ASSESSING THE IMPACT OF THE CHOICE OF MODELLING STRATEGY FOR QUANTITATIVE COVARIATES ON RISK ADJUSTMENT

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Context

- Observational study
- Exposure (E) – Disease (D) association
- Adjustment for Risk Factors (RF)
- E and D are binary, RF are quantitative
- RF have non-linear association with response

Methods for modelling RF

1. Single linear term?
2. Dummy variables on categories?
3. Fractional polynomials?
4. Generalized Additive Models?

OBJECTIVE

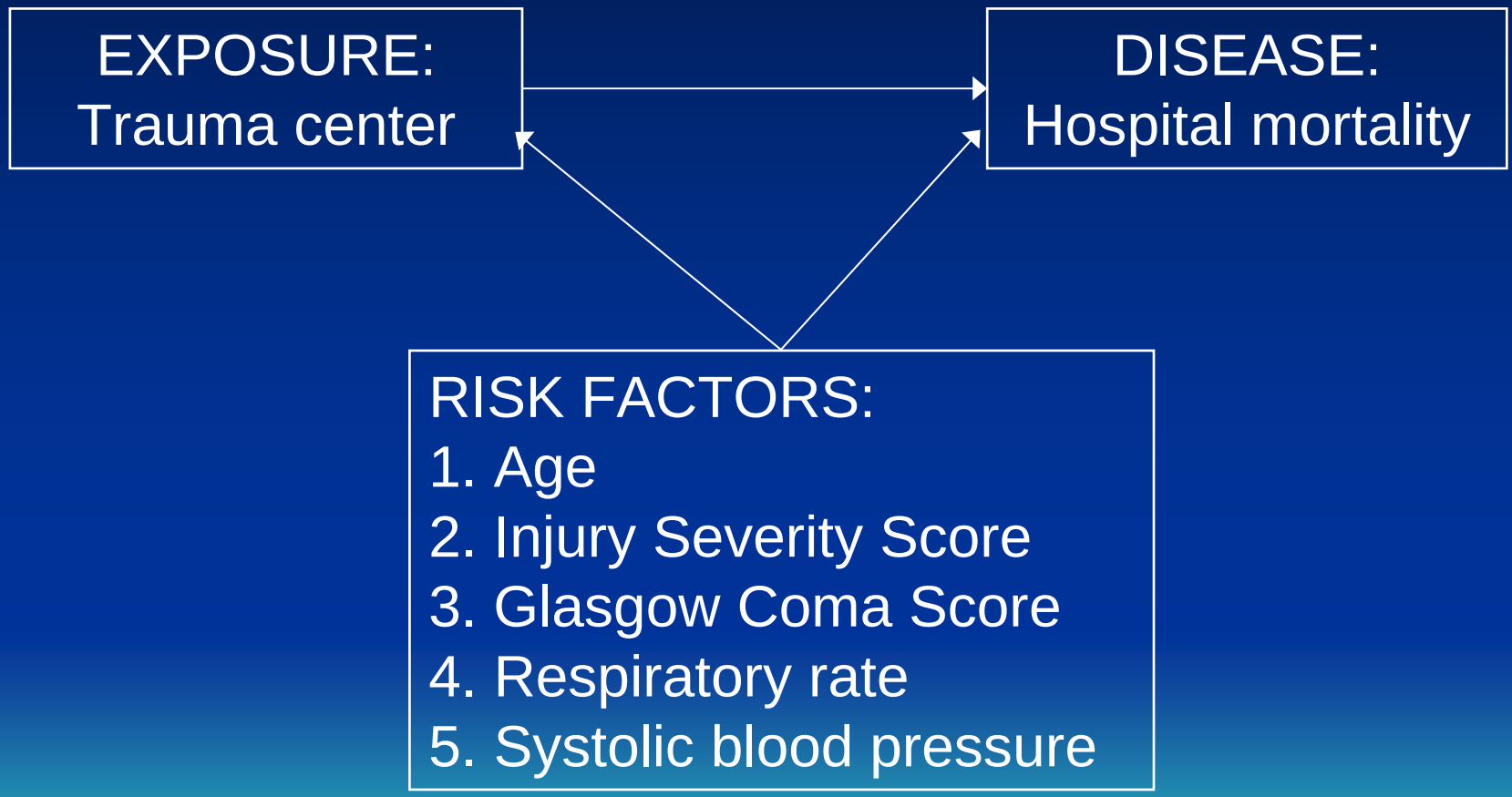
Evaluate whether GAM can offer better risk adjustment than single linear terms, dummy variables on categories, and FP

METHODS

Study population

- Quebec Trauma Registry 1999-2006
- Regionalized inclusive trauma system
- 59 trauma centers (level I, II, III, and IV)
- Mandatory participation of all trauma centers
- Uniform inclusion criteria
- Standardized data collection protocols

Analysis


EXPOSURE:
Trauma center
DISEASE:
Hospital mortality
RISK FACTORS:
1. Age
2. Injury Severity Score
3. Glasgow Coma Score
4. Respiratory rate
5. Systolic blood pressure

Risk adjustment

1. Randomly select 2 hospitals
2. Derive an adjusted OR of hospital mortality
3. Compare OR obtained with GAM to that obtained with 3 other modelling strategies
4. Repeat 1-3 100 times by resampling with replacement

Single Linear Term

$$\text{Logit } \pi_i = \alpha + \beta_1 AGE_i + \beta_2 ISS_i + \beta_3 GCS_i + \beta_4 RR_i + \beta_5 SBP_i + \beta_6 HOSP_i$$

Dummy variables on categories

$$\text{Logit}\pi_i = \alpha + \beta_1 AGE_{55\text{-}64i} + \beta_2 AGE_{65\text{-}74i} + \beta_3 AGE_{75\text{-}84i} + \beta_4 AGE_{>84i}$$

$$+ \beta_5 ISS_{9\text{-}15i} + \beta_6 ISS_{16\text{-}24i} + \beta_7 ISS_{25\text{-}40i} + \beta_8 ISS_{>40i}$$

$$+ \beta_9 GCS_{9\text{-}12i} + \beta_{10} GCS_{6\text{-}8i} + \beta_{11} GCS_{4\text{-}5i} + \beta_{12} GCS_{3i}$$

$$+ \beta_{13} RR_{0i} + \beta_{14} RR_{1\text{-}5i} + \beta_{15} RR_{6\text{-}9i} + \beta_{16} RR_{>29i}$$

$$+ \beta_{17} SBP_{0i} + \beta_{18} SBP_{1\text{-}49i} + \beta_{19} SBP_{50\text{-}75i} + \beta_{20} SBP_{76\text{-}89i} + \beta_{21} HOSP_i$$

Fractional Polynomials

$$\text{Logit}\ \pi_i = \alpha + \beta_1 AGE_i^{p1} + \beta_2 AGE_i^{p2} + \beta_3 ISS_i^{p1} + \beta_4 ISS_i^{p2} + \beta_5 GCS_i^{p1}\ \beta_6 GCS_i^{p2} + \beta_7 RR_i^{p1} + \beta_8 RR_i^{p2} + \beta_9 HOSP_i$$

Generalized Additive Model

$$\text{Logit } \pi_i = \alpha + \beta_1 HOSP_i + s(AGE_i) + s(ISS_i) + s(GCS_i) + s(RR_i) + s(SBP_i)$$

RESULTS

- N = 88,235
- 4731 (5.4%) hospital deaths
- Crude mortality: 1.3% to 14.3%

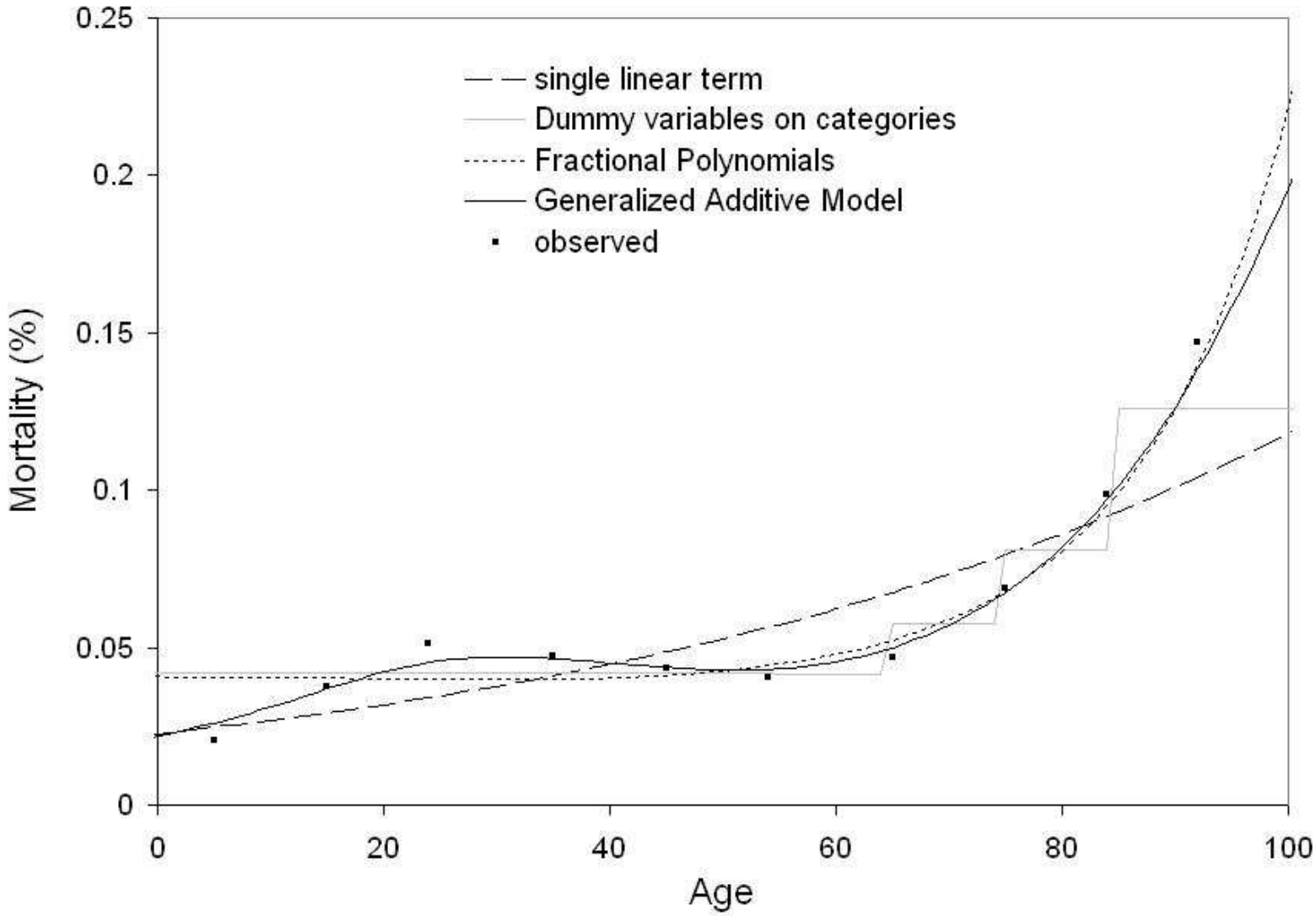
Predictive accuracy

Discrimination and model fit in the whole study sample (n=123 732) according to the four modeling strategies

Model	AUC	AIC
Single linear term	0.886 (0.882-0.889)*	37944
Dummy variables on categories	0.894 (0.891-0.897)*	35364
FP	0.901 (0.898-0.904)	35054
GAM	0.901 (0.898-0.905)	34908

*p<0.0001 when compared to the generalized additive model

Predictive accuracy: Age



Risk adjustment

Median changes in Odds Ratio (OR), Standard Error (SE), and statistical significance ($p<0.05$) over 100 risk-adjusted hospital comparisons.

Model	Median absolute % change in OR* (q1;q3)	Median % change in SE*	% changed statistical significance*
No adjustment	30.60 (12.13 ; 46.56)	-25.66 (-30.76 ; -21.12)	48
Single linear term	9.94 (4.26 ; 28.84)	-4.62 (-7.73 ; -3.29)	13
Categories	3.74 (1.93 ; 6.75)	0.48 (-0.89 ; 1.46)	15
FP	3.59 (1.30 ; 6.18)	0.83 (0.31 ; 2.40)	2
GAM	0	0	0

*Compared to the Generalized Additive Model

In summary

Results suggest that:

- Single linear term:
  - most parsimonious model
  - can lead to residual confounding
- Dummy variables on categories:
  - Similar effect estimates
  - Change in statistical significance
  - Clinically implausible step functions
- FP :
  - equivalent risk adjustment to GAM

Limitations

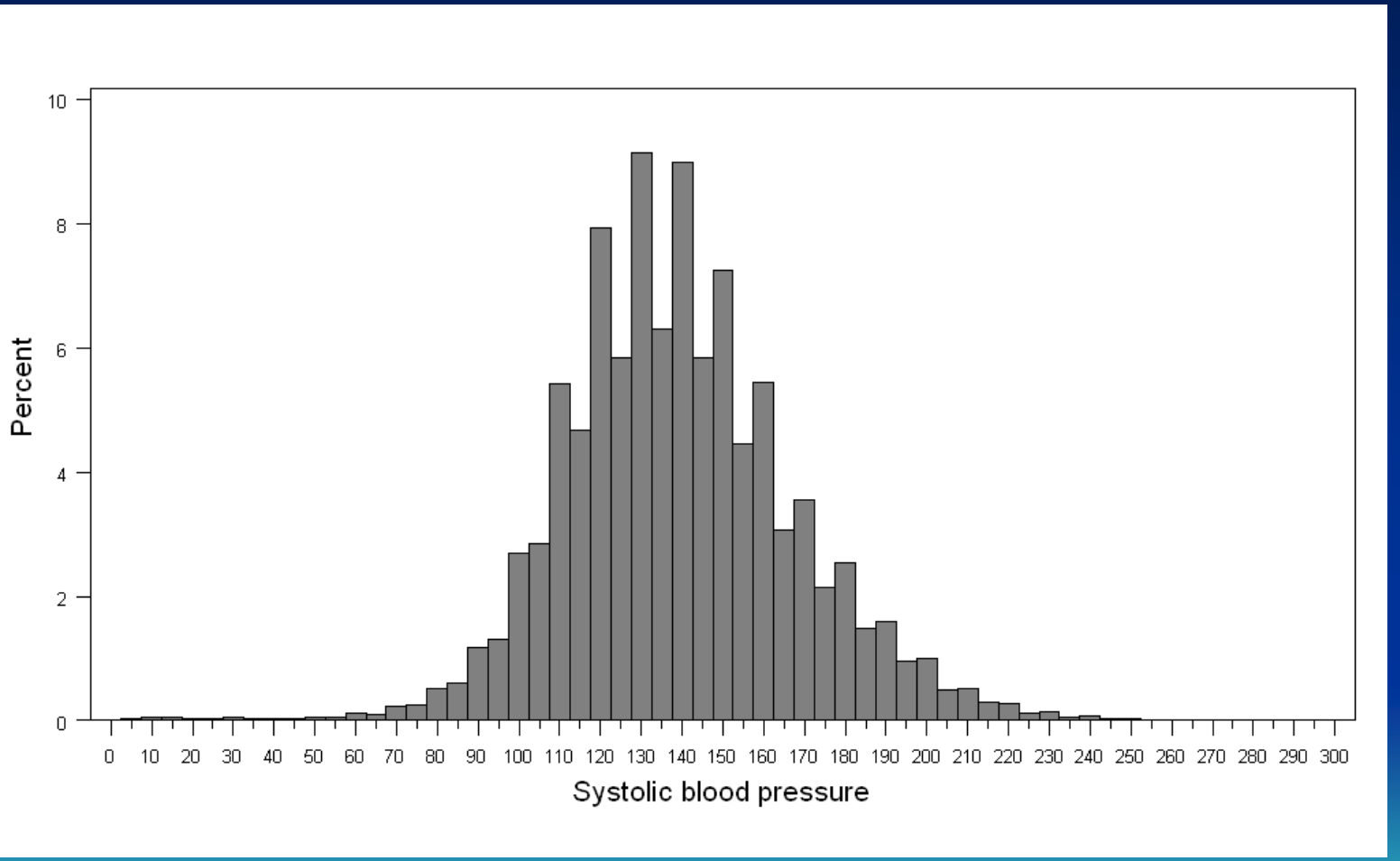
- One clinical context
- GAM gold standard?
- Care needed in fitting FP and GAM

CONCLUSION

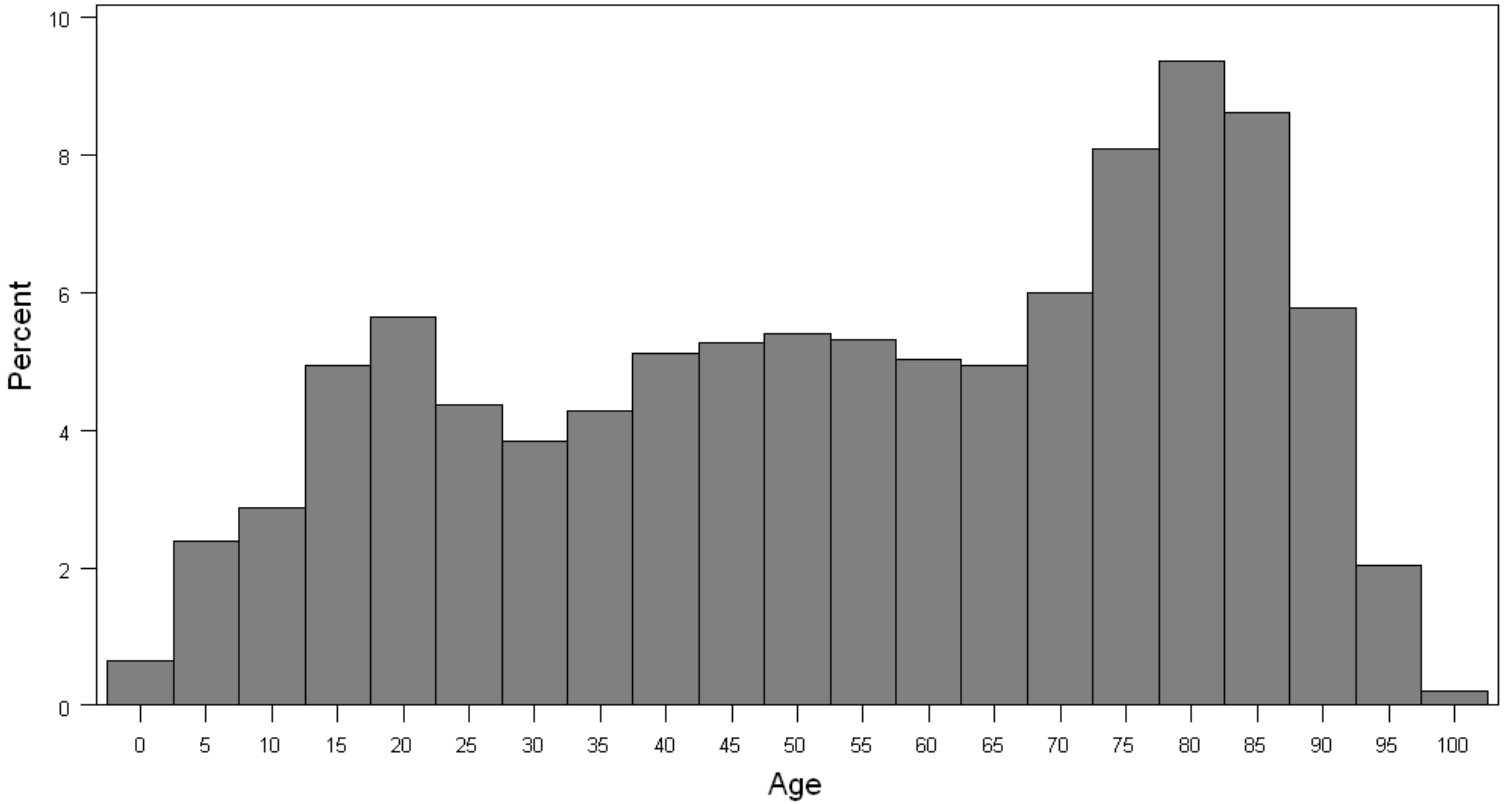
GAM and FP can both offer superior risk adjustment than the other modelling strategies tested but should be implemented with care!

Thank You!

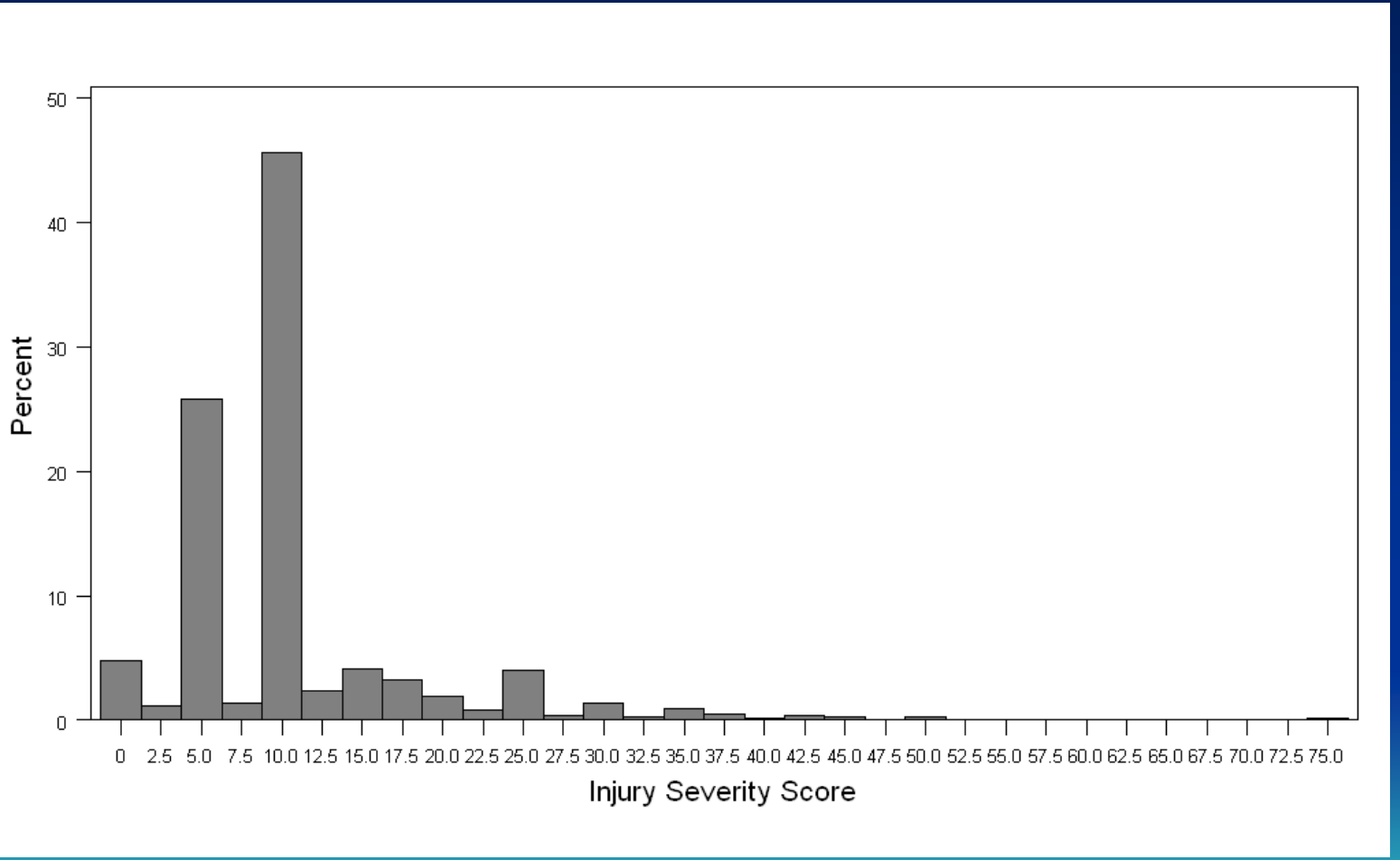
Systolic Blood Pressure



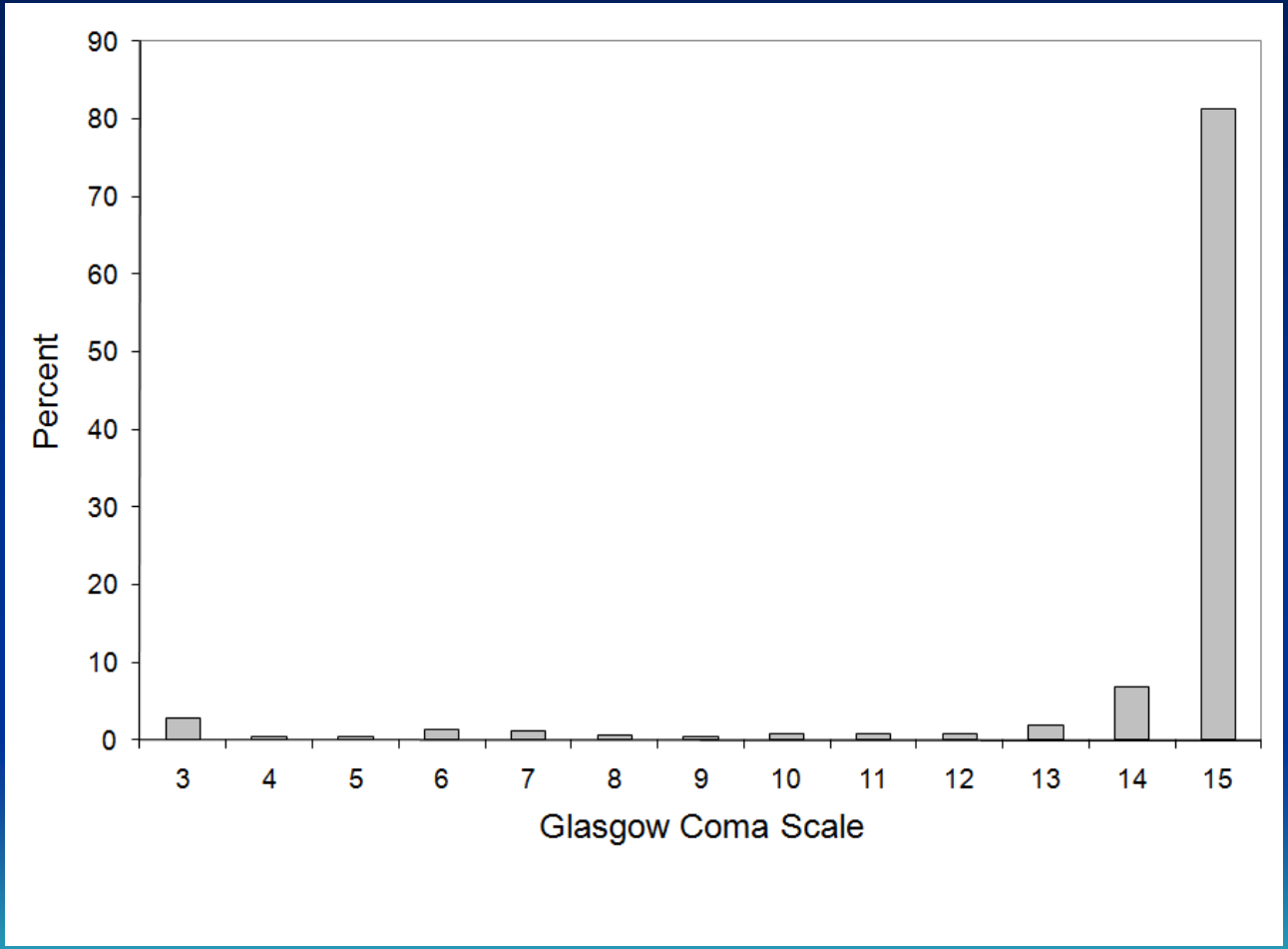
Age


Percent
10
8
6
4
2
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Age

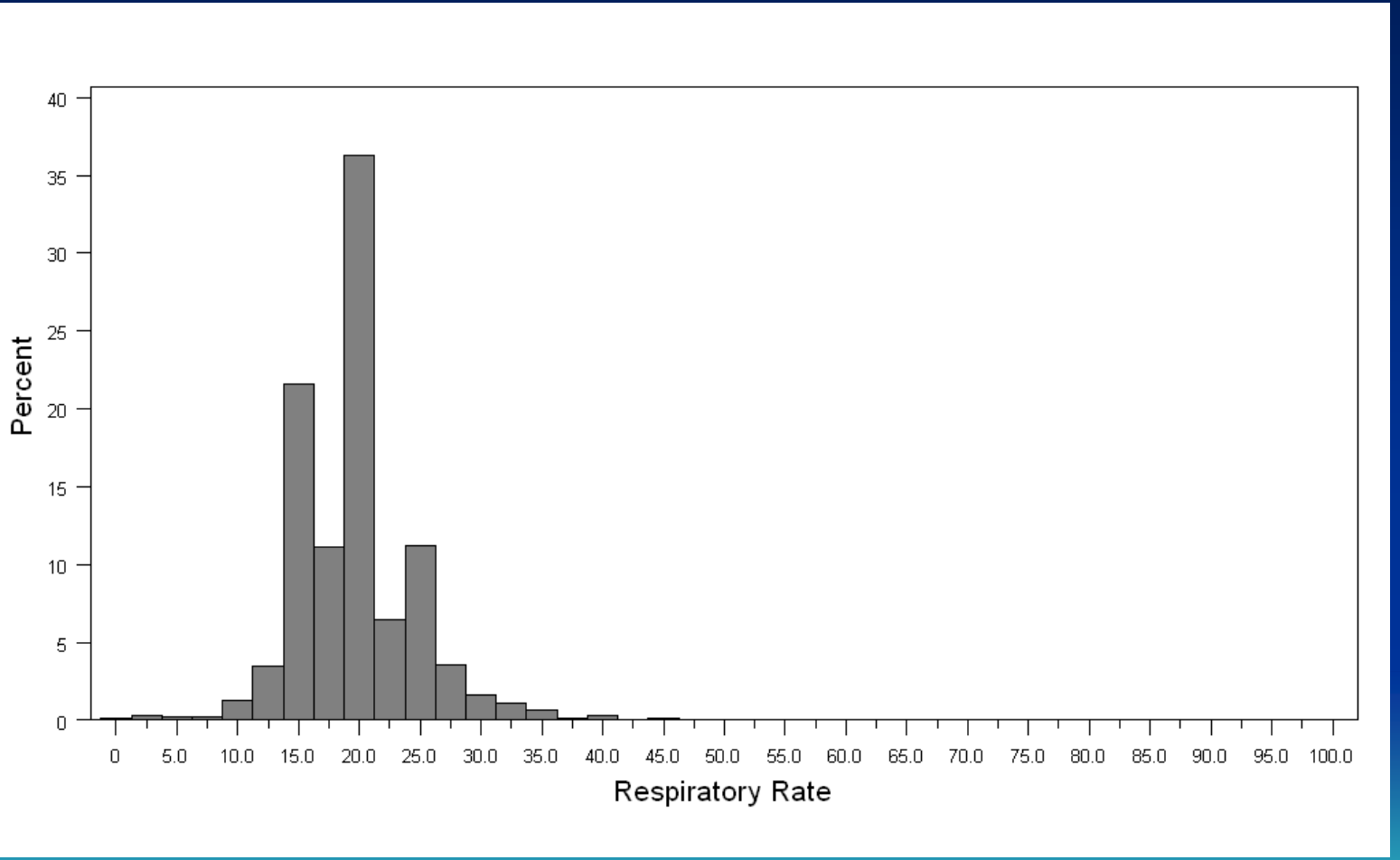
Injury Severity Score



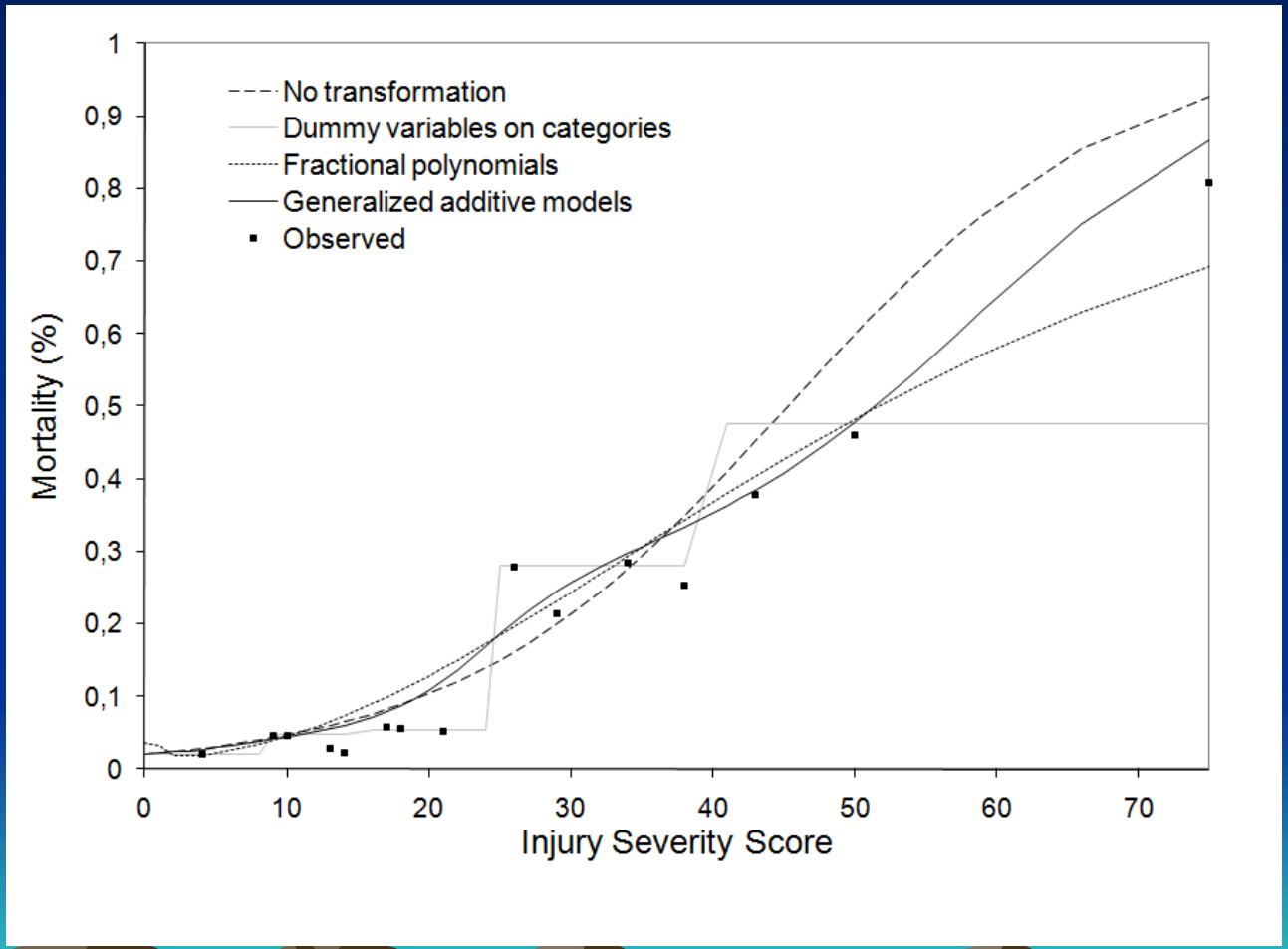
Glasgow Coma Scale score



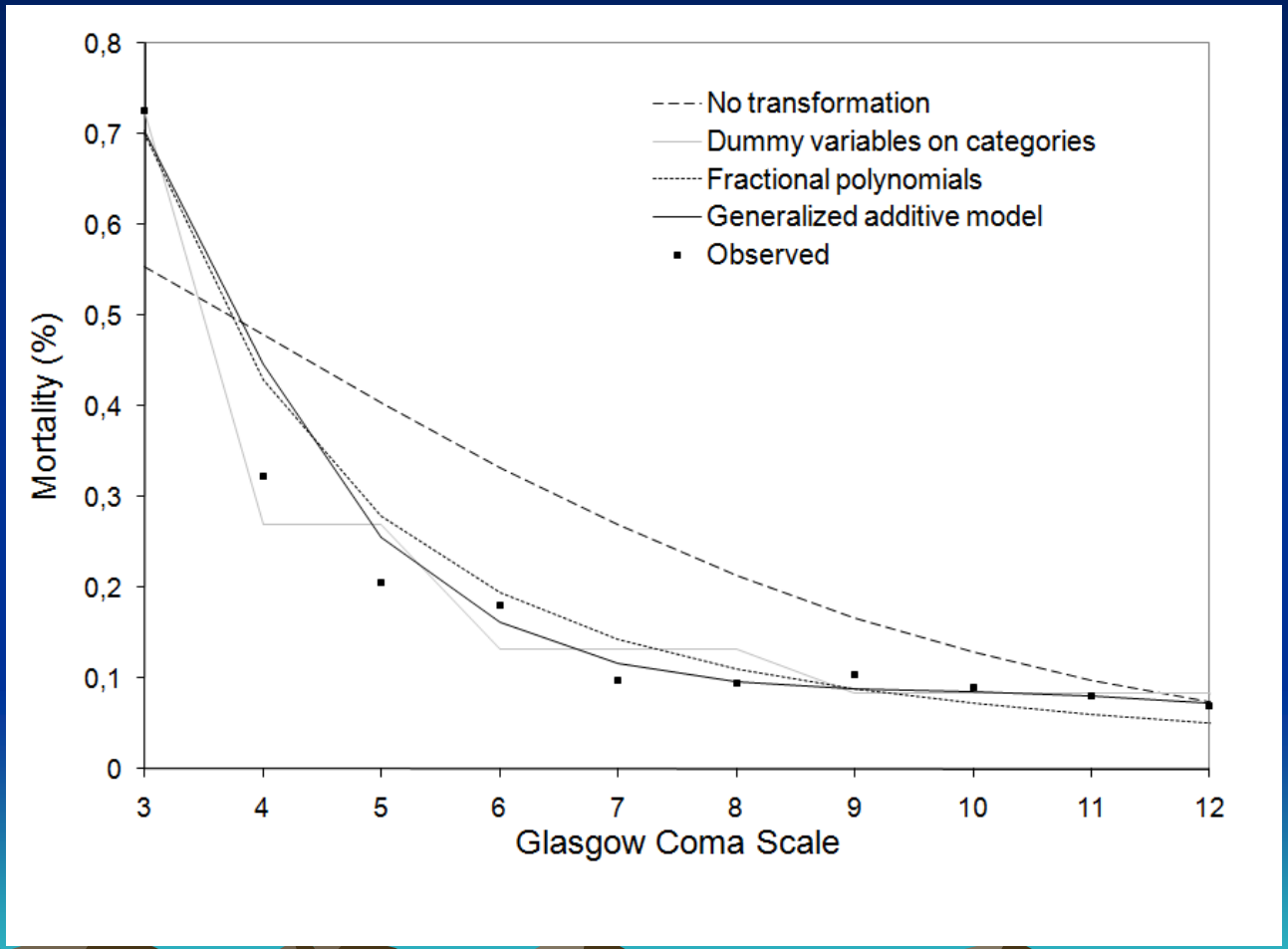
Respiratory Rate



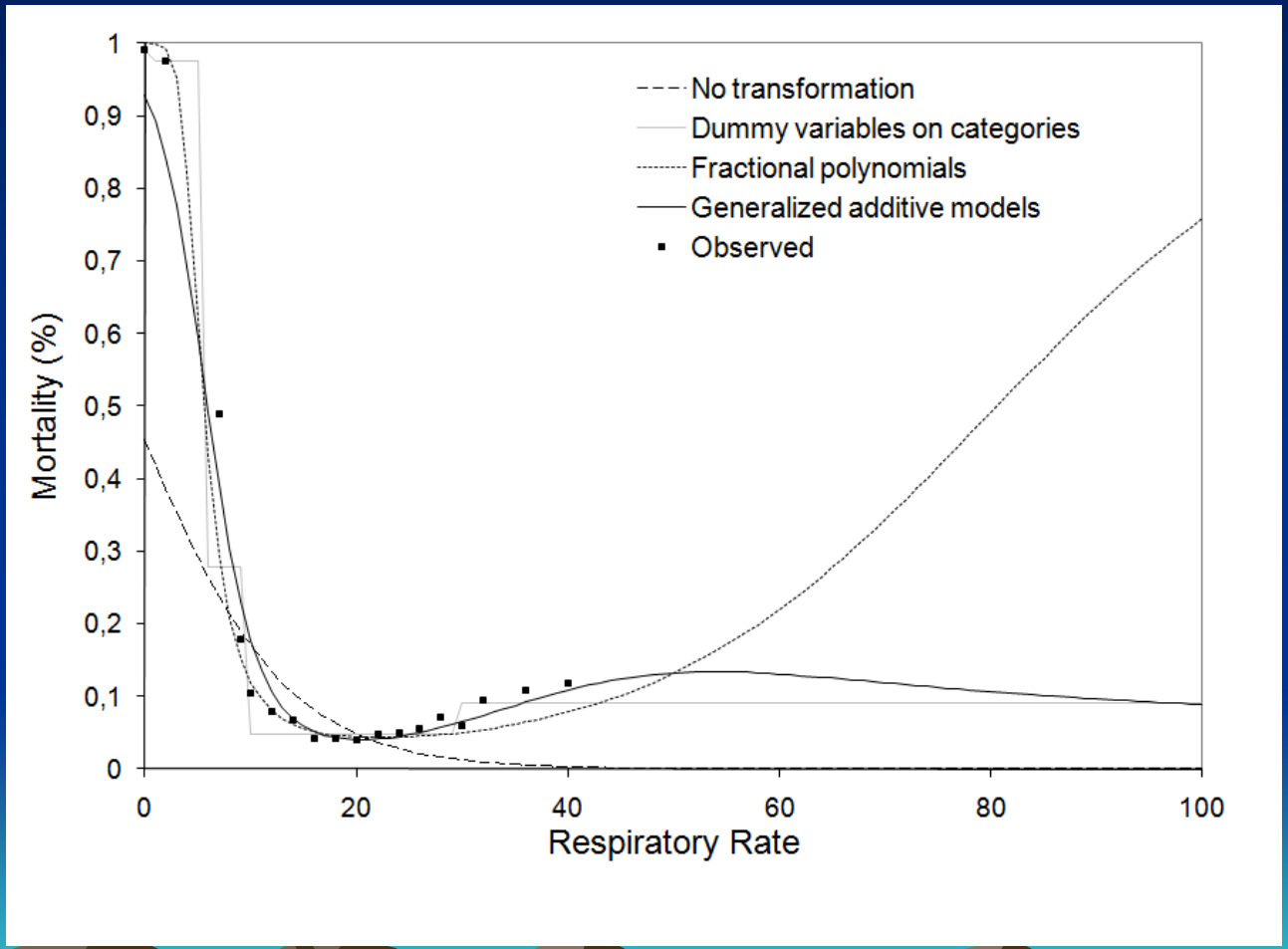
Injury Severity Score



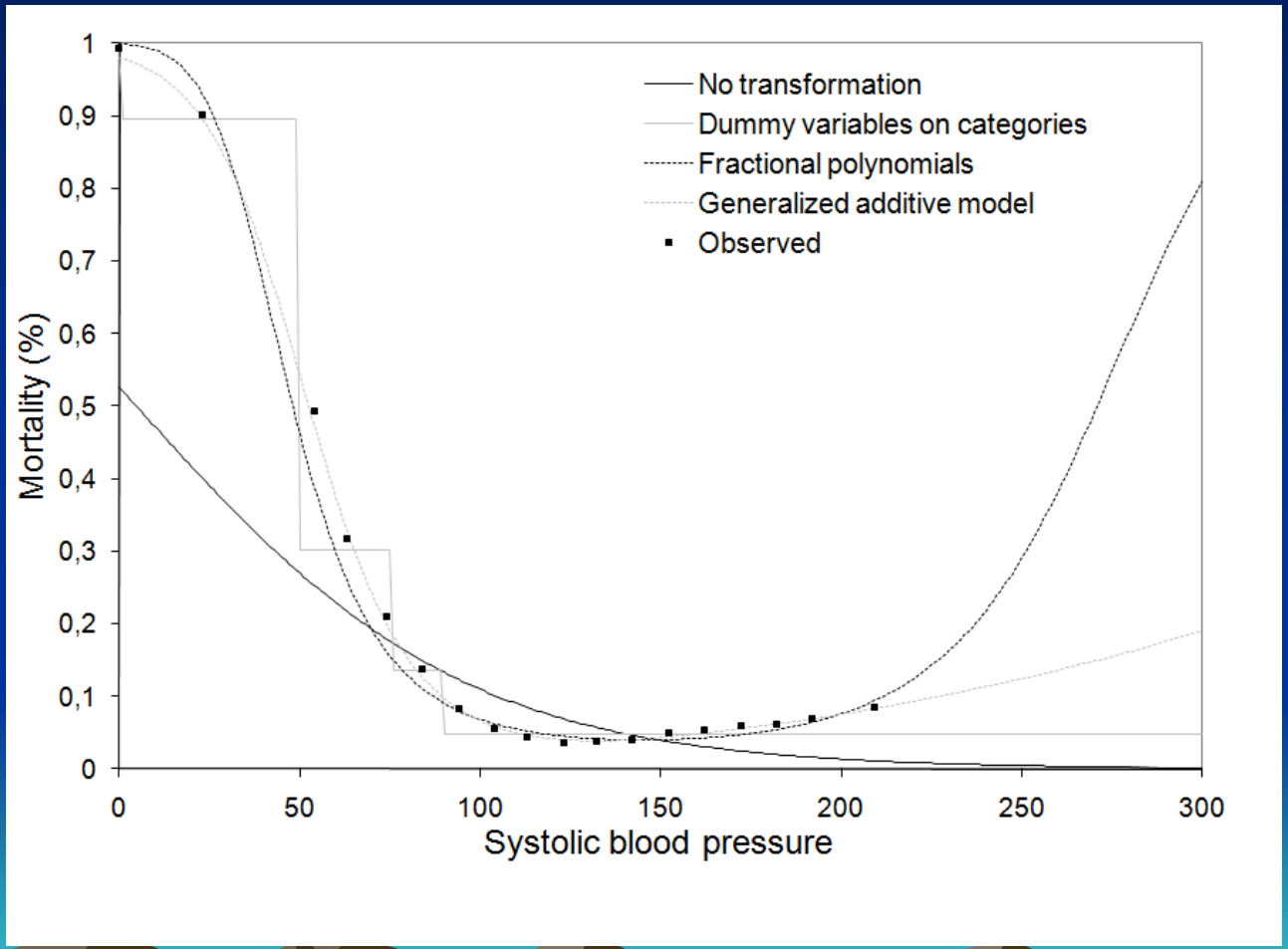
Glasgow Coma Score

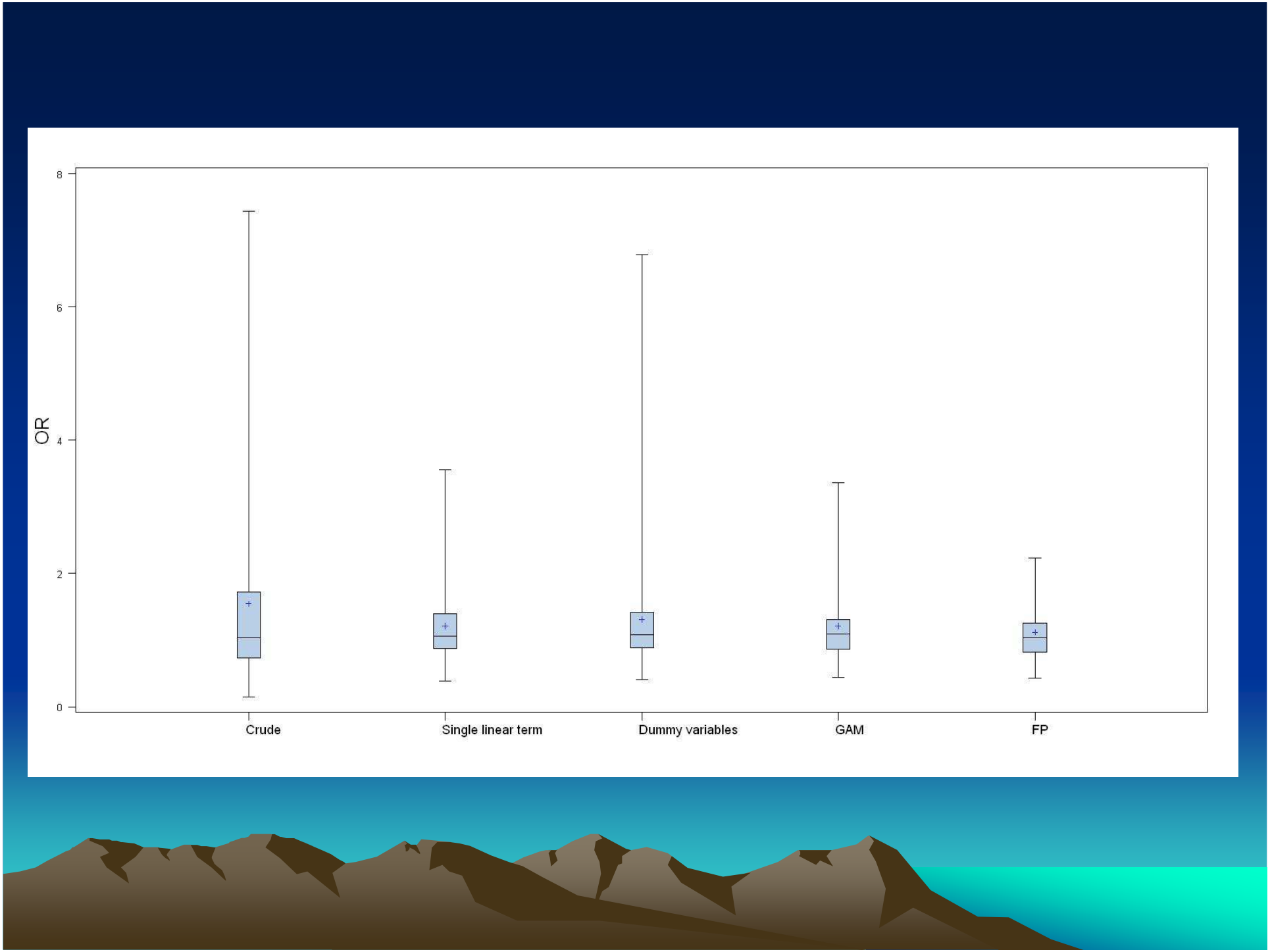


Respiratory Rate



Systolic Blood Pressure




OR
8
6
4
2
0
Crude
Single linear term
Dummy variables
GAM
FP