Safety-in-numbers: a systematic review and meta-analysis of evidence

International Cycling Safety Conference

Gothenburg, November 18-19 2014

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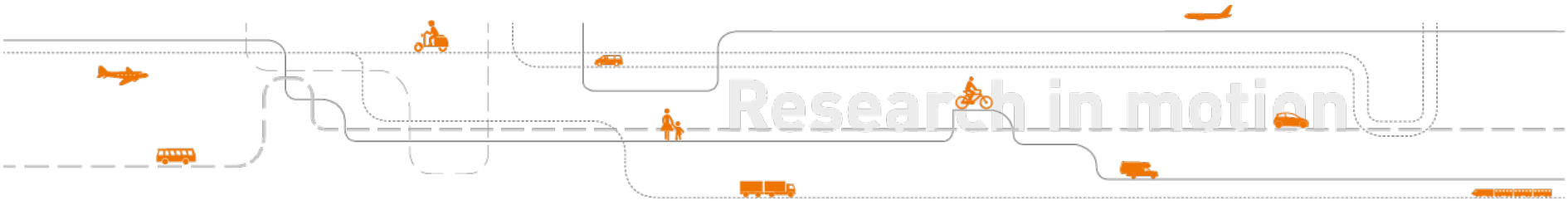


What is safety-in-numbers?

- Safety in numbers is the tendency for the risk of accident for each road user of a given group to go down the more road users of that group there are in traffic

- There is safety-in-numbers if this pattern holds:

Cyclists:	100	Risk per cyclist:	0.010
Cyclists:	200	Risk per cyclist:	0.008
Cyclists:	500	Risk per cyclist:	0.005
Cyclists:	1000	Risk per cyclist:	0.002

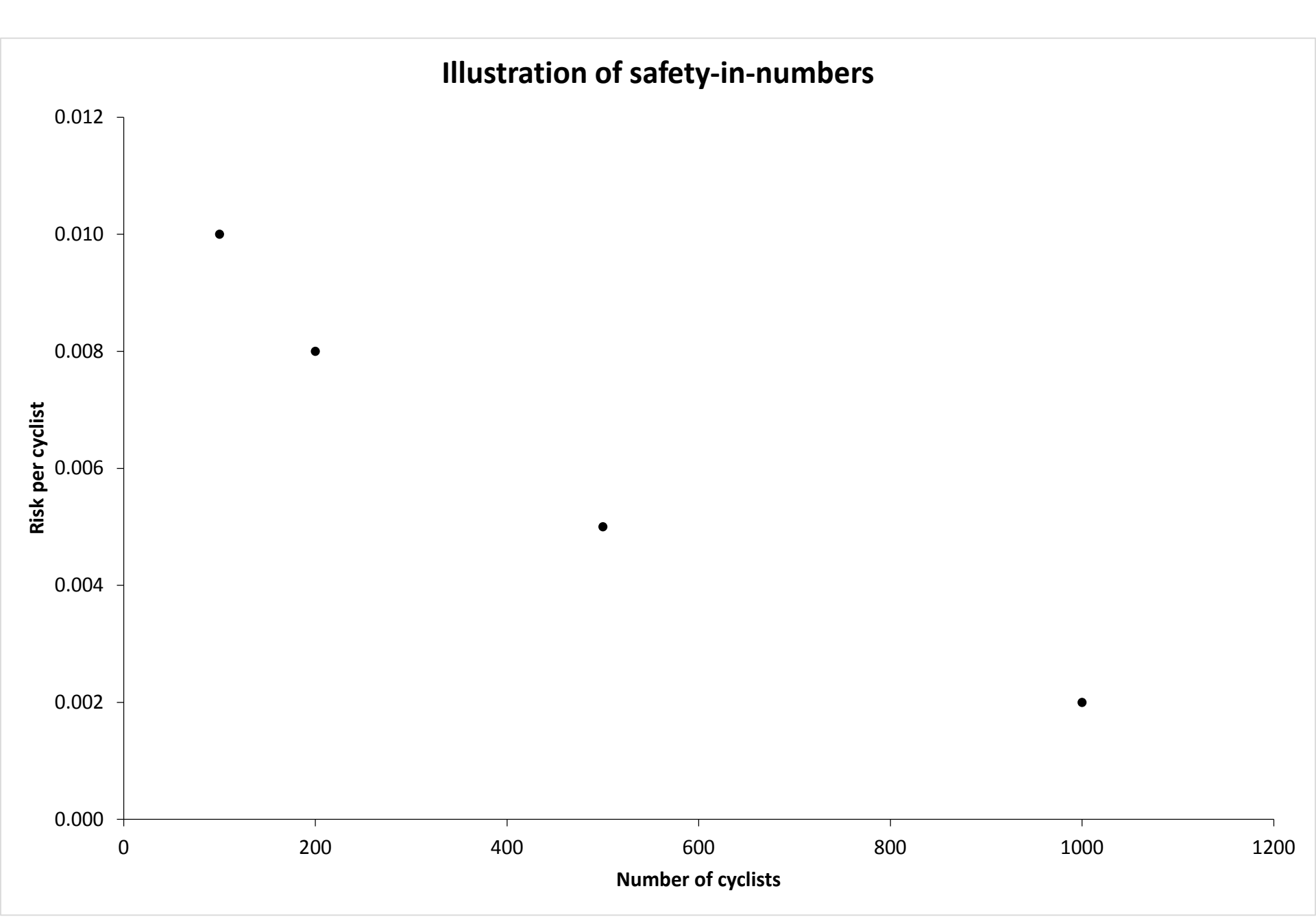


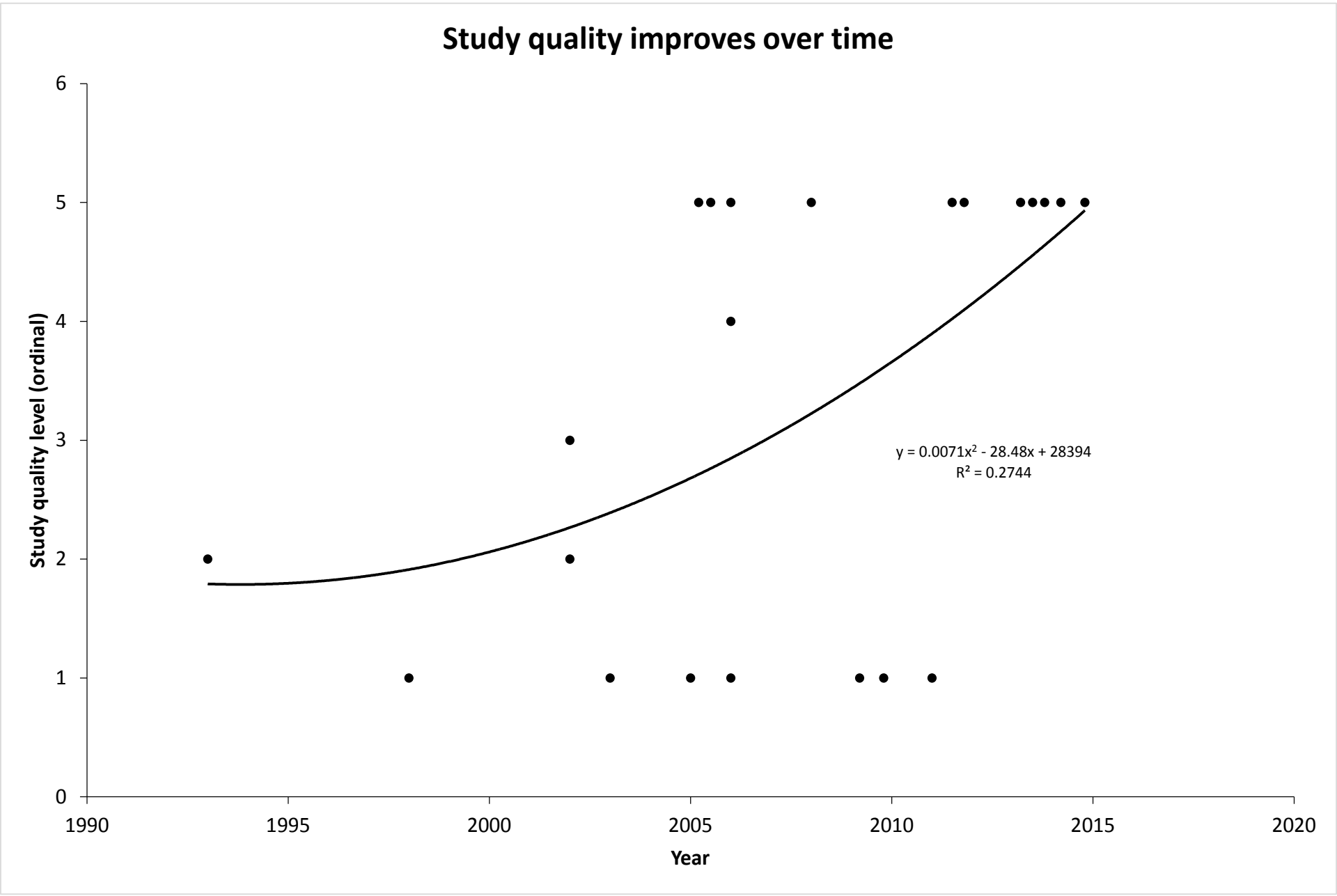
Illustration of safety-in-numbers
0.012
0.010
0.008
0.006
0.004
0.002
0.000
Risk per cyclist
0
200
400
600
800
1000
1200
Number of cyclists

Systematic literature review and meta-analysis

- Relevant studies were identified by means of a systematic literature survey
- 22 studies were identified
- These studies were published between 1993 and 2014
- The suitability of including the studies in meta-analysis was assessed
- 15 studies could be included in some form of meta-analysis
- 12 studies could be included in inverse-variance meta-analysis

Levels of study quality

- Level 1: Studies using inappropriate measures of risk or including only one group of road user
- Level 2: Studies including conflicting traffic volumes only; standard errors not stated
- Level 3: Studies including conflicting traffic volumes only; standard errors stated
- Level 4: Studies including conflicting traffic volumes and other variables; standard errors not stated
- Level 5: Studies including conflicting traffic volumes and other variables; standard errors stated


Study quality improves over time
Study quality level (ordinal)
Year
y = 0.0071x² - 28.48x + 28394
R² = 0.2744
0
1
2
3
4
5
6
1990
1995
2000
2005
2010
2015
2020

Preferred type of model

Number of accidents = $e^{\beta_0} MV^{\beta_1} CYCL^{\beta_2} e^{\left(\sum_n^{i=1} \beta_n X_n\right)}$

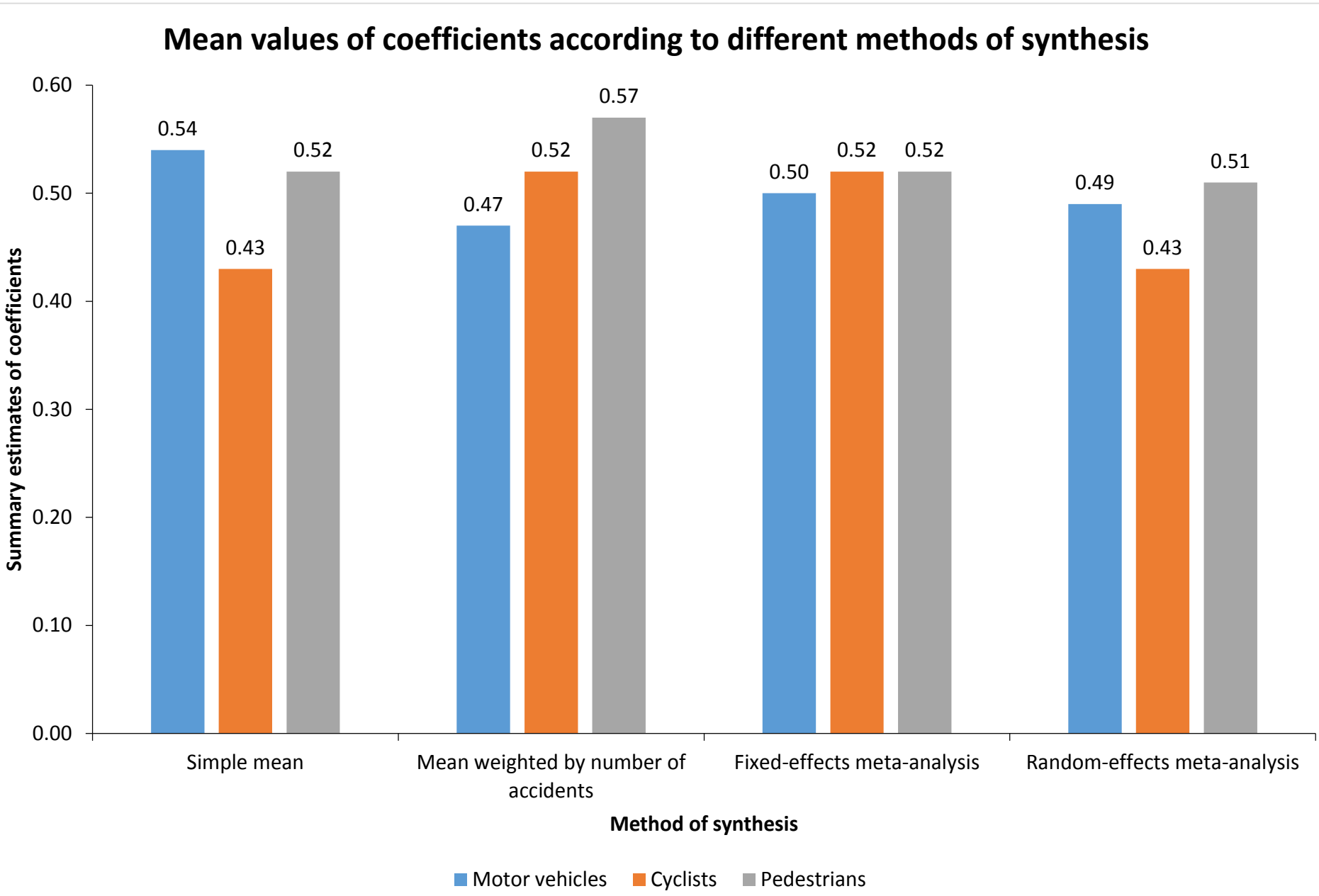
Summary estimate = $\overline{\boldsymbol{Y}} = \frac{\sum \boldsymbol{W_g Y_g}}{\sum \boldsymbol{W_g}}$

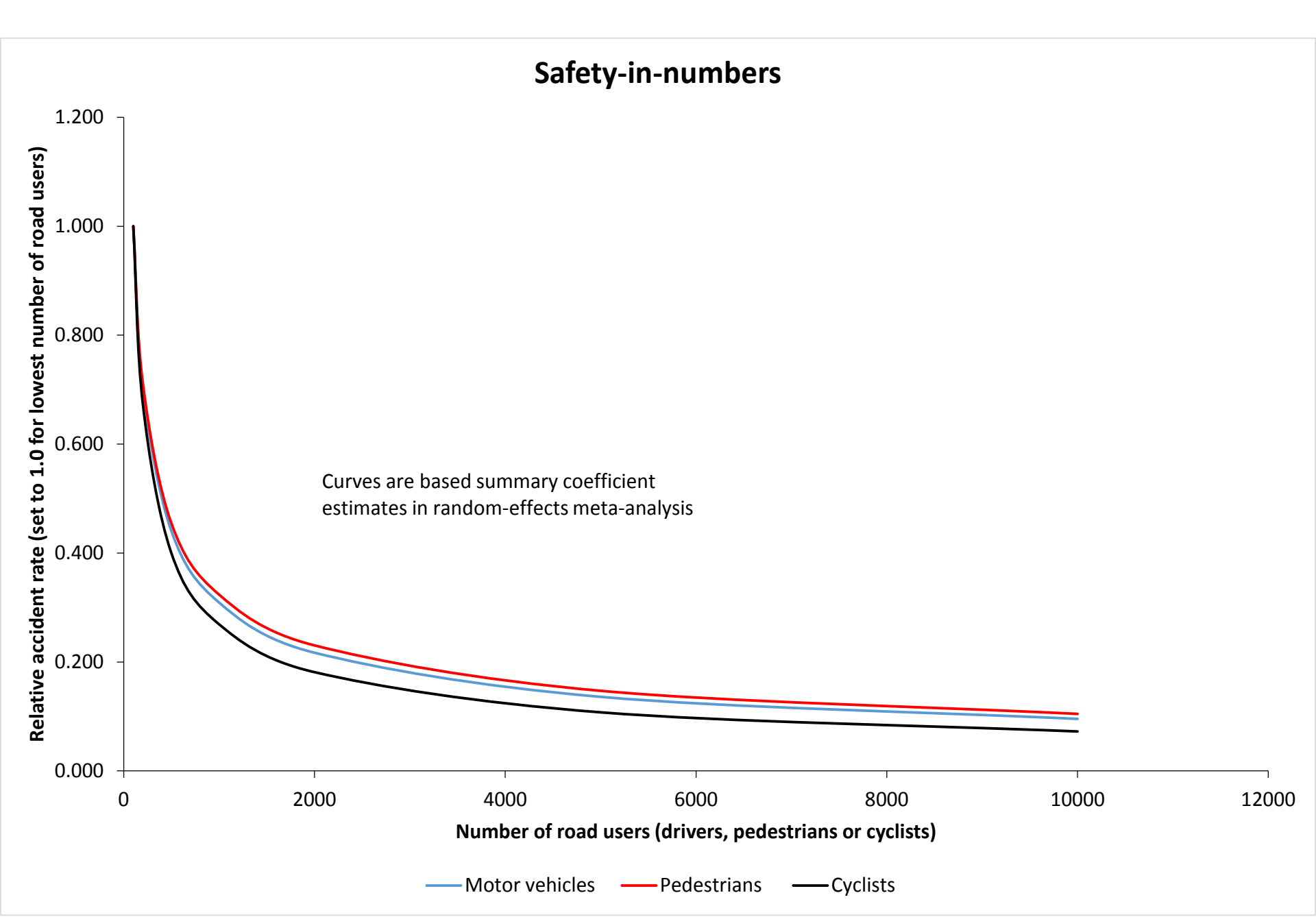
Statistical weight = $\boldsymbol{W} = \frac{1}{\boldsymbol{SE}^2}$

Methodological challenges

- Model coefficients should have known standard errors
- Model coefficients should be stable across model specifications
- There should not be any outlying estimates of model coefficients
- There should not be evidence of publication bias
- The distribution of model coefficients should be unimodal

- All these challenges were found, but analysis nevertheless produced meaningful results


Mean values of coefficients according to different methods of synthesis
Summary estimates of coefficients
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.54
0.43
0.52
0.47
0.52
0.57
0.50
0.52
0.52
0.49
0.43
0.51
Simple mean
Mean weighted by number of accidents
Fixed-effects meta-analysis
Random-effects meta-analysis
Method of synthesis
Motor vehicles
Cyclists
Pedestrians

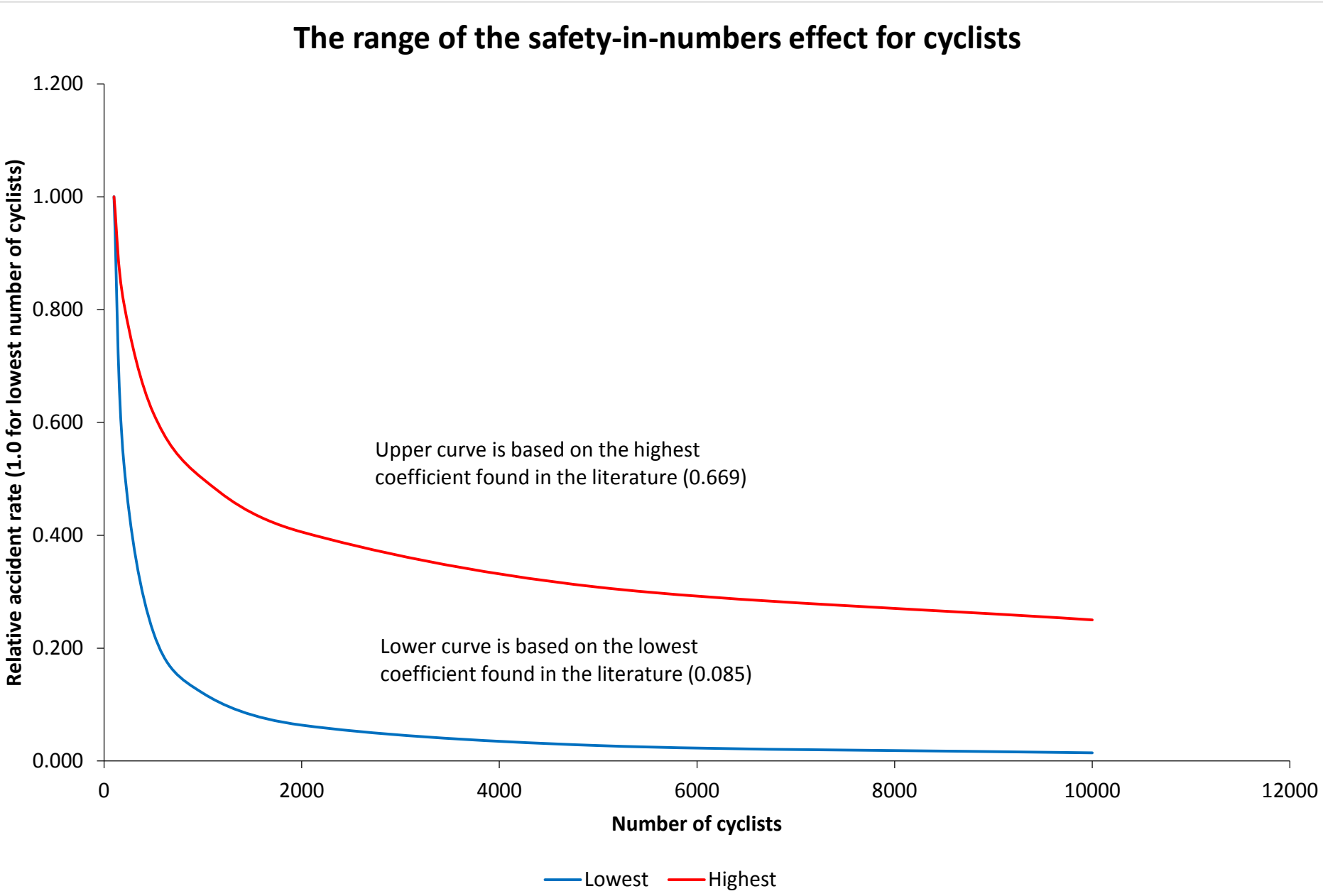

Safety-in-numbers
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Relative accident rate (set to 1.0 for lowest number of road users)
Curves are based summary coefficient estimates in random-effects meta-analysis
0
2000
4000
6000
8000
10000
12000
Number of road users (drivers, pedestrians or cyclists)
Motor vehicles
Pedestrians
Cyclists

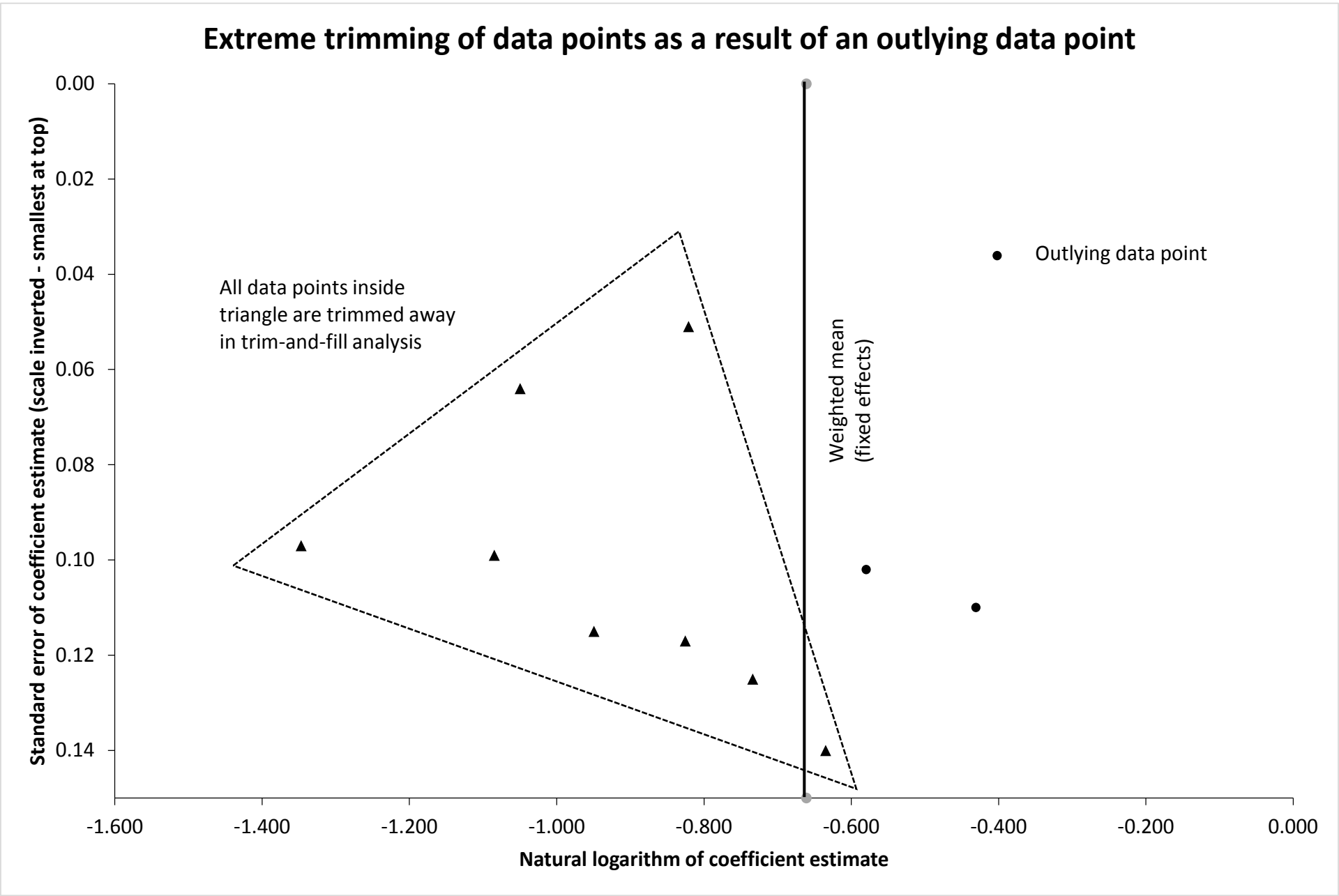
Issues for discussion

- Does a safety-in-numbers effect exist?
  - *Yes, it does*
  - *The evidence is highly consistent regarding the direction of the effect*
  - *It is less consistent regarding the magnitude of the effect*
- Does the effect reflect a causal relationship?
  - *It probably does, but this has still not been shown convincingly*
  - *No study controls for all potentially relevant confounding factors*
  - *Therefore, alternative interpretations cannot be ruled out*
  - *Selective recruitment: different types of cyclists in different traffic environments*
  - *Safer infrastructure: more people cycle when the infrastructure provides for safety*

Further issues for discussion

- Could the safety-in-numbers effect have a turning point?
  - *One can imagine it might, at least for cyclists, but this is unknown*
- Does it apply to single accidents?
  - *There is evidence it does so for cyclists; it remains unknown for pedestrians*
- Does it apply to all levels of accident severity?
  - *Evidence is conflicting; some studies show it is weaker for more severe accidents; others show the opposite*
- Can the strength of the effect be influenced?
  - *It seems reasonable to think that it can be reinforced by means of infrastructure measures, but this has not been shown*


The range of the safety-in-numbers effect for cyclists
Relative accident rate (1.0 for lowest number of cyclists)
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
2000
4000
6000
8000
10000
12000
Number of cyclists
Upper curve is based on the highest coefficient found in the literature (0.669)
Lower curve is based on the lowest coefficient found in the literature (0.085)
Lowest
Highest


Extreme trimming of data points as a result of an outlying data point
Standard error of coefficient estimate (scale inverted - smallest at top)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
All data points inside triangle are trimmed away in trim-and-fill analysis
Weighted mean (fixed effects)
Outlying data point
-1.600
-1.400
-1.200
-1.000
-0.800
-0.600
-0.400
-0.200
0.000
Natural logarithm of coefficient estimate