# Chapter 4

# Generalized linear mixed models (GLMMs)

## 4.1 Introduction

I again begin with an example. Korff et al. (1994) studied the effects of physicians' practice style in treating back pain and its influence on functional measures (disability score, activity limitation days, etc.), patient satisfaction (e.g., "After your visit with the doctor, you fully understood how to take care of your back problem") and cost. Forty-four primary care physicians in a large HMO were classified according to their practice style in treating back pain management (low, moderate or high frequency of prescription of pain medication and bed rest). An average of 24 patients per physician was followed for 2 years (1 month, 1 year and 2 year followups) after the indexed visit. I'll focus on two types of questions: (1) Does practice style influence function, satisfaction or cost? and (2) How much variability is there in physician outcomes within a practice style?

There are a number of outcomes in this study, with a variety of different distributions. Outcomes like the disability score (which was calculated as the average of 3 scales, each on a range from 0-10) are almost certainly approximately normal and statistically well behaved (though averaging the 3 scales might create interpretational difficulties). An outcome like number of days on which activity was limited by the back pain might more properly be treated as Poisson distributed and an outcome like whether or not the patient understood the intended care is binary. Each of these would require a different distributional assumption and (probably) a different form of regression, indicating the use of generalized linear models.

There is an additional statistical complication with this study: there are multiple patients per physician and multiple measures (for some of the outcomes) per patient. This data is thus clustered or hierarchical in nature with predictors specific to each level of the data structure. As examples: at the physician level we have practice style, at the patient level we have age and gender, and at the visit level we have time since the indexed visit. The clustered nature of the data set significantly impacts the statistical analysis since the data must be regarded as correlated. Further, to answer a question about variability in outcomes attributable to physician differences, we