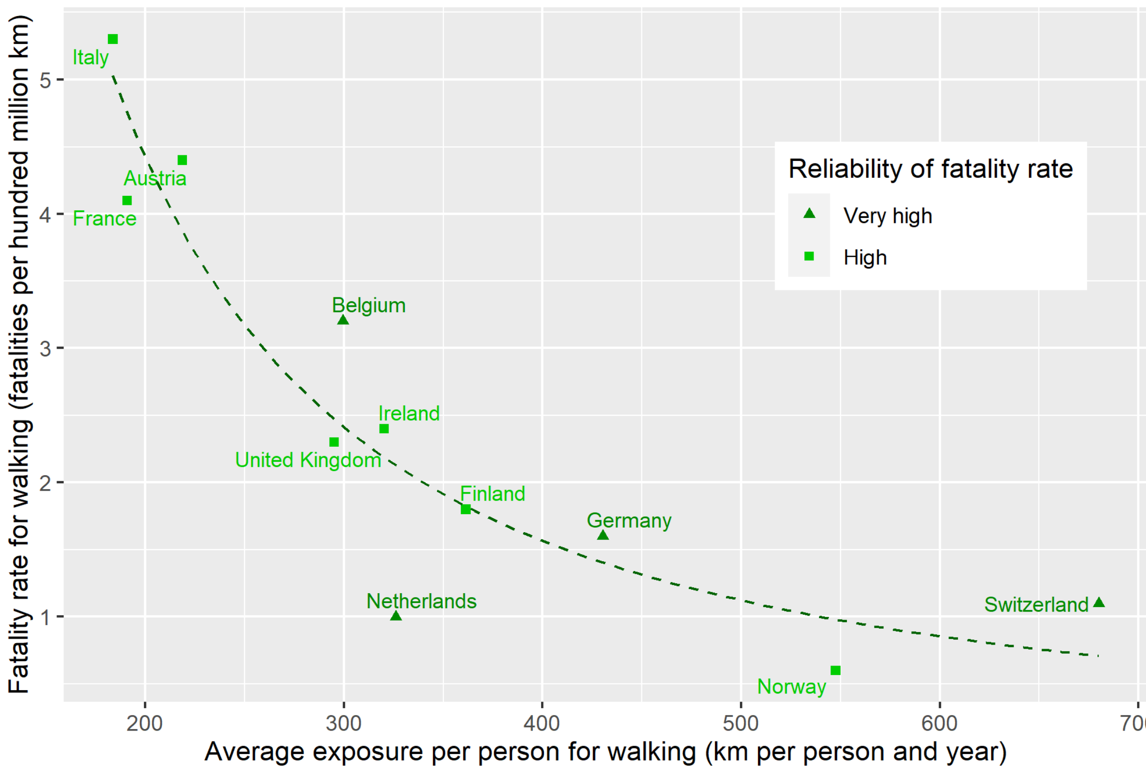
Table 5: **Walking fatalities, exposure and fatality rate in the WHO European Region by country**

Country	*Fatalities (walking fatalities per year)*				*Exposure (million km travelled by foot per year)*				*Fatality rate (walking fatalities per hundred million km)*	
	Value	*Year*	*Data*	*Source*	*Value*	*Year*	*Data*	*Source*	*Value*	*Reliability*
Austria	81.2	2011-2015	O, 5y	(20)	1 862	2014[b]	N, A[c][i]	(32, p. IV)	4.4	High
Belgium	102.8	2011-2015	O, 5y	(20)	3 250	2009	N, NA	(33, p. 17)	3.2	Very high
Cyprus	11.0	2013	O, 5y[a]	(21)	211	2009	N, A[d][j]	(31), (34, p. 31)	5.2	Moderate
Finland	34.4	2011-2015	O, 5y	(20)	1 950	2011[b]	N, A[e][j]	(31), (36)	1.8	High
France	488.0	2011-2015	O, 5y	(20)	11 899	2008	N, A[c][i]	(37)	4.1	High
Germany	550.2	2011-2015	O, 5y	(20)	34 700	2011-2014	N, NA	(38, pp. 224–226)	1.6	Very high
Ireland	36.4	2011-2015	O, 5y	(20)	1 497	2012-2014	N, A[f][j]	(31), (39)	2.4	High
Italy	579.2	2011-2015	O, 5y	(20)	10 984	2011-2015	N, A[g][i]	(40, p. 3,9-10)	5.3	High
Netherlands	57.8	2011-2015	O, 5y	(20)	5 520	2011-2015	N, NA	(47)	1.0	Very high
Norway	18.2	2011-2014	O, 5y	(20)	2 819	2014	N, A[e][j]	(31), (41, p. 29)	0.6	High
Switzerland	62.8	2011-2015	O, 5y	(20)	5 643	2011-2015	N, NA	(43)	1.1	Very high
United Kingdom	438.2	2011-2015	O, 5y	(20)	19 098	2015	N, A[h][j]	(44), (45), (48, p. 18)	2.3	High

Notes: O = Observed deaths, E = Model estimate, 5y = 5-year estimate, 4y = 4-years estimate, 1y = Single year estimate, N = National data from travel survey or similar, MS = Estimation based on world region mode share estimates, NA = No assumptions are required, A= Assumption(s) are required (see details in table footnote)
[a] Projected death registration data in distribution of fatalities by mode.
[b] Data were collected for period that covers more than one year; the last year of the period has been assigned to this field.
[c] Exposure was estimated as follows: walked kilometres per day (data from national survey) * 365 days per year.
[d] Exposure was estimated as follows: walked kilometres by all survey participants per day / number of participants (data from national survey) * population in the corresponding year (31) * 365 days per year.
[e] Exposure was estimated as follows: walked kilometres per person per day (data from national survey) * population in the corresponding year (31) * 365 days per year.
[f] Exposure was estimated as follows: km per trip by all modes (data from national survey) * 3 trips per person and day by all modes (assumption based on WALCYNG report (2, p. 13) and PASTA data (28)) * walking modal share (data from national survey) * population in the corresponding year (31)* 365 days per year.
[g] Exposure was estimated as follows: Population in the corresponding year (31)* share of population travelling in working days (data national survey) * daily trips per travelling inhabitant in working day (national survey) * walking modal share in working day (data from national survey) * km per walk trip in working day (data national survey) * 365 days.
[h] Exposure was calculated by summing exposure data from Great Britain (in 2015) and Northern Ireland (2013-2015 assigned 2015). Exposure in Great Britain was calculating by multiplying yearly km per person in England (48, p. 18)* (population in 2015 in United Kingdom (31) - population in Northern Ireland (45)). Exposure in Northern Ireland was estimated as follows: km per year and person (44) * population (in 2015) (45).
[i] This estimation assumes same mobility demand in working days and in weekends.
[j] This estimation assumes the same mobility demand for people younger and older than the age group studied in the national survey.

Figures 1 and 2 show fatality rates for countries with acceptable data quality, plotted against average annual exposure per person, for cycling and walking, respectively[8]. Both figures suggest a negative association between fatality rates and levels of active travel modes.

Figure 1. **Fatality rate vs. exposure for cycling for countries with high and very high reliability only as well as trend line**



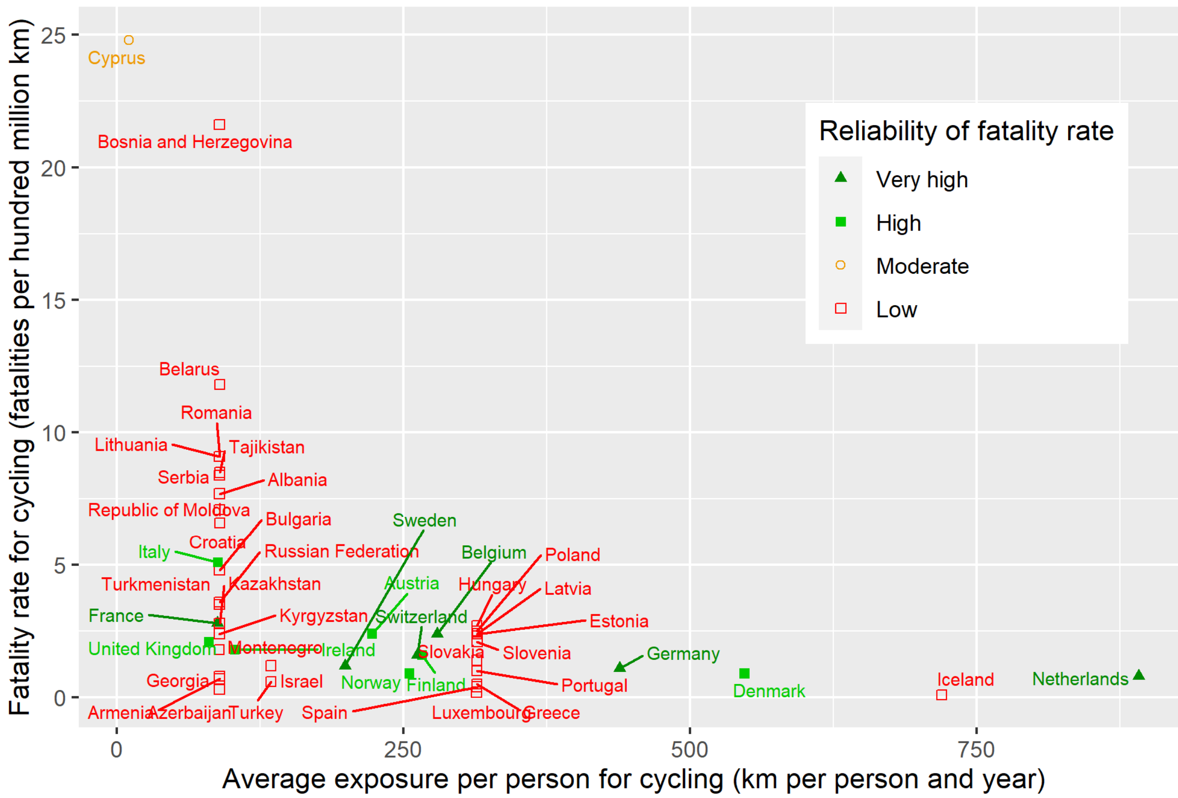
Note: Figure has been amended to reflect United Kingdom (07 June 2021).

Figure 2. **Fatality rate vs. exposure for walking for countries with high and very high reliability only as well as trend line**

Note: Figure has been amended to reflect United Kingdom (07 June 2021).

Figure 3 in addition includes fatality rates of weak quality plotted against average annual exposure per person (cycling only).

Figure 3. **Fatality rate vs. average yearly exposure per person for cycling**



Notes: Exposure estimations for low reliability rates are calculated assuming 3 trips per day by all modes, 4 km per trip by bicycle and the following bicycle mode shares: 16% for Iceland based on extrapolation of selected Nordic cities, 7% for European OECD countries, 2% for non-OECD countries and 3% for Middle Eastern countries following the world regions defined in the original source.

Note: Figure has been amended to reflect United Kingdom (07 June 2021).

Discussion

As part of a project to develop a crash module for the Health Economic Assessment Tool (HEAT) for walking and cycling (www.heatwalkingcycling.org), a dataset of fatality rates for active travel modes at national level in the WHO European region was successfully compiled. For 13 countries of the WHO European region, cycling fatality rates of high and very high quality could be found, while for 33 countries, only crude approximations based on world region mode share estimates could be derived.

Walking fatality rates could only be calculated for 11 countries with high or very high quality data. Among the rates rated highly reliable, cycling fatality rates ranged from 5.1 deaths per 100 million km cycled in Italy to 0.8 deaths per 100 million km cycled in the Netherlands. Walking fatality rates are of similar magnitude and range from 5.3 to 0.6 deaths per 100 million km walked, for Italy and Norway, respectively. Rates based on world region mode share estimates may be used for the purpose of very crude assessments, but apparent limitations must be considered carefully, as differences among countries in the same world regions can be considerable. Thus, it would be crucial for countries to invest into specific data collections on cycling and walking fatalities as well as exposure data, as exposure-adjusted fatality rates and even comparable travel data present a major void in international as well as many national datasets.

Therefore, this data collection as part of the HEAT project presents a rare effort of systematically compiling exposure-adjusted fatality risk data for active travel modes following a common methodology. The data allows for sound comparisons of fatality risks of active travel modes across about a dozen European countries. It further allows for comparisons of crash risks versus health benefits of cycling in assessments of multiple impact pathways as part of HEAT, for approximately another 30 countries, albeit only in cruder terms. Aside from these strengths, this project reveals several limitations of currently available data on road safety of active travel modes.

Even among the high quality data sources, there is considerable variation in methodology that adds some uncertainty to the fatality rates derived, mainly on the exposure side. International standardisation of travel surveys, as addressed e.g. in the SHANTI project (Survey Harmonisation with New Technologies Improvement report funded by the COST action) (50), is desirable, but faces obstacles rooted in the preservation of longitudinal comparability with past national efforts. Development of post-harmonisation methods (harmonisation after data publication) by means of factors published by national authorities, when survey methods or scope have weaknesses, could additionally contribute to comparability. As long as this is not achieved, a standardised way of publishing survey metadata (e.g. age range of surveyed population, exclusion criteria, temporal distribution of the sampling scheme, etc.) would be most helpful in strengthening the comparability of derived fatality rates.

For example, in the more rare and age-dependent mode of cycling, a lack of consideration of the age range of the survey population may have introduced an unknown degree of error, when extrapolated using population figures including all inhabitants. Age ranges were not distinguished here due to lack of access to this information and the considerably higher effort required for obtaining age-adjusted data. Available information suggests that travel surveys set lower age boundaries anywhere between 6 and 16 years, and sometimes apply upper boundaries as well. Similarly, travel surveys conducted on a rolling basis (rather than conducted only during parts of a year) will result in more accurate estimates of active modes due to high variability across seasons. As such considerations are more relevant for active than for other modes, it may be desirable to invest into “travel survey standards” specifically for active modes, complementing the SHANTI project (50), which addressed the whole scope of travel surveys.

In countries without travel surveys, mode shares for cycling were estimated according to world region modal shares extrapolated from selected city data, as published in a report by The Institute for Transportation and Development Policy (ITDP) and the Institute of Transportation Studies (ITS) (27). Obviously, such estimates (and fatality rates based on them) are of much lower reliability than data stemming from a national travel survey. In addition, the inaccuracy of fatality rates may be aggravated by the use of constant assumptions for number of trips and average trip lengths, which may differ across countries. Limitations of these rates become apparent in Figure 3, where exposure estimates seem inflated for a number of countries, presumably as a result of combining our assumptions for number of trips, trip length and mode share estimates (16% in Iceland as a Nordic country, 7% among the group of European OECD countries). For several countries, including Cyprus, the low numbers of cycling fatalities contribute to the lack of reliability.

In future efforts these rates may be somewhat improved by modelling the relationships of mode share, number of trips and trip length based on a larger number of countries or city data. Thus, exposure could be estimated more realistically following Equation 2 and considering different trip lengths in dependence of mode share levels (bicycle trip lengths become shorter as mode share increases (28).

In light of these limitations, it is important to recall the context of HEAT, which aims to provide estimations of the health impacts of cycling and walking to provide a sense for the order of magnitude in economic valuations. As scientific literature has shown repeatedly, benefits associated with physical activity from active travel typically outweigh the risks from crashes ((9) and (10)); with very few exceptions (e.g. work of Woodcock et al., (51)). As such, it is justifiable and preferable to include rather crude risk estimates when assessing health impacts, rather than ignoring crash risks entirely. However, such crude risk estimates may not be valid in direct comparisons across countries, or for the purpose of evaluating the success of road safety policies.

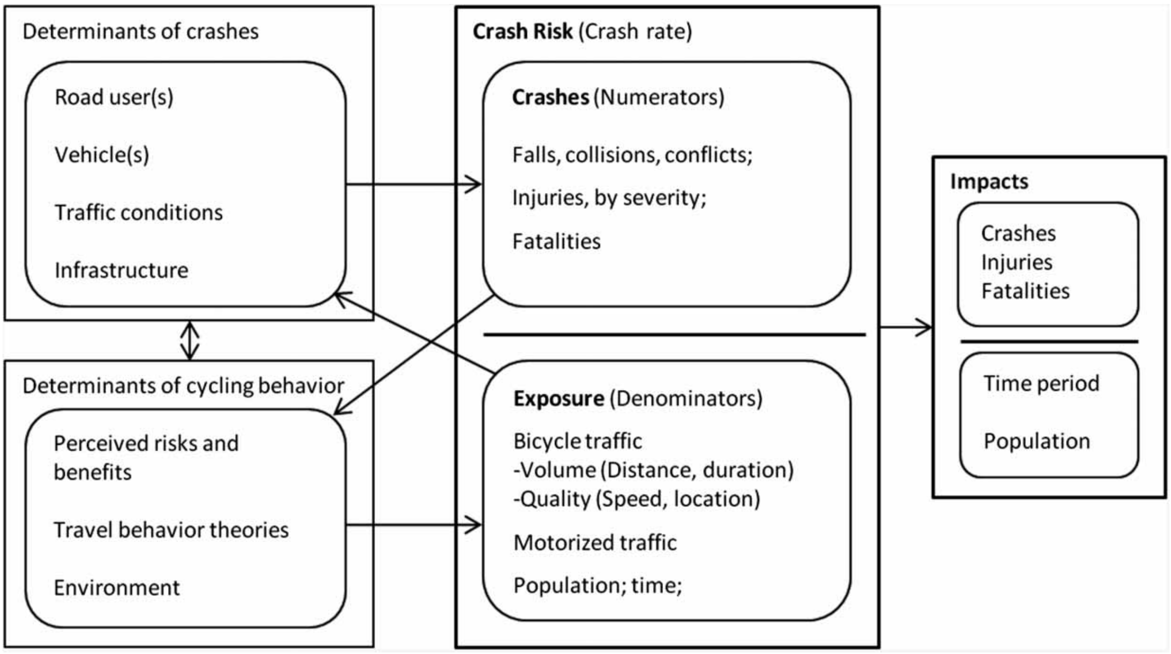
As pointed out earlier, published fatality rates for cycling are rare. Compared with rates published by Pucher and Buehler (52) for four countries for 2007 (i.e. cyclist deaths per 100 million km cycling: 1.1 in the Netherlands, 1.5 in Denmark, 1.7 in Germany, 3.6 in the United Kingdom), the rates published here show the same pattern across countries, but are approximately 30% lower. To which degree this reflects methodological differences or actual safety improvements are difficult to say without further investigation. The rate published for the United Kingdom by Mindell et al. (53) (2.5 cyclist deaths/100 million km cycling) is very similar to the value presented here (2.3).

A major limitation of HEAT cycling fatality rates in predicting adverse health impacts from crashes is that neither the collected rates, nor the calculation in HEAT take into account the role of cars – which are involved in fatal cycling crashes. More sophisticated models as for example proposed by Elvik (54) and implemented in more advanced health impact assessment tools such as the Integrated Transport and Health Impact Model (ITHIM) by Woodcock et al. (55) consider exposures of active and motorised modes interactively, but come at the cost of increased data requirements and substantial challenges of generalisation of model parameters.

In addition, an important limitation to keep in mind is the fact that fatalities only represent one part of crash-related impacts, while injuries are much more common. According to some estimations (56), they can cause an economic impact of comparable magnitude to fatalities. While injury rates could be based on the same exposure estimates as fatality rates, under-reporting and lack of standardisation of outcomes represent a considerably higher challenge than for fatalities.

Aside from these methodological considerations, exposure-adjusted rates do invite a number of comparisons. However, one needs to consider some caveats when interpreting these figures. In contrast to mortality rates for natural causes of death (i.e. diseases), fatality rates in particular for cycling are not equally comparable across countries. Age is the strongest predictor of natural deaths, and hence, once adjusted for age, so-called age-standardised mortality rates provide indicators for cross-country comparisons. Crash risks, in contrast, are the result of a complex set of factors leading to crashes and/or affecting exposure. Vice versa, cycling demand (i.e. exposure) is strongly influence by (real or perceived) crash risk (safety of cycling), as Figure 4 illustrates.

Figure 4. Conceptual framework of safety of cycling



Source: from Götschi et al. 2016 (3), adapted from Schepers et al., 2014 (62).

It would therefore be flawed to identify the safest places for walking and cycling based on the fatality rate alone, without considering exposure levels. Low safety leads to low exposure, because most people will not choose "to risk their lives" by walking and cycling in traffic, and those who will, represent a specific selection – for cycling typically young, "brave" men and often highly skilled cyclists. Such selection effects can also be caused by other factors, like general convenience of cycling e.g. with regards to climate, or if cycling culture, or purpose of cycling trips differ, e.g. for sports and recreation, versus utilitarian cycling. As such, the Netherlands compared to Norway should be rated safer than the similar fatality rates show (0.8 versus. 0.9 deaths per 100 million km cycled), since people cycle three times more in the first country than in the second one (see Figure 1). It may also be speculated that helmet wearing prevalence – anecdotally reported to be lower in safer cycling environments – may counter-balance some of the safety contrasts, in particular when only considering fatalities. Helmets effectively increase survival probability in severe crashes (57). As such, contrasts between (non-head) injury rates or crash rates may be more pronounced than for general fatality rates (52).

The relationship between safety and exposure levels also becomes apparent when plotting the rates for countries with moderate or better data quality, for both cycling and walking (see Figure 1 and Figure 2). The pattern confirms the well-established phenomenon of "safety-in-numbers" - or "numbers-in-safety", so as not to imply any (false) causal direction ((49) and (54)).

From a policy perspective, the crash rates presented here are well suited to be used in impact calculations, such as in HEAT, to put risks and benefits into perspective at a large spatial scale (i.e. on a national, and eventually city level assessments). Furthermore, these crashes may be used for monitoring and benchmarking among countries. However, the related measures, namely the improvements of infrastructure and regulations on motorised traffic, to name two, are typically implemented at more local scales (i.e. streets, intersections, communities, etc.). To base such measures on empirical evidence – such as to identify safety improvement needs, but also to evaluate the success of such measures – more refined data in terms of spatial location of crashes as well as spatial distribution of exposure would be required. In a particular street, crash rates might lack on statistical robustness due to the low number of crashes. Some research has been carried out to assign injury risk ratios to certain street typologies, e.g. by Teschke et al. (58) in Toronto, but broader studies are required to apply these ratios worldwide given the diversity of local urban landscapes. Therefore, beyond national exposure-adjusted crash rates, city-wide data collections are recommended.

Within the scope of HEAT, upcoming priorities are the completion of national data for walking and for selected countries outside of Europe, the inclusion of fatality rates for selected major cities, and eventually the inclusion of injury rates. Research progress permitting, the tool may eventually also include crash risk adjustment widgets, which would allow users to adjust national or city-level crash risks according to the type of infrastructure, or a certain sub-population assessed.

In the broader discourse of improving road safety data of active travel modes, the presented work suggests a two-pronged approach

For countries that already conduct regular travel surveys, efforts should focus on harmonisation of methods, such as separate collection and presentation of walking and cycling data and specific consideration of e-bikes where warranted. Recommendations for harmonisation can be found in reports of Eurostat (59), the COST SHANTI project (50), and Walk21 (for walking) (60). In particular, access to transparently presented safety indicators and corresponding meta-data should be made easier. As such, combined publication of crash and travel exposure data should become the norm. Developing an active-mode specific “gold standard” to that effect would be a worthwhile effort. Although harmonisation should be prioritised, it might be unfeasible in some countries and cities in the short-term. In such cases post-harmonisation is suggested instead following the recommendations of Eurostat (59) and the COST SHANTI project (50).

For countries that currently do not (and likely cannot afford to) conduct traditional travel surveys, efforts may have to focus on improving exposure estimates through alternative data collection approaches. The advent of smart-phone based surveying technologies, crowd-sourcing, opportunistic online surveying and advancements in active transport modelling offer promising opportunities to develop exposure data collection methods that would be considerably cheaper than state-of-the-art travel surveys. In particular smart-phone tracking stands a good chance to be integrated into future travel surveys. Two recent examples of data collection using some of the above mentioned technologies are the PASTA survey in seven European cities (28), the work Hardling et al., in Toronto (Canada) (61).

Such efforts would benefit from intergovernmental institutions playing a leading role, such as the OECD/ITF, or European Union DG MOVE, be it as facilitators of the required expert dialogues or funders of the necessary research efforts.

Conclusions

Exposure-adjusted fatality rates for active modes have been estimated based on available data. Data needs are most pressing for exposure estimates in countries without travel surveys. Further, compilation of data at the sub-national level and on non-fatal outcomes remains a major task.

Safety-related research and planning would benefit greatly if availability and presentation of existing data would be improved by the relevant national agencies. International guidance and/or standards on how to compile crash risk data for active travel modes may help facilitate progress in this area, which presumably ranks low in many agencies in charge. Ultimately, the goal of compiling an international database should be promoted by an international institution.

Available data on crash rates are suitable for crash risk assessments as part of HEAT, although accuracy may be limited for countries with low quality data. From a public health perspective, the mandate to consider risks of active transport along with benefits is clear, and the new HEAT tool now offers the option to include crash risks as well as impacts from air pollution exposure. However, in the context of promotion of active travel, and in particular cycling, planners will need to keep the individual perspective in mind. As long as perceived risks outweigh benefits, the demand for active transport modes will not increase.

As such, the compiled exposure-adjusted fatality rates help to fill a gap in the health impact assessment of active travel, and eventually in monitoring and benchmarking. However, major challenges regarding safety data remain to further advance evidence-based transport planning and promotion of active travel modes.

Notes

1 Norway is an exception with 4 years' time series (2011-2014).

2 The data set of COWI [24] contains exposure data in 14 countries for walking and 15 for cycling, but 2 countries for walking and 5 countries for cycling provided exposure data in km per cyclist, per pedestrian or per unknown type of person, which cannot be converted into km per inhabitant (general population including all transport mode users) without additional information

3 Austria, Belgium, Czech Republic, Cyprus, Denmark, Finland, France, Germany, Ireland, Italy, Latvia, Luxembourg, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, United Kingdom.

4 6% for Iceland based on extrapolation of selected Nordic cities, 7% for European OECD countries, 2% for non-OECD countries and 3% for Middle Eastern countries (i.e. Turkey and Israel as non-European countries included in the WHO European region)

5 PASTA participants reported on average 3.4 trips per day ranging from 3.0 trips per day in Rome to 3.6 trips per day in Antwerp, Barcelona, and Vienna.

6 Average values for the United Kingdom (5 km for cycling and 1 km for walking) (29) and the Netherlands (3 km for cycling, 1 km for walking) (30), analysed as part of the HEAT project. Cycling trip distances across 7 PASTA cities ranged from 3.1 to 5.2 km (28).

7 Fatality rate could not be estimated in 6 countries out of the 53 countries of the WHO European region: Monaco, Uzbekistan and Ukraine are missing because no crash data were found. Andorra, Malta and San Marino report 0 fatalities (21) , therefore no fatality rate can be estimated

8 Exposure was calculated by dividing total annual exposure from Table 4 by country population in the last year of the time series of fatalities. Trend line fits according to the formula from the work of Jacobsen(49): $y = a * x^{(b-1)}$.

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Exposure-Adjusted Road Fatality Rates for Cycling and Walking in European Countries

This paper presents fatality rates for walking and cycling in European Countries used in the World Health Organization's Health Economic Assessment Tool (HEAT). It evaluates and ranks the quality of data sources and gives fatality rates adjusted by exposure (i.e. distance travelled). It also discusses the different methodologies applied for national exposure data, as well as the proposed solutions to make these figures comparable across countries.

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