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## Trends in cycling and cycle related injuries and a calculation of prevented morbidity and mortality

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### ABSTRACT

The objectives were to describe trends in cycling and cycle related injuries in Denmark overall and in the four largest Danish cities to see if changes in cycling trips and injuries were associated. Further, we compared number of prevented deaths, type 2 diabetes (T2D), cardiovascular diseases (CVD) and cancers with registered injuries. We analyzed cycling trends over past 17 years in Denmark based on national statistics from 56 electronic counters as an ecological study. Cycle related injuries were collected by Statistics Denmark from hospital records. We also calculated the annual prevented disease and mortality accrued from the health benefits of physical activity in cycling based on relative risk (RR) of cycling derived from population studies, number of cyclists, and number of death, T2D, CVD and cancers in Denmark.

Since 1998 till 2015, cycling has increased by 10% in the whole country; the cycling related injuries however, have gradually declined and were only 45% in 2015 as compared to 1998 level. In Copenhagen specifically, cycling even increased more than 30% since 1998 while cycling related injuries decreased during the same period to one third. Diseases prevented in Denmark by cycling were annually 3328 T2D cases, 5742 CVD cases and 2076 cancer cases and prevented deaths were 6190. In comparison, in 2015, 26 cyclists were killed in the traffic, 512 were seriously injured and 297 experienced light injuries in the whole country.

In conclusion, in Denmark, the number of cycling trips have steadily increased over the past 17 years while cycling related injuries show a concomitant decline. Intuitively one might expect cycle related injuries to increase with increased cycling, but a decrease was observed in injuries. Health benefits of cycling calculated from cohort studies were 21 times higher than risk of injuries and for mortality alone the ratio was 238.

### 1. Introduction

The world is struggling with the rising burden of non-communicable diseases (NCDs) and is looking for doable and deliverable population based interventions to prevent them (GBD\_Risk\_Factors\_Collaborators, 2016; Giles-Corti et al., 2016). In addition, environmental and inequity concerns need actionable solutions. A shift to cycling from motorized transport can enhance physical activity levels in daily living of populations, is cost saving, is good for the environment and enhance equity. A major concern, however, is a potential rise in the road traffic and transport injuries (Giles-Corti et al., 2016; Lozano et al., 2012). Globally, road

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injuries was the leading cause of deaths in the 15–24 years olds in the recent 2015 global burden of disease (GBD) analysis, and the 8th leading cause of death worldwide ([GBD\\_Mortality\\_Causes\\_of\\_Death\\_Collaborators, 2016](#)). The burden on low-income individuals was proportionately high ([GBD\\_Risk\\_Factors\\_Collaborators, 2016](#)). Further, the fear of injury from cars has been found to be the most important perceived barrier to bicycling ([Manton et al., 2016](#)). In a recent study, Stevenson et al. modeled the relationship between land-use, transport and population health based on six cities - Melbourne, Delhi, Copenhagen, London, São Paulo and Boston. The association between cycling, walking for transport and traffic related injuries during bicycling was expected to be positive in five of six cities including Copenhagen ([Stevenson et al., 2016](#)). It may therefore be relevant not just to model expected changes, but to measure trends over time in cities where changes actually occur to verify whether expected changes are true.

Cycling is known to promote health and has a potential to increase physical activity globally ([Hallal et al., 2012](#)). Prospective cohort studies ([Oja et al., 2011](#)) and four randomized trials ([Hemmingsson et al., 2009](#); [Hendriksen et al., 2000](#); [Moller et al., 2011](#); [Ostergaard et al., 2012](#)) have consistently shown health benefits of cycling. However, with increase in cycling, a possible rise in cycling related injuries is a perennial concern. Therefore, it is important for public health to know whether it is possible to increase cycling but decrease injuries or at least prevent injuries from rising. There are to our knowledge no studies of high quality using national statistics, which report the trends in cycling and cycle related injuries over the years.

The Scandinavian countries have always prided themselves with the most health friendly federal structure, local laws, and road design, with a high priority on maintenance of roads, cycling lanes and pedestrian paths. Cycling for daily transport is taken up by people across all economic sections and all age groups. In this manuscript, we describe time trends in cycling trips and in cycling injuries over the last 17 years in whole of Denmark and in the four larger cities of Denmark specifically. With Denmark specific data, we also estimate prevented deaths and morbidity for selected common diseases due to high levels of cycling. We chose type 2 diabetes (T2D), cardiovascular disease (CVD) and cancers, because relative risk (RR) in relation to cycling does not exist for other diseases.

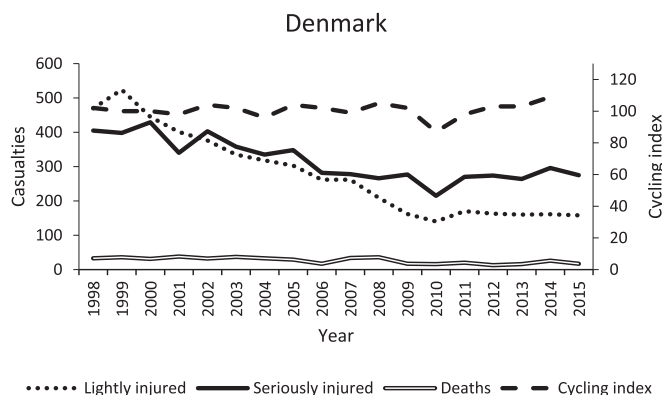
## 2. Methods

Denmark is a small country with only 5.7 million citizens, 75,000 km roads and detailed monitoring of population statistics. The average temperature during the day is 2 °C in the winter months and 20 °C in the summer. We retrieved and synthesized cycling statistics from several sources summarized below.

### 2.1. Sources of data for trends in cycling

Data from the whole country was extracted and synthesized from the Danish Road Directory (Vejdirektoratet) ([Vejdirektoratet, 2016a](#)). Cycle statistics from Vejdirektoratet describe trends in number of cycle trips and kilometers driven in Denmark since 1998 as shown in [Fig. 1](#) (upper curve). Data was based on electronic counters and collected in a database called MASTRA (Machine Traffic Registration) held by Vejdirektoratet under the Ministry of Transport and Building ([Vejdirektoratet, 2016a](#)). In 1990, there were 28 electronic counters, which were extended to 56 counters in 2008. Counts from counters in different parts of the country are weighted and an index calculated. The level of cycling in year 2000, measured as number of trips from the counters, was used as reference and set to 100, and level in other years were calculated according to year 2000 level. The index is based on many million counts per year and has been validated against the TU Studies (Transport Behavior Studies) ([Transport\\_Institute, 2016](#)). The TU studies consist of 8000–24,000 annual interviews in relation to transport behavior where responders are randomly selected from the Central Personal Registry (CPR). All citizens in Denmark have a unique CPR number, which means the population contacted is representative of the population and the only selection bias is that caused by dropout. Based on the interviews it was possible to calculate kilometers ridden and number of trips. Two years of TU data were used in the validation (1993 and 2009) and comparison showed high validity of the cycle index ([Transport\\_Institute, 2016](#)). The cycle index includes both cycling and mopeds. However, moped transport has decreased over time and constituted only 3% of the index in 2007 ([Vejdirektoratet, 2016b](#)).

The cycle index used in [Fig. 2a–d](#) for the four larger cities in Denmark are comparable within the city, but different methods have



**Fig. 1.** Trends in cycle traffic and cycling related casualties in the traffic since 1998 in Denmark. Cycle traffic index is based on electronic counters.

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