Letters to the Editor

The use of Bayes factor in clinical cardiology research

El uso del factor Bayes en la investigación clínica de cardiología

To the Editor,

I have read with interest the article by Solano-López J et al.,[1] an important article that finds a statistically significant association ($P < .05$) between in-hospital mortality and positive COVID-19 diagnosis in patients with acute myocardial infarction by the measure of association of the odds ratio (OR).

The replication of significance test-based clinical research is recommended to acquire more credible evidence in cardiology. A potential approach is Bayesian inference, which can be used to reanalyze the significant findings reported by Solano-López et al.,[1] where the Bayes factor (BF) method is referred to as the likelihood of the data under one hypothesis compared with the other (null vs alternative hypothesis).[2,3] In other words, the BF estimates the quantification of the evidence or extent to which the data support the null hypothesis and the alternative hypothesis for comparison beyond the mere dichotomous interpretation of the rejection or acceptance of the null hypothesis.[2,3] The statistical repetition of significant findings using the BF strengthens the practical credibility of future articles in the field of cardiology (clinical trials, interventions, and treatments, among others), needed when Bayesian inference produces conclusive (strong) or superior ($BF_{10} > 10$) evidence by interpreting the Jeffreys classification[4] for BF: anecdotal, moderate, strong, and very strong (figure 1).

The purpose of this letter is to provide a simple example of Bayesian reanalysis to determine the degree of evidentiary strength of the statistical hypotheses. Therefore, transformation of the OR value (8.23) to correlation effect size (r) using Lenhard and Lenhard's online calculator,[5] was first considered, yielding an r = value of 0.502, and the sample size (187) was also considered for BF reproduction.[2] This method results in 2 interpretations: BF_{10} (in favor of the alternative hypothesis of significance) and BF_{01} (in favor of the null hypothesis), with a credibility interval of 95%.[6] The results obtained for the Bayes factor were $BF_{10} = 3.18^{10}$ and $BF_{01} = 3.14^{-11}$ and a 95% confidence interval of 0.383 to 0.599, which supports the significant findings reported by Solano-López et al.,[1] with very strong evidence in favor of the alternative statistical hypothesis (correlation).

Likewise, the maximum Bayes factor parameter ($BF_{10max} = 3.568^{10}$) was estimated to determine the stability of the results, with the larger value strengthening the Bayesian reanalysis estimate.

The effect-size (ES) transformation and other statistical measures based on a hypothesis contrast methodology (d, f, η^2, OR, χ^2, Z) using the correlation coefficient (r), used more widely in health sciences, is beneficial for future analyses and Bayesian reanalyses. Additionally, these estimates are easy to perform using Lenhard and Lenhard's calculator.[5] The BF is useful in other statistical significance tests[7,8] (linear regression, ANOVA, among others) with ES measures that are also transformable. The handbook by Goss-Sampson[6] is recommended for Bayesian inference of the analyses most commonly used in cardiology research.

The inclusive use of several transformable ESs supports further research employing various statistical methods for future meta-analyses. Moreover, the use of the BF is beneficial for selecting ESs with the most robust evidence ($BF_{10} > 10$) for meta-analytical design, as it strengthens the credibility of clinical meta-analytical conclusions.

	BF_{01} Null hypothesis	Valor	BF_{10} Alternative hypothesis	
For	Very strong	> 30	Very strong	For
	Strong	10-30	Strong	
	Moderate	3.1-10	Moderate	
	Anecdotal	1.1-3	Anecdotal	
	No evidence	1	No evidence	
Against	Anecdotal	0.3-0.9	Anecdotal	Against
	Moderate	0.09-0.03	Moderate	
	Strong	0.09-0.03	Strong	
	Very strong	< 0.03	Very strong	

Figure 1. Quantifiable values of the Jeffreys' Bayes factor.[4].

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In summary, the BF is a useful methodological tool with practical implications for decision-making based on the confirmation of conclusive results, now even more important in the context of COVID-19.

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The use of Bayes factor in clinical cardiology research. Response

El uso del factor Bayes en la investigación clínica de cardiología. Respuesta

To the Editor,

We greatly appreciate Cristian Antony Ramos-Vera's interest in our article; in his letter he highlights the virtues of using Bayes factor (BF) as an alternative to the traditional dichotomous interpretation of hypothesis testing, and his analysis provides more robust support for our findings.[1]

Frequentist statistics almost entirely dominate medical research. The average reader has interiorized the concepts of hypothesis testing, *P* value, and statistical significance. The limitations of frequentist statistics and the problems with their interpretation have been widely discussed[2] and, in addition, repeated appeals have been made to include Bayesian statistics in biomedical research.[3] While it is true that Bayesian statistics allow a more natural and intuitive interpretation, the reality is that their use is not widespread and most readers do not understand them.

Hoekstra et al.[4] performed a reanalysis of 36 articles with negative results and calculated the BF. The smallest BF was 2.42 (observed data are 2.42 times more probable under the null hypothesis) and the largest, 560.9. A key point is that there was a poor correlation between the *P* value and the BF. A high *P* value may have been present in studies with little evidence in favor of the null hypothesis (low BF) or in studies with strong evidence (high BF). This allows us to assert that the BF intuitively communicates the probative strength of the hypothesis; therefore, we, like Dr Ramos-Vera, recommend that this should routinely be included in scientific articles.

SEE RELATED CONTENT:
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AUTHORS' CONTRIBUTIONS

J.M. Monteagudo conceived and wrote the article. J. Solano-López critically reviewed the manuscript. J.L. Zamorano critically reviewed the manuscript. Á. Sanchez-Recalde conceived the idea for this article and critically reviewed the manuscript. All authors have approved the final version of the manuscript.

CONFLICTS OF INTEREST

Á. Sánchez-Recalde is associate editor of *Revista Española de Cardiología*; the journal's established editorial procedure was followed to ensure the impartial handling of this manuscript.

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