Incorporating a Value of a Statistical Life Year approach into the WHO Europe HEAT Walking and Cycling tool

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# Introduction

There has been an increasing awareness of the need to incorporate Health in All Policies to ensure that non-health government agencies work in partnership to incorporate considerations of health and wellbeing when developing policy (WHO and the Government of South Australia, 2010). One simple way in which HiAP is often facilitated is through Health Impact Assessments (HIA) (WHO, 2000).

The WHO-Europe’s Health Economic Assessment Tool (HEAT) is an example of a Health Impact Assessments (HIA) method which has been designed specifically for a HiAP purpose, allowing transport planners to incorporate the health implications of walking and cycling into economic appraisals. The HEAT has four modules: physical activity, air pollution, crash risk and carbon emissions. The benefits of reductions in mortality risk associated with increases in physical activity generally dwarf the other three modules (Mueller et al., 2015). Within the physical activity module the estimated net mortality risk change is monetised using the Value of a Statistical Life (VSL), an estimate of the willingness to pay for reductions in mortality risk commonly used in transport planning (Viscusi & Aldy, 2003).

This paper outlines an alternative method of estimating the monetary benefit of increased physical activity, by monetising life years gained with the Value of a Statistical Life Year (VSLY), the estimated willingness to pay for a statistical year of life. The method, referred to henceforth as the VSLY method, relies on country specific lifetables, demographic data and VSL estimates to estimate life years gained (lost) and the associated monetary benefit (cost). This paper describes the methodology developed to calculate the VSLY for each country and compares the results using the current (VSL), and alternative (VSLY) methods for the 49 countries within the WHO-Europe area. All data and code is provided on an open access online repository (<https://github.com/RobertASmith/heat_vsly_public>).

# Material and Methods

## Data & measures

This study relies on data currently used in the HEAT model and described in Kahlmeier et al. (2017); WHO country names, country ISO3 codes, VSL estimates from Lindhjem et al. (2011), mortality rates for 5 year age-groups (European Mortality Database (MDB), 2017), and a linear dose response relationship from Kelly et al., (2014). It also uses two additional sources of data; the Global Burden of Disease Study population estimates described in detail in Murray et al. (2018) and available from the Disease Collaborative Network (DCN, 2018), and the World Health Organization Global Health Observatory life tables (GHO, 2018).

**Table 1. Variables used in the analysis, descriptions and sources.**

|  |  |  |
| --- | --- | --- |
| Variable | Description | Source |
| **Currently used in the HEAT model and described in Kahlmeier et al. (2017):** | | |
| MRVSL | HEAT age-group mortality rates | European Mortality Database 2017 |
| VSL | Value of a statistical life at age 50. | Lindhjem et al. 2011 |
| RR | Relative Risk of mortality assuming linear dose response function. | Kelly et al., 2014 |
| **Additional data sources for this study:** | | |
| pop | Age-group population estimates | DCN, 2018 |
| MRVSLY (11 group) | Mortality rates in five-year age-groups | GHO, 2018 |

## Analysis

The VSLY method can be described in four steps: Firstly a dataset was created from the sources described above which included, for each country: population in each 5-year age band, percentage female in each five year age band, mortality risk for males and females in each 5 year age band, Value of a Statistical Life estimate used in HEAT. The dataset created was then used to estimate the Value of a Statistical Life Year (VSLY) for each country using the method described below:

Estimating the Value of a Statistical Life Year

The VSL estimates used in the HEAT model are based on a stated preference study conducted by the OECD (Lindhjem et al., 2011). The study had (XXX) participants with a mean age of 50. By making the assumption that the VSL at age of elicitation is the value derived from future life years until death, we can write this as:

Note: All life years are assumed to be valued equally - there is one single VSLY figure.

However, a population of individuals aged 50 will die at different ages. Some will live until 52, others 102. Since we know the mortality rates in each year it is possible to estimate the probability of survival at each age. The probability of a random individual being alive at age i is simply the product of the survival probabilities for each year between elicitation (age 50) and age i: .

We can therefore adapt the equation to state that the VSL is the sum of the expected life years remaining (the area under the survival curve) multiplied by the value assigned to each year (VSLY).

However, in an added layer of complexity, we need to discount future benefits accruing to individuals, as is commonly done to future benefits in economic analysis. Therefore we add in discounting into the equation, at a rate of r, using the equation to estimate the appropriate multiplier for time i.

In laymans terms, the Value of a Statistical Life Year is the sum of the discounted value of the expected life years remaining between age 50 and infinity. So, for example, using an age of elicitation of 50, and a discount rate of 1.5%, we get:

However, data from the WHO data repository only provides mortality rates to 85. Therefore, the periods from 50 to 85, and 85+ are estimated seperately. The period from 50 to 85 is estimated as above, using the equation:

The period from 85 onwards is estimated by assuming every individual lives the exact years provided in the WHO data repository as "expectation of life at age x" where x is 85, and discounting the period accordingly. This can be written as:

Therefore, the actual equation utilised to estimate VSLY is:

The results of this method are higher than simply dividing the VSL by the life expectancy at age 50 if r (discounting) is greater than 0 primarily because of discounting. There is considerable heterogeneity in VSLY between countries, as shown in figure 4 below which depicts the VSLY estimates for the 49 countries. There is a clear tendency for higher values in the western countries than in the east. A full table of the VSLY are provided in the appendix.

VSLY Method

The VSLY approach estimates monetary benefit of an intervention in a specific country using the equation below which estimates monetary benefit as discounted life years saved by an intervention multiplied by the value of a statistical life year.

Discounted life years saved can be estimated by multiplying the absolute difference in the relative risk of death by the age specific mortality rate to estimate changes in mortality for each 5 year age-group, and multiplying this by discounted expected life years remaining for the group and the population of the group. Since the absolute difference in relative risk is constant between age groups this can be factorised, giving the below

Inputting this back into our original equation gives:

Where i has 11 values representing the 5 year age bands from 20-74

The variables have all been derived as follows:

was previously estimated for each country in the step above.

- absolute difference in relative risk, is calculated using the same equation as the current heat tool, using a linear dose response relationship described in Kahlmeier et al., 2017.

mortality risk for specific age band from GBD.

, was calculated from WHO lifetables.

figures are calculated using user input and the GBD study data.

Models compared:

In order to compare the proposed VSLY model with the current HEAT models, we estimate the annual, per capita monetary benefit using four different methods: 1) **HEAT-1**group uses the current HEAT model with a single age-group (20-74), 2) **HEAT-2**groups uses the current HEAT model with two age groups (Walking: 20-44, 45-74; Cycling: 20-44, 45-64). 3) **VSL-11** groups adapts the existing HEAT model methodology to include mortality risk for 11 age-groups (20-24, ... , 70-74) seperately and finally, 4) the **VSLY** model described above with the same 11 age-groups as in (3).

In all cases the discount rate was set to zero in this comparison.

Scenarios compared

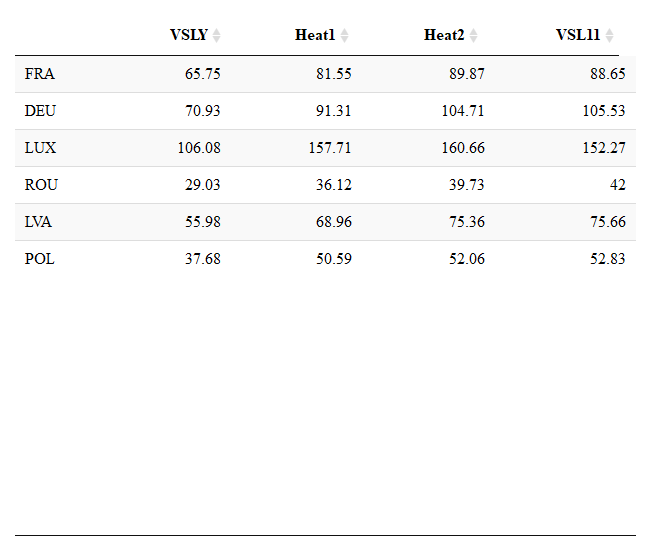
The valuations, and the differences between them, will vary depending on the user input. Therefore, we test six scenarios using a representative sample of the country specific populations: 1) Population aged between 20 and 74 doing an additional 10 minutes of walking per week, 2) Population aged between 20 and 64 doing an additional 10 minutes of cycling per week. 3) Population aged between 20 and 44 doing an additional 10 minutes of walking per week. 4) Population aged between 20 and 44 doing an additional 10 minutes of cycling per week. 5) Population aged between 45 and 74 doing an additional 10 minutes of walking per week. 6) Population aged between 45 and 64 doing an additional 10 minutes of cycling per week.

The results from scenarios 1, 3 and 5 (walking for different ages) are described in the results section below. The results from the cycling scenarios (2,4 & 6) were similar to that of the walking ones (1,3 & 5) and can be found in the supplementary material.

# Results

In the first simple scenario, an extra 10 minutes walking per week for every person aged 20-74, the VSLY method results in approximately 20-30% lower estimated beneﬁts than using the current HEAT method with either one or two age-groups. The effect is not simply due to more precise mortality rate estimates, the HEAT method applied to a population categorized in 5-year age bands (VSL11) results in similar estimates to the HEAT model with one and two groups. Table 2 below shows these results for France, Germany, Luxembourg, Romania, Latvia and Poland. These countries are selected as a mix of eastern and western European countries.

Table 2. Estimated Monetary Beneﬁt (2017 Euro) of 10minutes additional weekly walking for six countries.



\begin{table}[t]

\caption{\label{tab:}Walking age 20-74}

\centering

\begin{tabular}{l|c|c|c|c}

\hline

& VSLY & Heat1 & Heat2 & VSL11\\

\hline

FRA & 65.75 & 81.55 & 89.87 & 88.65\\

\hline

DEU & 70.93 & 91.31 & 104.71 & 105.53\\

\hline

LUX & 106.08 & 157.71 & 160.66 & 152.27\\

\hline

ROU & 29.03 & 36.12 & 39.73 & 42.00\\

\hline

LVA & 55.98 & 68.96 & 75.36 & 75.66\\

\hline

POL & 37.68 & 50.59 & 52.06 & 52.83\\

\hline

\end{tabular}

\end{table}

Figure 1 below displays the results from the same scenario graphically. The current HEAT method with two age-groups (HEAT2) is shown on the x axis, and all other methods are depicted in a color-coded scatterplot. A 45-degree line is used to depict equity, such that points below (above) the line represents a lower (higher) estimate than that generated by HEAT2. The monetary benefits estimated by the VSLY (blue) are generally lower than those estimated by the current HEAT-2 model (black line), HEAT-1 (red) and HEAT-11 model (green), though the extent differs by country.

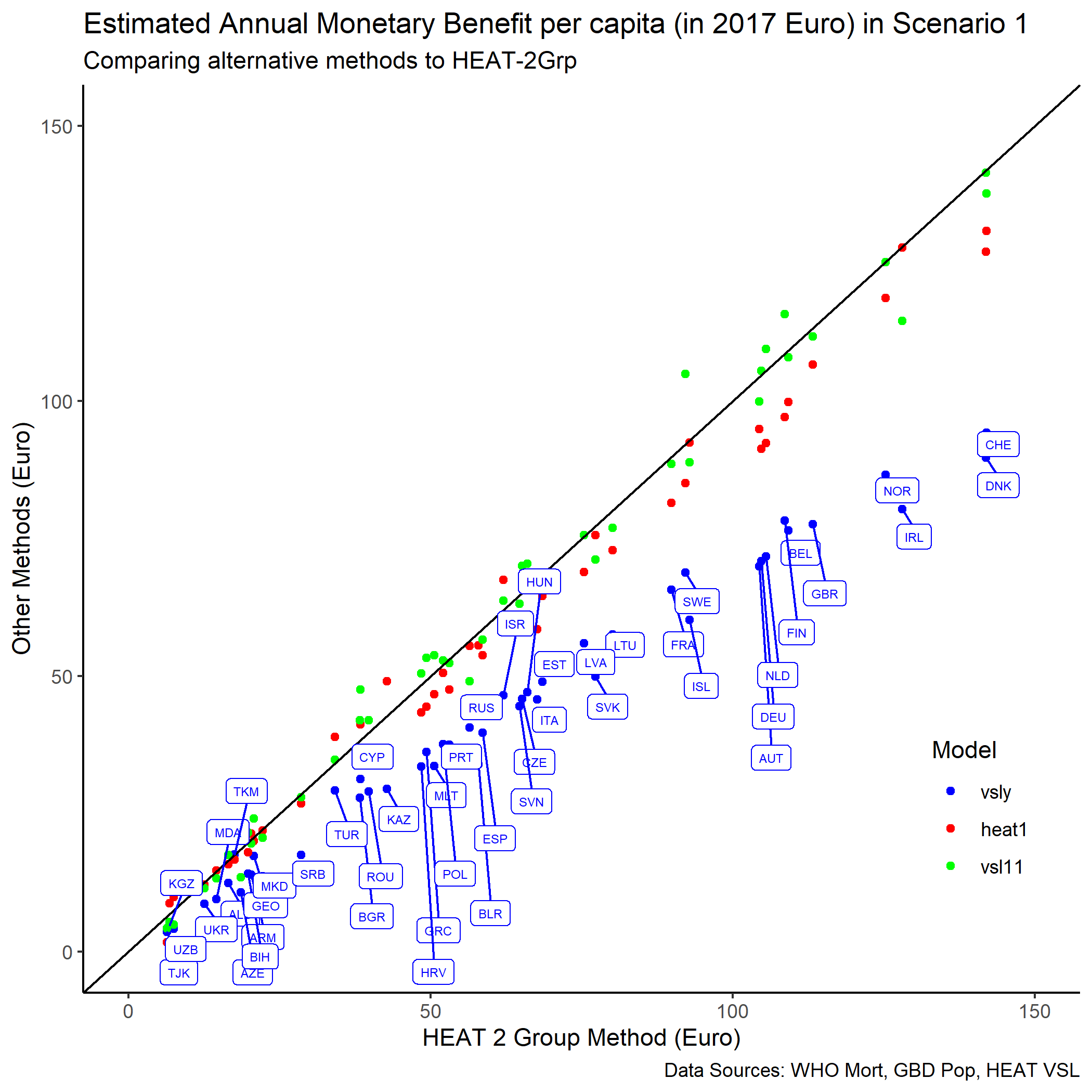
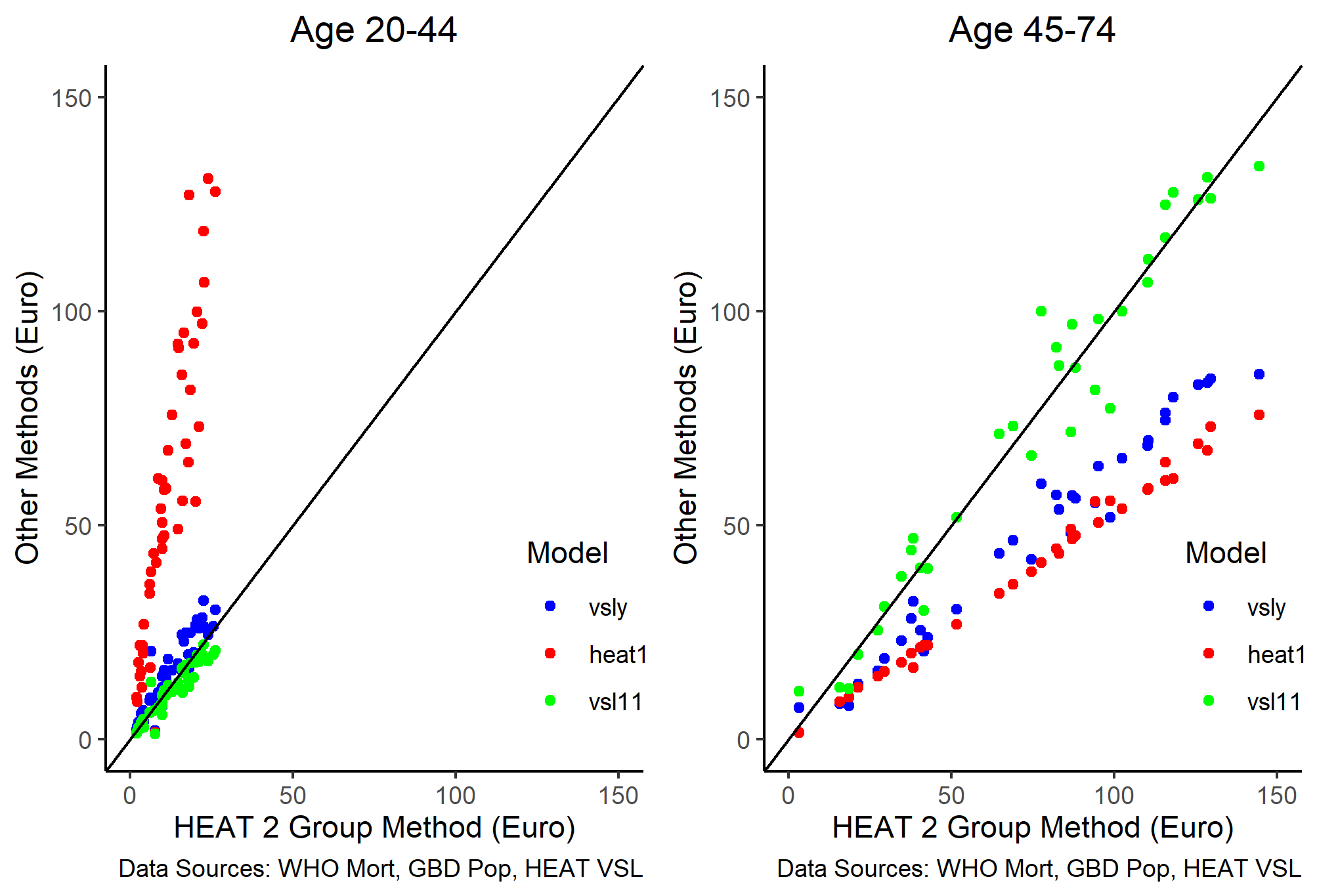
Figure 1. Estimated Annual Monetary Beneﬁt per Capita (in 2017 Euro) in Scenario 1, Comparing Alternative Methods to HEAT-2Grp

Figure 1 above showed the estimates generated by increased activity in the population aged 20-74. However, this masks differences between the approach for the two age-groups (20-44,45-74). Figure 2 depicts the estimates generated by restricting the analysis to the population aged 20-44 (left) and 45-74 (right). In both cases the VSL11 (green) estimates are very similar. The HEAT-1 (red) method results in higher (lower) values when restricting the analysis to younger (older) people. The VSLY (blue) estimates tend to be higher in younger people and lower in older people.

Figure 2. Estimated Annual Monetary Beneﬁt (in 2017 Euro) per capita from 10mins additional weekly walking using country speciﬁc population age distributions from 20-44 (left) and 45-74 (right), VSLY vs current HEAT models.

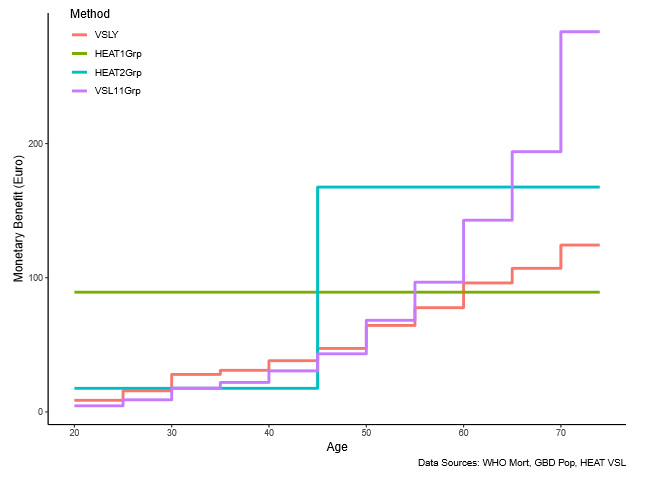


Since there are clear difference in the values generated by different methods, and these differences vary between older and younger populations, it seems relevant to look at how the valuation methods differ over the life course in an exemplar country.

Figure 3 below shows a comparison of annual monetary benefits per capita (2017 Euro) associated with 10mins/week of additional walking, for each individual age from 20 to 74 for the Latvian population using the four different models: HEAT-1Grp (red), HEAT-2Grp (black), VSL-11 (green), VSLY (blue).

Figure 3. Annual monetary beneﬁt per capita (in 2017 Euro) from 10mins additional weekly walking for each age of Latvian population, using each method.

<insert figure 3>



The HEAT-1Grp method generates the same results regardless of age, since there is a single mortality risk and VSL applied. The HEAT-2Grp method generates different results for the population aged 20-44 to those aged 45-74, as the populations have different baseline risks and the same VSL. The VSLY (blue) and VSL-11 (green) results are similar, with monetary benefit increasing as age, and therefore mortality rates, increase. However, the VSLY model does not increase as quickly with age due to the process of valuing life years remaining rather than life.

Finally, it was interesting to observe the differences in results between countries when using the VSLY methods. Figure 4 shows the estimated per capita annual monetary benefit of an additional 10 minutes of walking per week per person aged 20-74 for the HEAT countries on a choropleth map. The differences are in the same order to those observed in the VSLY estimates. Differenced in VSL and mortality rates mean that there are large differences in estimated monetary benefit per capita.

Figure 4. Map of estimated per capita annual monetary beneﬁt (2017 Euro) of an additional 10 minutes of walking per week per person aged 20-74.

<insert figure 4>



# Discussion

In order to incorporate the benefits of physical activity into the decision-making process for other sectors, it is useful to have a common metric. By monetizing the mortality reductions associated with increased physical activity the HEAT allows transport planners to incorporate health considerations into their decision-making process. It is a good example of a health impact assessment tool used to encourage Health in All Policies and has been used widely, including in Kuopio (Finland), Parnu (Estonia), Brighton & Hove (UK), Modena (Italy) and Viana do Castelo (Portugal) all of which were included in a review of the early applications of HEAT (WHO, 2013).

However, the current HEAT model values reductions in mortality equally regardless of the age of the individual. Taken at its extreme this means that the monetary benefit associated with increasing physical activity for those aged 20-44 is less than 1/6th that of a person aged 45-74.

The VSLY method attempts to bring the HEAT model toward the methods used by health economists which incorporate not only the number of deaths averted but the estimated additional life years lived as a result of the intervention (Drummond et al., 2015). It falls short of considering quality of life, although it could be adapted to incorporate quality adjusted life years by estimating expected quality adjusted life years remaining at each age based on mortality rates and mean population quality of life estimates for each age-group (Janssen & Szende, 2014).

The VSLY method differs from the current HEAT method in two fundamental ways. Firstly, the current HEAT model has at most two age groups (20-44, 45-74) while the VSLY model has 11 age groups, in 5-year age bands from 20-74. Secondly, the HEAT model applies the country specific Value of a Statistical Life regardless of age. This model calculates life years saved due to an intervention and applies the country specific Value of a Statistical Life Year.

The result of these two differences is that the VSLY model is more sensitive to the age of those affected by an intervention. Interventions which affect young (old) people will have small (large) mortality rate reductions but lives saved will be long (short). This helps to mitigate the extreme differences between the estimated benefit of increasing activity levels in young and old people in the current HEAT model.

The main limitation of the method is that it can require an additional user input. In the current HEAT the user specifies how many people are in the two age groups (20-44, 45-74 for walking; 20-44, 45-64 for cycling). The VSLY approach could use the distribution of age in the general population as a default, requiring no user input… but if the user wanted to change this they would be required to either enter the numbers in each 5 year band (11 groups) or, if the intervention is targeted at a specific age group the user could simply state the minimum, maximum and median age which could be used to create a triangular distribution. The latter may be an additional burden on the user, and therefore provides a trade-off between accuracy and ease of use.

An additional issue for accurate estimation of benefit, unrelated to the use of the HEAT-2 or VSLY methods, remains that the VSL estimates used are derived from a stated preference study with a median age of 50. There are numerous limitations of stated preference studies when estimating the VSL (REF), but particular to this case is the limitation that VSL has been shown to peak in middle age (approx. 40-50), and therefore calculating the value of a life year from this figure may lead to overestimates.

# Conclusion

This study comparing the use of the existing HEAT methodology and an adapted method, referred to as the ‘VSLY method’ has shown that the VSLY method is more sensitive to age than the current HEAT model, incorporates a consideration of length of life lost, and allows users to use the default country age distributions. The VSLY method is a approach which can be used to value mortality reductions, with limited additional user inputs. The differences in model results may be particularly important for programs targeted at specific age-groups, such as middle-aged commuters or investments around schools (young people) or improving ease of access (elderly people). Prior to implementing the change, it is recommended that tests are undertaken to ensure users can deal with the additional, albeit minimal, inputs required.

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