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Comparing Two Independent Proportions Using the Z-Test: Improving the Statistical Quality of Our Studies

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In health sciences research, it is common to compare percentages or proportions between groups without using appropriate statistical techniques to validate whether the differences are significant. This simplistic approach relies on the visual comparison of values in tables or graphs, ignoring sampling variability and confidence intervals. As a result, statistically or clinically relevant differences are erroneously assumed, leading to incorrect conclusions and affecting decision-making. This error is frequent in basic epidemiological studies or publications with low methodological rigor.

Let's look at two examples below. Remember that the p-value measures the probability of observing differences, assuming that no real difference exists (null hypothesis). If $p < 0.05$, we reject the null hypothesis. The 95% confidence interval (CI) shows the plausible range of the real difference; if it does not include 0, there is evidence of a difference.

Example 1: Prevalence of arterial hypertension.

A study aims to compare the prevalence of hypertension in two worker samples: Sample 1, with 10,000 workers, where 2,800 cases of hypertension (28%) were detected, and Sample 2, with 1,500 workers, where 455 cases (30.3%) were observed. At first glance, it appears that the prevalence in Sample 1 is higher than in Sample 2 (Figure 1).

To determine this, we must perform a statistical test comparing the proportions found in the study. The recommended test is the Z-test. The Z-test for two independent proportions yields a p-value of 0.061 (greater than 0.05), indicating no significant difference between the prevalences. The

95% confidence interval (95% CI) for the difference is 0.0015 to -0.048; since it includes 0, it confirms the lack of a statistically significant difference. The moderate width of the CI indicates a reasonably precise estimate.

In summary: There is no evidence of a higher prevalence of hypertension in the company compared to the national level.

Example 2: Prevalence of overweight and obesity.

In sample 1, 6,200 out of 10,000 workers are overweight or obese (62%). In sample 2, 970 out of 1,500 present this condition (64.7%). The absolute difference (2.7 percentage points) is very similar to the previous example (Figure 1). However, in this case, the z-test for two independent proportions yields a p-value of 0.047 (less than 0.05), indicating significant differences. The 95% confidence interval for the difference is -0.001 to -0.053; by not including 0, it confirms that the prevalence in the company is higher.

In summary: There is evidence of a higher prevalence of overweight/obesity in the company compared to the national level.

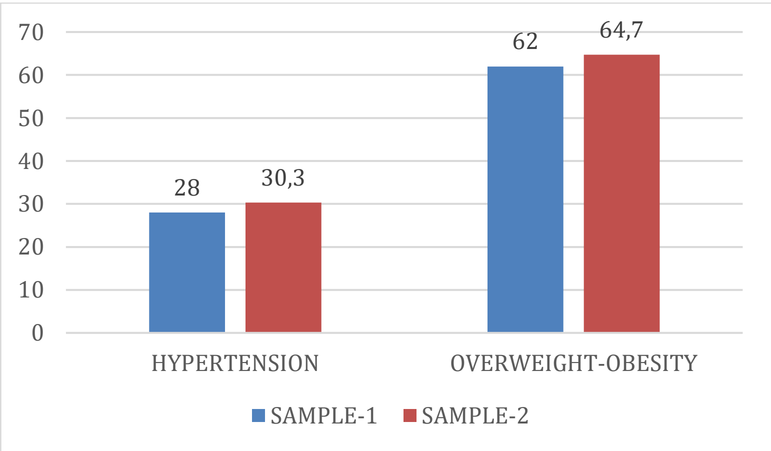


Figure 1. Comparison of prevalences (proportions) between the two study samples for hypertension and overweight-obesity.

These examples highlight that comparing percentages without proper statistical analysis can lead to misinterpretations. The two-proportion Z-test is a simple, accessible, and essential tool for assessing whether the observed differences between proportions in two groups are statistically significant, thus providing a more solid foundation for scientific and clinical communication. Furthermore, calculating confidence intervals in conjunction with the test allows us to understand the plausible range of differences and their precision, which is fundamental for a correct interpretation of the results.

How to improve the writing of results

We move away from erroneous and simplistic statements such as:

“The percentage of hypertensive individuals in our population was higher than the national average of 28% (30.3%), as was the percentage of overweight/obesity (62% vs. 64.7%).”

Statistically based reports:

“The prevalence of hypertension in our population (30.3%) did not differ significantly from the national prevalence (28%; p = 0.061; 95% CI 0.0015 to -0.048). Conversely, the prevalence of overweight/obesity was significantly higher in our population (64.7%) than in the national prevalence (62%; p = 0.047; 95% CI -0.001 to -0.053).”

Z-test for comparing two independent proportions

The Z-test for comparing two independent proportions is a statistical method used to determine whether there is a significant difference between the proportions of two distinct groups. It is applied when there are two independent samples (e.g., men vs. women, control group vs. experimental group) and it is desired to evaluate whether the observed difference between their proportions is due to chance or reflects a real difference in the population. This test is based on the standard normal distribution and requires a sufficiently large sample size.

The test statistic is calculated from the difference between the sample proportions, considering a pooled proportion and the standard error of the difference. The formula is:

$$Z = \frac{p_1 - p_2}{\sqrt{p(1-p)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

where p_1 and p_2 are the proportions of each group, n_1 and n_2 are their sample sizes, and p_1 is the pooled proportion. The resulting Z-value is compared to the critical values of the normal distribution to decide whether to reject the null hypothesis, which generally states that both proportions are equal.

Assumptions of the z-test for two proportions

Like any statistical test, it must meet certain assumptions to be applicable:

- Independent samples (no subject belongs to both groups).
- Representative samples of their populations.
- Dichotomous variable (yes/no, such as hypertension or not).
- Sufficient sample size: at least 5 cases (successes) and 5 non-cases (failures) per group for the normal approximation.

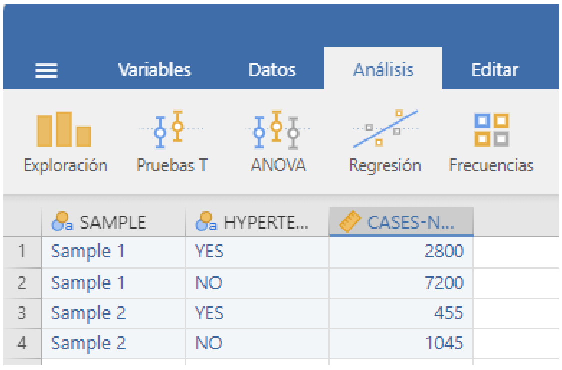
Free statistical software for performing the Z test

a) JAMOVI

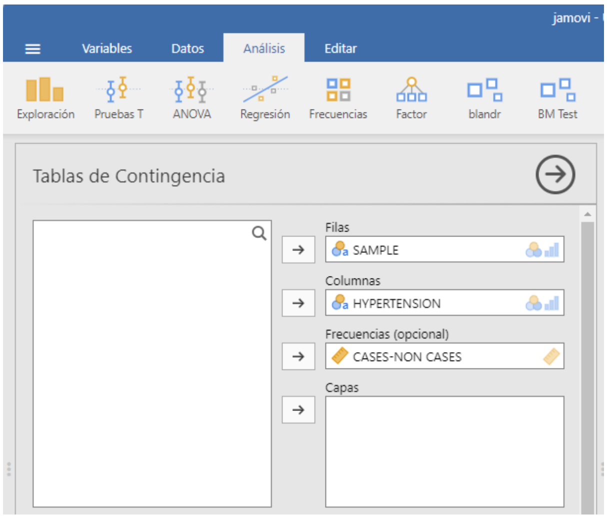
Jamovi is a free and open-source statistical analysis software designed to be easy to use, especially for students and people without advanced programming experience. It is based on the R language but offers a very intuitive graphical interface that allows statistical analysis to be performed using menus and buttons, without the need to write code. This makes it an accessible alternative to more complex programs like SPSS or Stata.

With Jamovi, you can quickly perform descriptive analyses, hypothesis tests, regressions, ANOVA, and many other statistical procedures. Furthermore, it allows you to expand its functionality through additional modules that are easily installed from within the application itself. Another important advantage is that it generates results and tables that are automatically updated when the data changes, facilitating interpretation and reducing errors. For these reasons, it is a widely used tool in educational and research settings.

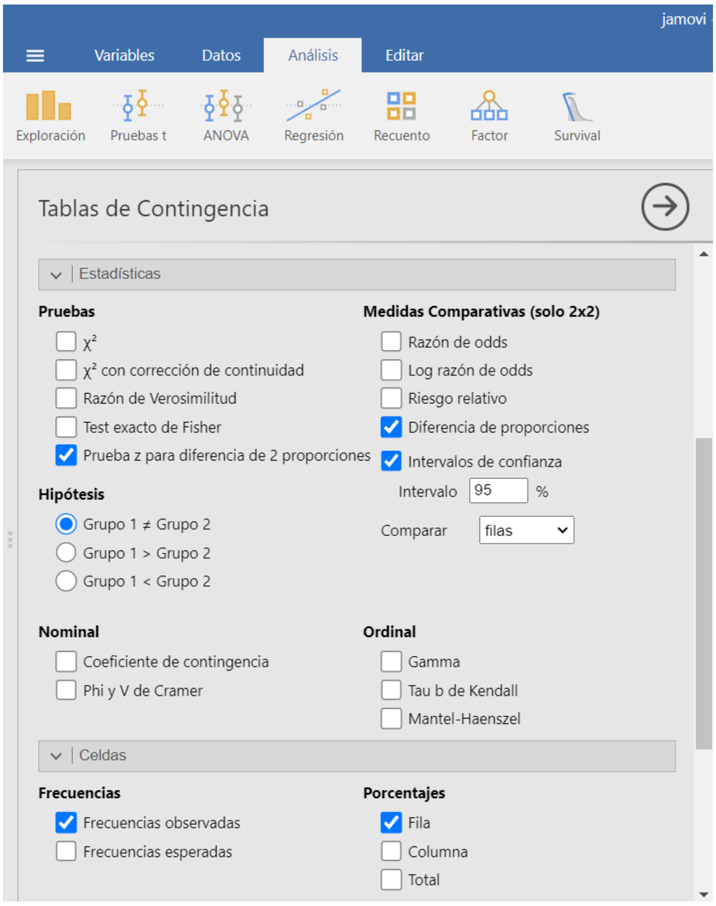
1. Create three variables: SAMPLE (nominal), hypertension (nominal), and cases-non cases (numeric).
2. Enter the data. In this case, we only have the total count, not the number of cases.



3. Select the Analysis tab, Frequencies, Contingency Tables, Independent Samples. Enter the Group variable in the rows, the Hypertension variable in the columns, and the Count variable in the frequencies.



4. In Statistics, select z-test for difference of two proportions, difference of proportions, and confidence intervals. The hypothesis to state is that both groups are different. In the Cells tab, enter observed frequencies and percentages per row.



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5. The results appear on the right:

Tablas de Contingencia

Tablas de Contingencia

SAMPLE	HYPERTENSION YES	HYPERTENSION NO	Total
Sample 1	2800	7200	10000
Sample 2	455	1045	1500
Total	3255	8245	11500

Pruebas de χ^2

	Valor	gl	p
Prueba z para diferencia de 2 proporciones	−1.87		0.061
N	11500		

Medidas Comparativas

	Valor	Intervalos de Confianza al 95% Inferior	Superior
Diferencia entre 2 proporciones	−0.0233 [a]	−0.0482	0.00154

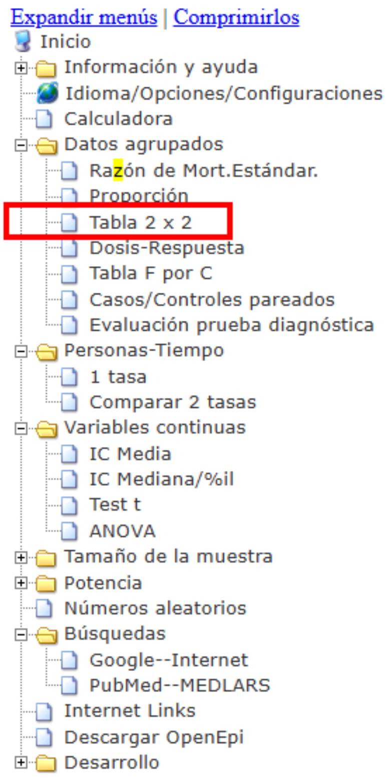
[a] Se comparan filas

b) OpenEpi

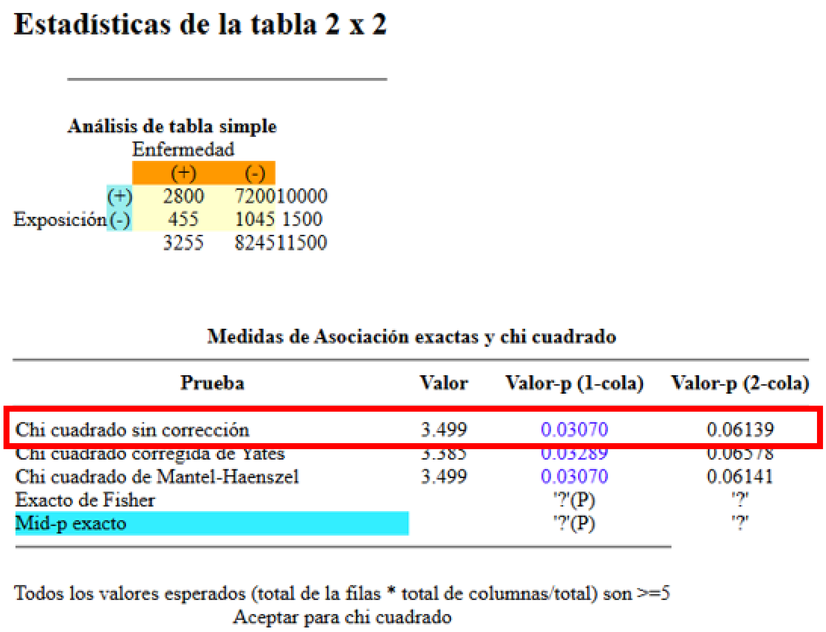
OpenEpi is a suite of free and open-source tools designed for statistical analysis in epidemiology and public health. It is primarily used through a web browser, allowing users to perform calculations without installing specialized software. It was developed as an accessible alternative to more complex programs like Epi Info and is geared toward students, researchers, and healthcare professionals who need to perform fast and reliable analyses.

OpenEpi allows you to calculate epidemiological measures such as rates, ratios, relative risks, odds ratios, confidence intervals, and sample sizes, among others. Its interface is simple and organized into modules that guide the user according to the type of analysis they wish to perform. Furthermore, it includes examples and explanations that facilitate learning, making it a very useful tool for both academic practice and public health decision-making.

You can run OpenEpi online at www.openepi.com. In the main menu, select “2x2 Tables”.



Next, enter the data by generating the 2x2 table for the results of Arterial Hypertension. Then click on “calculate.”



Estadísticas de la tabla 2 x 2

Análisis de tabla simple

		Enfermedad (+)	Enfermedad (-)	
Exposición	(+)	2800	7200	10000
	(-)	455	1045	1500
		3255	8245	11500

Medidas de Asociación exactas y chi cuadrado

Prueba	Valor	Valor-p (1-cola)	Valor-p (2-cola)
Chi cuadrado sin corrección	3.499	0.03070	0.06139
Chi cuadrado corregida de Yates	3.385	0.03289	0.06578
Chi cuadrado de Mantel-Haenszel	3.499	0.03070	0.06141
Exacto de Fisher		'?'(P)	'?'
Mid-p exacto		'?'(P)	'?'

Todos los valores esperados (total de la filas * total de columnas/total) son >=5
Aceptar para chi cuadrado

We will see that, although Openepi does not have the Z-test for comparing two independent proportions, we can use the Chi-square test, which, although not the same test, is very similar and often yields the same results, as in the example we are considering.

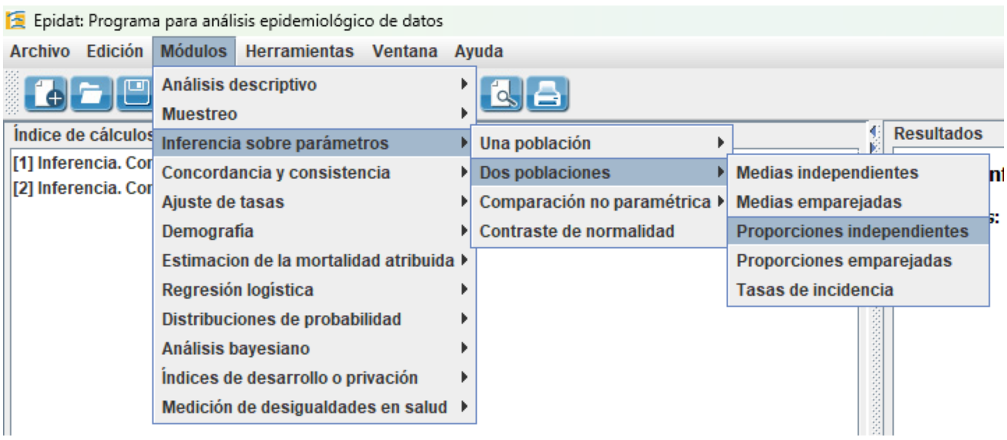
c) EPIDAT

Epidat is a free statistical analysis program for epidemiology, developed by the Xunta de Galicia in collaboration with the Pan American Health Organization. It is designed to facilitate the processing and analysis of public health data, allowing professionals, researchers, and students to conduct epidemiological studies without requiring advanced knowledge of statistics or programming.

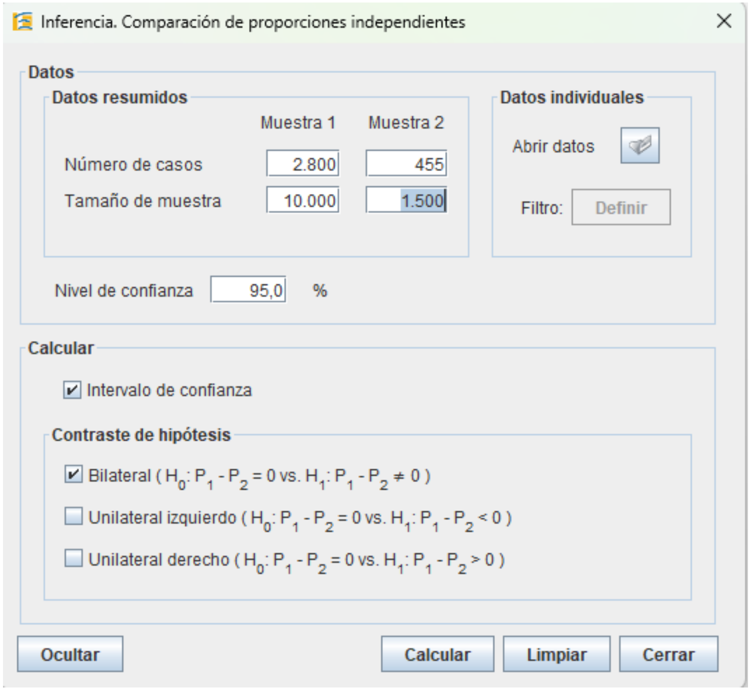
This software includes multiple modules for calculating epidemiological measures, analyzing outbreaks, conducting cohort and case-control studies, as well as performing statistical tests and risk estimation. Epidat also offers tools for calculating sample sizes and assessing agreement, among other functions. Thanks to its practical approach and user-friendly interface, it is widely used in academia and healthcare institutions to support data-driven decision-making.

You can download Epidat for free from https://www.sergas.gal/saude-publica/epidat?idioma=es

From the MODULES section, select "Inference on Parameters," then "Two Populations," and finally "Independent Proportions."



In the new window, enter the data for the two study samples.



As you can see, Epidat provides the Z-test in the results output.

Datos:

	Muestra 1	Muestra 2
Número de casos	2.800	455
Tamaño de muestra	10.000	1.500

Nivel de confianza: 95,0%
Calcular: Intervalo de confianza y contraste de hipótesis

Resultados:

Población	Porcentaje (%)
1	28,000
2	30,333

Intervalo de confianza (95,0%)

Diferencia de proporciones	Límite inferior	Límite superior
-0,023	-0,048	0,002

Prueba de comparación de proporciones

Contraste	Estadístico Z	Valor p
Bilateral	-1,871	0,061

d) Other Statistical Tools

There are websites (see the bibliography) and Excel spreadsheets that perform these calculations; they tend to be more limited, but also easier to use. Below is a calculator developed by the author in Excel (https://doi.org/10.5281/zenodo.18392870) that requires only one step to obtain results and also provides a summary of the results:

1. Enter the group data:

What is the name of group 1?	SAMPLE 1
Positive cases in group 1	2800
Total size of group 1	1000
What is the name of group 2?	SAMPLE 2
Positive cases in group 2	455
Total size of group 2	1500
What are you comparing?	HYPERTENSION

2. Display the results:

Resultados

Nivel de significación	0,05
Hipótesis de diferencia	0
Proporción agrupada	28%
Proporción grupo 1	**28,0%**
Proporción grupo 2	**30,3%**
Diferencia proporción	**-0,023**
Z a/2 (Dos colas)	1,960
Error estándar	0,013

Hipótesis nula: No hay diferencia entre grupos	
Test Statistics (Z-Test)	1,8440
p-Value	**0,065**
¿Hay diferencias?	**NO**

IC95% (dos colas) Limite inf.	**-0,048**
IC95% (dos colas) Limite sup.	**0,002**

3. Display the summary of the results:

You can write in your study:

The prevalence of high blood pressure in group 1 was 28% compared to 30,3% in group 2, the p-value was 0.065 with a 95% CI of -0.048, 0.002

Conclusion

Just as regularly consulting scientific studies is now a basic clinical skill, acquiring basic statistical knowledge should be part of this skill set, both for evaluating what we read and for conducting our own analyses. Some current software programs are accessible, intuitive, and do not require extensive technical knowledge. If we add to this the fact that artificial intelligence is a great ally in learning and interpreting results, the inclusion and subsequent deepening of statistical techniques should be on our professional agenda.

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