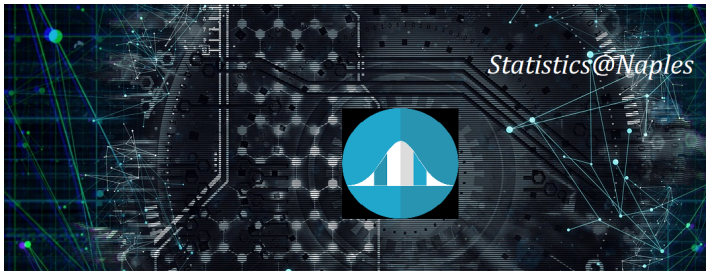

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Power Prior's Weight Parameter elicitation via Bayes Factor-Calibrated p-values

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In recent times, the integration of historical data in the design and analysis of new clinical trials has gained considerable attention, owing to ethical reasons and difficulties encountered in recruiting patients. In the Bayesian framework, the process of informative prior elicitation is widely recognized as a complex and multifaceted undertaking, requiring the careful quantification and synthesis of prior information into an appropriate prior distribution. Hence, there is a pressing need for developing techniques and methods that can facilitate synthesizing and quantifying prior information more effectively and efficiently. Within this context, the concept of *power priors* (Chen and Ibrahim, 2000) has emerged as a popular approach for incorporating historical data into the prior distribution of a treatment effect, in a flexible and controlled manner. The power prior methodology heavily relies on the *weight parameter* δ, ranging between 0 and 1, that is a crucial factor in determining the degree to which the historical data influences the prior distribution, and for which multiple elicitation strategies are available. A modification of the power prior allows a hierarchical prior specification by taking δ as a random quantity

$$\pi\left(\theta, \delta \mid D_0\right) \propto L\left(\theta \mid D_0\right)^{\delta} \pi_0(\theta)\pi_0(\delta),$$

where D_0 is an historical dataset with corresponding likelihood $L(\theta \mid D_0)$, $\pi_0(\theta)$ and $\pi_0(\delta)$ are the initial priors for θ and δ, respectively. Furthermore, a significant benefit of incorporating a normalizing factor in the power prior methodology is its adherence to the likelihood principle, as demonstrated by the joint normalized power prior

$$\pi\left(\theta, \delta \mid D_0\right) = \frac{L(\theta|D_0)^{\delta}\pi_0(\theta)\pi_0(\delta)}{\int_{\Theta} L(\theta|D_0)^{\delta}\pi_0(\theta)d\theta}.$$

Consequently, in a fully Bayesian approach, the ability to effectively elicit an appropriate initial prior distribution for the weight parameter δ is a crucial step. As far as we know from reviewing the existing literature, a comprehensive justification underlying the choice of a Beta distribution with fixed hyper-parameters, that is an usual choice for this framework, is pretty vague.

The Bayes factor (BF) constitutes a valuable statistical tool for model comparison; however, we explore the use of the Bayes Factor to discriminate between competing models that incorporate distinct initial Beta prior distributions for the weight parameter by exploiting some BF p-value calibration techniques (Garcia-Donato and Chen, 2005). This would enable the selection of candidate models based on a more accurate and reliable assessment of the available evidence, thereby enhancing the validity and robustness of statistical inference.

Keywords: Beta distribution, Clinical trial, Historical information, Robust selection.

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