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Guidance on Conducting Sample Size and Power Calculations

Applied Statistics Seminar Series
Northwestern University
Department of Preventive Medicine

Presented by: Lutfiyya N. Muhammad, PhD MPH
Assistant Professor
Department of Preventive Medicine – Biostatistics
Biostatistics Collaboration Center (BCC)
Northwestern University, Feinberg School of Medicine
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Who has taken a course that was focused on sampling methods and sample size calculations?

Outline

- Hypothesis Testing
- Power Analysis
- Required Information for Power Analysis
- Different Types of Effect Sizes
- Power Analysis via Software
- Power Analysis via Simulations
- Resources
- Summary

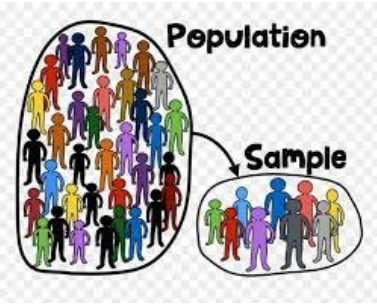
My General Process for Sample Size or Power Calculations

Examine aims, hypotheses, and key variables.

Think about how the key variables are collected.

Develop an analysis plan.

Determine values needed for power analysis and inform collaborators.



Conduct the power analysis.

Hypothesis Testing

- Hypotheses are stated clearly.
  - Null Hypothesis (e.g. no difference among groups/arms)
  - Alternative Hypothesis (e.g. difference among groups)
- Compute test statistic from data.
- Compare test statistic to a critical value.
- Reject or fail to reject null hypothesis.

Hypothesis Testing

Conclusion based on data	Truth	
	H_0 True	**H_0 False**
Reject H_0	Type I error (α)	Correct conclusion (Power = 1 - β)
Fail to reject H_0	Correct conclusion (1 - α)	Type II error (β)

(Kim, 2015)

Power Analysis

- Power analysis is the calculation that is used to determine the minimum sample size needed for a research study.

- Power analysis is conducted before the study begins.

- To compute the power or sample size, you will need:
  - Null and alternative hypotheses
  - The statistical method that will be used to test the null hypothesis
  - Effect size or variability
  - Statistical significance level ($\alpha = 0.05$)
  - Either sample size or power (opposite of what you are solving for)
    - Power is traditionally set at 80%

Keep in mind…

- Grant proposals includes several hypotheses depending on the number of aims.
  - Calculations for the sample size or power are based on the primary hypothesis.

- You can include a sample size calculation or power analysis for secondary hypotheses.
  - Secondary hypothesis may only be tested using a subset of the sample or a different sample from the primary hypothesis.

- Sample size can be dependent on the budget of the proposed study.
  - How many study participants can we have based on the budget?

- There is not one simple formula for computing a power analysis.

Obtaining the Values Required for a Power Analysis

- Investigators should provide statisticians with the values required for the power analysis.

- Values can come from:
  - Pilot Study
  - Literature Review
  - Cohen's recommendations

Things to consider…

- Are the values given for the power analysis consistent with how the primary outcome and primary variable(s) will be measured?
- You may need to utilize a meta-analysis method to get an overall effect size.
- Does the power analysis need to account for dropouts?

Common Effect Sizes

Index	Description[b]	Effect Size	Comments
Between groups			
Cohen's *d*[a]	$d = M_1 - M_2 / s$ $M_1 - M_2$ is the difference between the group means (*M*); *s* is the standard deviation of either group	Small 0.2 Medium 0.5 Large 0.8 Very large 1.3	Can be used at planning stage to find the sample size required for sufficient power for your study
Odds ratio (OR)	$\frac{\text{Group 1 odds of outcome}}{\text{Group 2 odds of outcome}}$ If OR = 1, the odds of outcome are equally likely in both groups	Small 1.5 Medium 2 Large 3	For binary outcome variables Compares odds of outcome occurring from one intervention vs another
Relative risk or risk ratio (RR)	Ratio of probability of outcome in group 1 vs group 2; If RR = 1, the outcome is equally probable in both groups	Small 2 Medium 3 Large 4	Compares probabilities of outcome occurring from one intervention to another
Measures of association			
Pearson's *r* correlation	Range, −1 to 1	Small ±0.2 Medium ±0.5 Large ± 0.8	Measures the degree of linear relationship between two quantitative variables
r^2 coefficient of determination	Range, 0 to 1; Usually expressed as percent	Small 0.04 Medium 0.25 Large 0.64	Proportion of variance in one variable explained by the other

(Sullivan & Feinn, 2012)

Cohen's Other Effect Sizes

- Cohen's w – effect size for Chi-Squared tests

$$w = \sqrt{\sum_{i=1}^{m} \frac{(p_{1i} - p_{0i})^2}{p_{0i}}}$$

- Cohen's h – effect size for comparing two independent proportions

$$h = 2(\arcsin \sqrt{p_1} - \arcsin \sqrt{p_2})$$

- Cohen's f^2 – effect size for F-test from ANOVA or multiple regression

$$f^2 = \frac{R^2}{1 - R^2}$$

Power Calculations via Software

- Power Analysis & Sample Size (PASS)
- R: pwr package
- SAS: PROC POWER & PROC GLMPOWER
- SPSS
- G*Power
- nQuery+nTerim4.0
- Stata: sampsi, fpower, powerreg, aipe

Example 1 – Finding the Sample Size

- Research Objective - To clinically validate the use of a biomarker that correctly identifies patients with pain.
  - Biomarker based on white blood cells count
  - Pain measured through conditioned pain modulation (CPM)

- Hypotheses
  - Null: Sensitivity = 60%
  - Alternative: Sensitivity = 80%

- Statistical analysis plan included computing the sensitivity between the two measures.

Example 1 – Finding the Sample Size

- Effect size for sensitivity is determined by the values of the prevalence of pain and by the values of sensitivity under the hypotheses.

- I came across a peer-reviewed publication (Bujang & Adnan, 2016) that computed multiple sample size calculation scenarios using PASS.
  - Power ≥80%
  - Various levels of alpha, prevalence, and sensitivity under the hypotheses

Bujang & Adnan, 2016

n (Sensitivity)						
Prev	H_o	H_a	Power	p-value	N1	N
5%	0.50	0.60	0.804	0.047	199	3980
5%	0.50	0.70	0.810	0.044	49	980
5%	0.50	0.80	0.804	0.041	20	400
5%	0.50	0.90	0.889	0.039	12	240
5%	0.60	0.70	0.801	0.048	181	3620
5%	0.60	0.80	0.826	0.034	45	900
5%	0.60	0.90	0.885	0.035	19	380
5%	0.70	0.80	0.818	0.044	155	3100
5%	0.70	0.90	0.807	0.048	31	620
5%	0.80	0.90	0.819	0.040	107	2140
5%	0.90	0.95	0.839	0.043	243	4860
10%	0.50	0.60	0.804	0.047	199	1990
10%	0.50	0.70	0.810	0.044	49	490
10%	0.50	0.80	0.804	0.041	20	200
10%	0.50	0.90	0.889	0.039	12	120
10%	0.60	0.70	0.801	0.048	181	1810
10%	0.60	0.80	0.826	0.034	45	450
10%	0.60	0.90	0.885	0.035	19	190

n (Specificity)						
Prev	H_o	H_a	Power	p-value	N1	N
5%	0.50	0.60	0.804	0.047	10	209
5%	0.50	0.70	0.810	0.044	3	52
5%	0.50	0.80	0.804	0.041	1	21
5%	0.50	0.90	0.889	0.039	1	13
5%	0.60	0.70	0.801	0.048	10	191
5%	0.60	0.80	0.826	0.034	2	47
5%	0.60	0.90	0.885	0.035	1	20
5%	0.70	0.80	0.818	0.044	8	163
5%	0.70	0.90	0.807	0.048	2	33
5%	0.80	0.90	0.819	0.040	6	113
5%	0.90	0.95	0.816	0.048	12	243
10%	0.50	0.60	0.804	0.047	22	221
10%	0.50	0.70	0.810	0.044	5	54
10%	0.50	0.80	0.804	0.041	2	22
10%	0.50	0.90	0.889	0.039	1	13
10%	0.60	0.70	0.801	0.048	20	201
10%	0.60	0.80	0.826	0.034	5	50
10%	0.60	0.90	0.885	0.035	2	21

Example 1 – Finding the Sample Size

Prevalence of Pain	Sensitivity – Under the Null Hypothesis	Sensitivity- Under the Alternative Hypothesis	Minimum Sample Size for Cases of Pain	Minimum Total Sample Size
20%	60%	80%	45	225
	70%		155	775
30%	60%		45	150
	70%		155	517

Power Calculations via Simulations

- Power analyses conducted using options from standard software may not be suitable for complex study designs

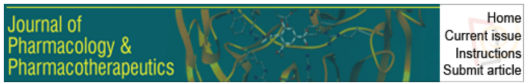
- Power calculations via simulations can be useful when conducting a power calculation that is not standard.

General Steps for Power Calculations via Simulations

- Step 1 – Generate random data from the distribution with the properties that you expect.
- Step 2 – Conduct the statistical analysis that you have planned to do.
- Step 3 – Store the p-value for the statistical test of interest ($\beta=0$).
- Step 4 – Repeat steps 1-3 many times (e.g. 1000).
- Step 5 – Compute power by averaging the number of times the p-value ≤ 0.05.

Resources – Power Analysis for Animal Studies

Journal List > J Pharmacol Pharmacother > v.4(4); Oct-Dec 2013 > PMC3826013



J Pharmacol Pharmacother. 2013 Oct-Dec; 4(4): 303–306.
doi: 10.4103/0976-500X.119726
PMCID: PMC3826013
PMID: 24250214

J Pharmacol Pharm

How to calculate sample size in animal studies?

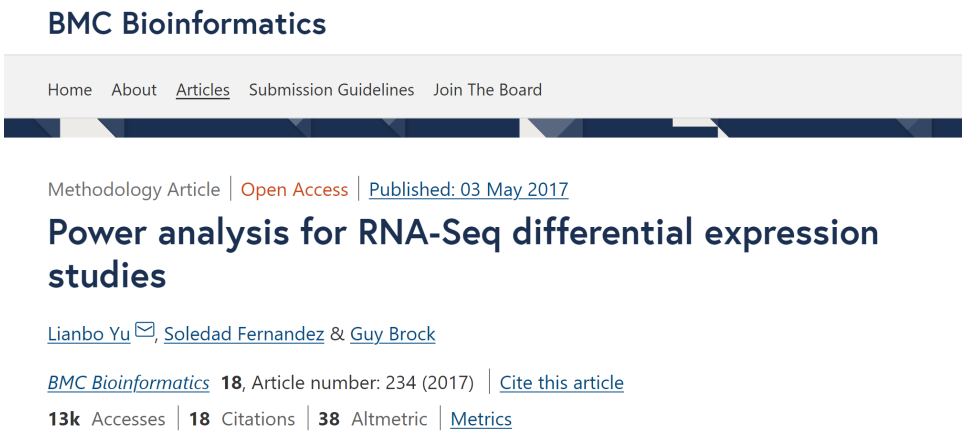
Jaykaran Charan and N. D. Kantharia

Malays J Med Sci. 2017 Oct; 24(5): 101–105.
Published online 2017 Oct 26. doi: 10.21315/mjms2017.24.5.11
PMCID: PMC5772820
PMID: 29386977

Sample Size Calculation in Animal Studies Using Resource Equation Approach

Wan Nor Arifin[1] and Wan Mohd Zahiruddin[2]

Resources – RNA-Seq Power Analysis



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Power analysis for RNA-Seq differential expression studies

Lianbo Yu, Soledad Fernandez & Guy Brock

BMC Bioinformatics **18**, Article number: 234 (2017) | Cite this article

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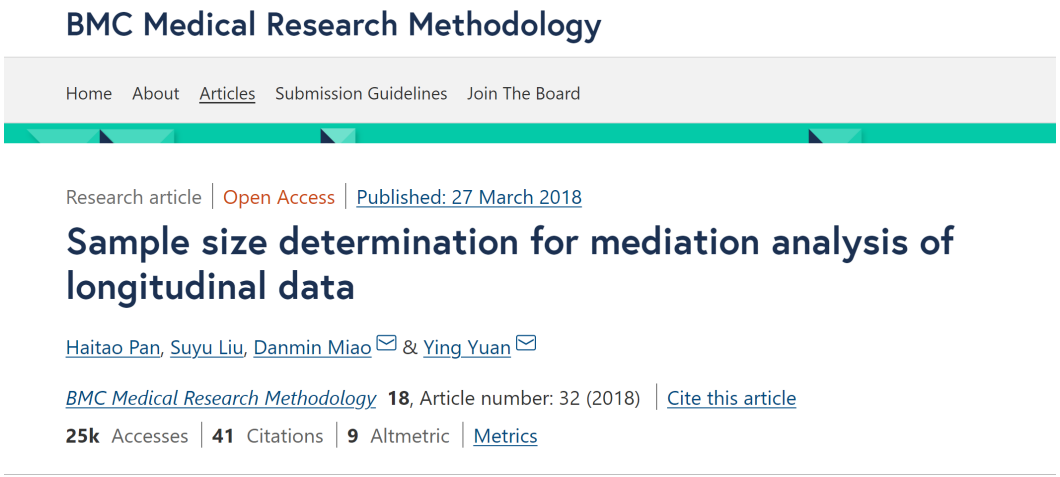
Resources – Mediation Analysis with Longitudinal Data



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Sample size determination for mediation analysis of longitudinal data

Haitao Pan, Suyu Liu, Danmin Miao & Ying Yuan

BMC Medical Research Methodology **18**, Article number: 32 (2018) | Cite this article

25k Accesses | **41** Citations | **9** Altmetric | Metrics

Summary

- Research questions and hypotheses must be well defined.
- Power analyses are based on the primary hypothesis.
- Sample size can be dependent on the budget of the proposed study.
- Many factors that can impact power.

References

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Thank You!

Email: lutfiyya.muhammad@northwestern.edu

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