Conducting Meta-Analysis for Systematic Reviews Using R

Sherman Centre for Digital Scholarship

Thursday, January 29, 2026

4:00pm - 5:30pm **(Online)**

Conducting Meta-Analysis for Systematic Reviews Using R

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A Beginner-Friendly Workshop

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Feb 04: Introduction to REDCap for Electronic Data Collection
Feb 05: Map Making for Absolute Beginners using QGIS

Digital Research

February 11: Visualizing Bibliometric Networks with VOSviewer

Research Data Management

February 19: Communities Empowered by Data 101: Tools and Best Practices

May 12: Data Management Plan Bootcamp (In-Person)

May 19: Data Deposit Bootcamp (In-Person)

Do More with Digital Scholarship

February 6: Create a Digital Exhibition with Omeka S

February 9: Rethinking "Good" Data: Power, Vulnerability, and Queer Data Care

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Workshop Overview

What You'll Learn Today

- Get your data into R and prepare it for analysis
- Perform fixed-effect and random-effects meta-analysis
- Create and interpret forest plots
- Assess heterogeneity between studies
- Check for publication bias

This is a hands-on workshop! You'll practice running meta-analyses in R using the meta package.

Scope of This Workshop

What We WILL Cover

- ✓ Practical R coding
- ✓ Using the meta package
- ✓ Interpreting results
- ✓ Forest plots
- ✓ Heterogeneity basics

What We WON'T Cover

- ✗ Mathematical derivations
- ✗ Systematic review methods
- ✗ Advanced techniques (NMA)
- ✗ Bayesian meta-analysis

📚 **For deeper understanding of systematic review and meta-analysis**

Cochrane Handbook for Systematic Reviews of Interventions
https://training.cochrane.org/handbook

For deeper understanding of systematic review and meta-analysis

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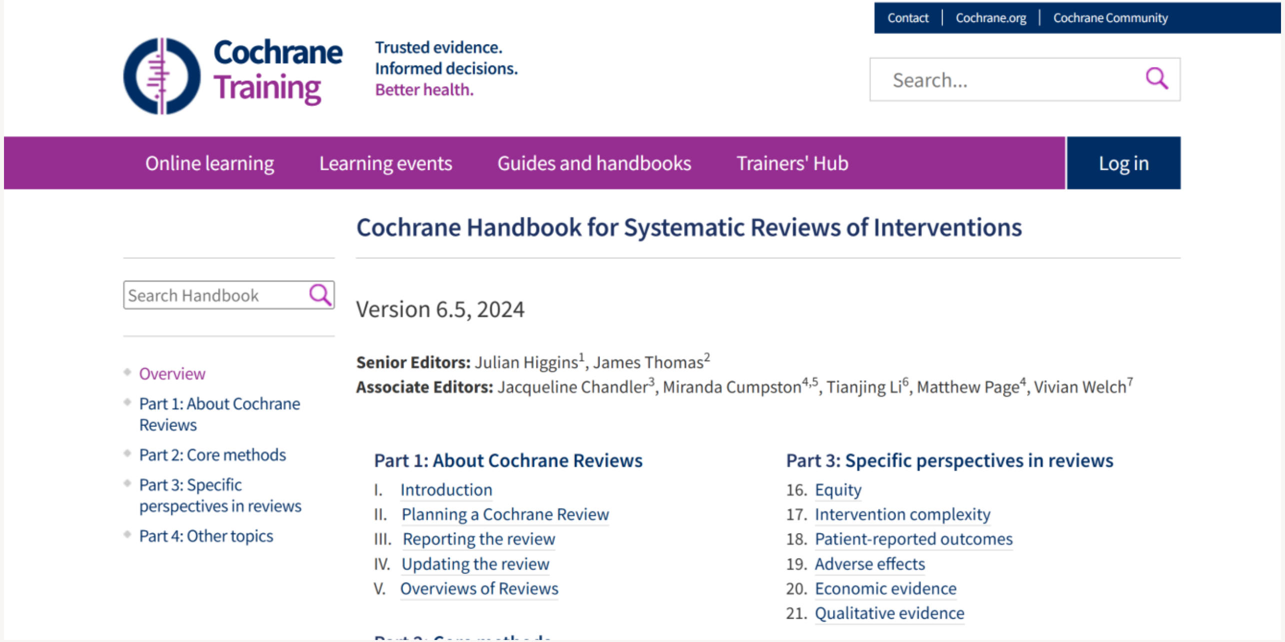
https://training.cochrane.org/handbook



PART 1

Understanding Meta-Analysis

Key concepts before we start coding

What is Meta-Analysis?

A statistical procedure for combining data from multiple studies to produce a single, estimate of an effect.

Think of it like this:

Study 1 | Study 2 | Study 3 → **Pooled Estimate (Weighted Average)**

Key Characteristics:

- Combines results from 2 or more studies on the same topic
- Uses weighted averaging (larger studies contribute more)
- Produces a pooled estimate with confidence interval

Systematic Review vs. Meta-Analysis

Systematic Review

A comprehensive literature search and critical appraisal of all relevant studies on a specific question.

- Define research question
- Search databases
- Screen & select studies
- Extract data
- Assess quality

may include →

Meta-Analysis

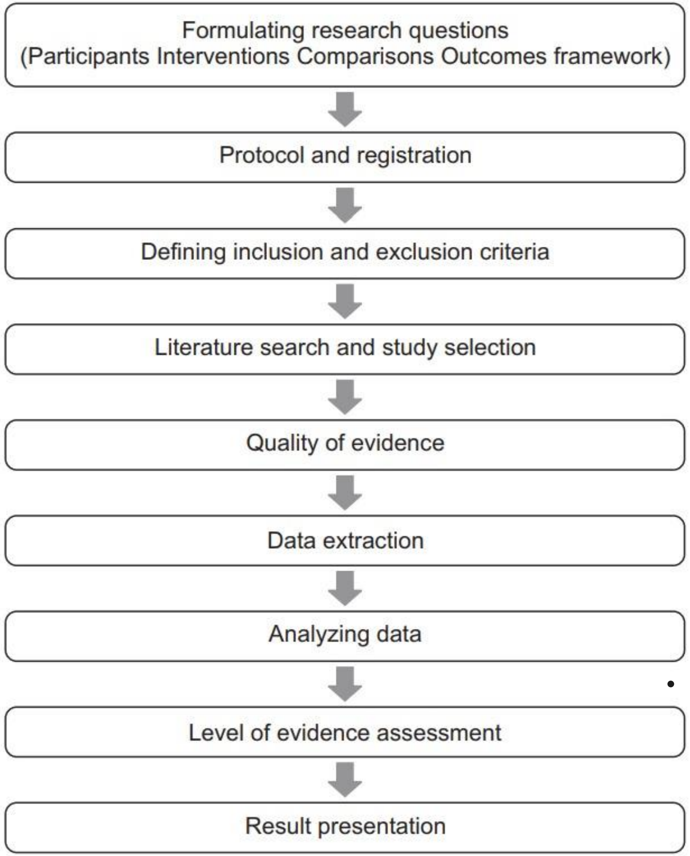
The statistical technique used to combine quantitative results from multiple studies.

- Calculate effect sizes
- Assign weights
- Pool estimates
- Assess heterogeneity
- Create forest plots

Key Insight

Not all systematic reviews include a meta-analysis! Meta-analysis is only appropriate when studies are similar enough to combine meaningfully.

Systematic Review vs. Meta-Analysis



- Ahn E, Kang H. Introduction to systematic review and meta-analysis. Korean J Anesthesiol. 2018 Apr;71(2):103-112. doi: 10.4097/kjae.2018.71.2.103. Epub 2018 Apr 2. PMID: 29619782; PMCID: PMC5903119.

Types of Meta-Analyses

Traditional (Pairwise)

Compares two interventions directly

Today's Focus

Network Meta-Analysis

Compares multiple interventions simultaneously

IPD Meta-Analysis

Uses individual participant data from studies

Cumulative Meta-Analysis

Shows how evidence evolves over time

Meta-Regression

Explores sources of heterogeneity

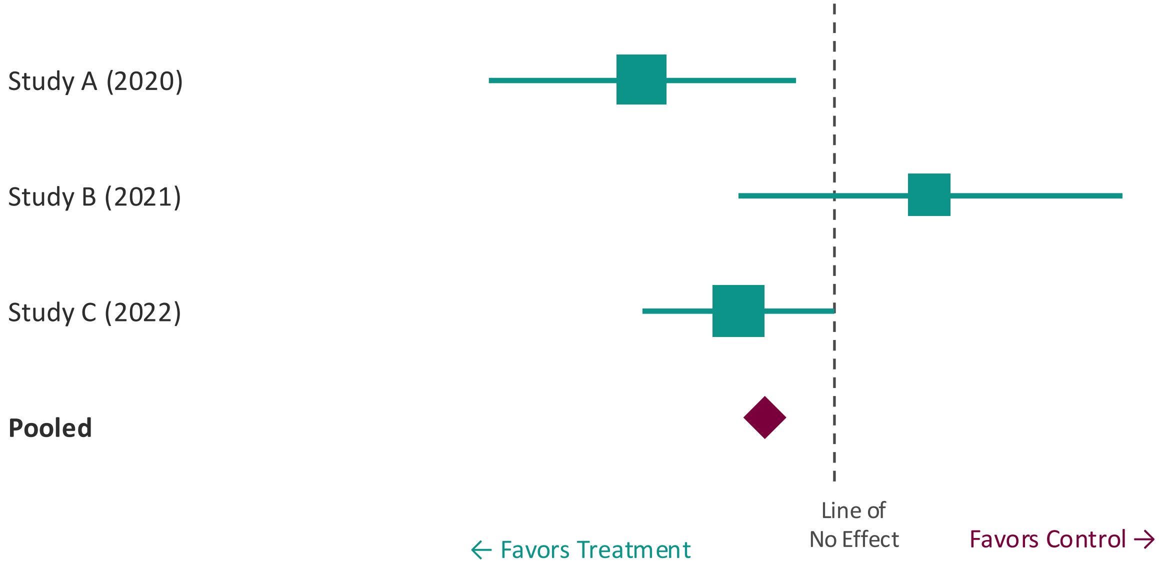
Bayesian Meta-Analysis

Incorporates prior beliefs into analysis

💡 Today we focus on traditional pairwise meta-analysis, which is the foundation for understanding all other types.

The Forest Plot: Your Main Output

A forest plot is the visual representation of a meta-analysis. Let's understand its components:



Square = Point estimate
Size = Study weight

Horizontal line = 95% CI

◆ Diamond = Pooled result

Confidence Intervals

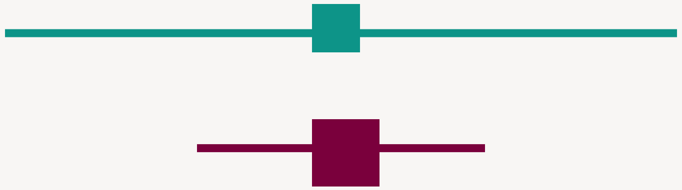
Why This Matters in Meta-Analysis

Studies with narrower CIs (more precision) get more weight in the pooled estimate. This makes sense - we trust more precise estimates more!

Visual Example:

Small study (n=50)

Large study (n=500)



Wide CI = More uncertainty

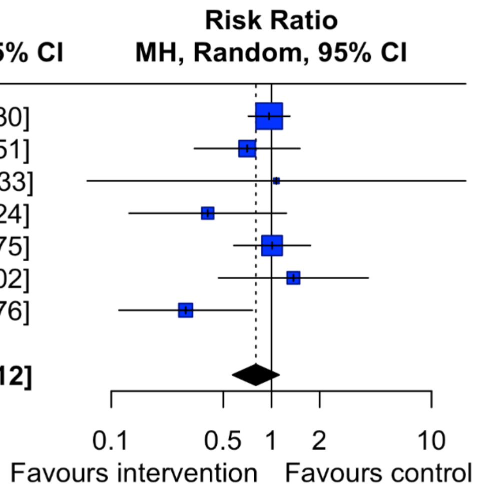
Narrow CI = More precision

The Forest Plot: Your Main Output

Let’s see a real word example :

Study	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Risk Ratio MH, Random, 95% CI
Feng (2023)	52	135	53	133	37.1%	0.97 [0.72; 1.30]
Gonzalez-Plaza (2022)	10	65	12	55	14.2%	0.71 [0.33; 1.51]
Herring (2016)	1	27	1	29	1.5%	1.07 [0.07; 16.33]
Kennedy (2018)	4	114	10	114	7.5%	0.40 [0.13; 1.24]
Olson (2018)	37	865	18	425	21.7%	1.01 [0.58; 1.75]
Teoule (2024)	7	49	5	48	8.2%	1.37 [0.47; 4.02]
Uria-Minguito (2023)	5	102	17	101	9.9%	0.29 [0.11; 0.76]
Total (95% CI)		**1357**		**905**	**100.0%**	**0.80 [0.57; 1.12]**

Heterogeneity: $Tau^2 = 0.0551$; $Chi^2 = 8.59$, df = 6 (P = 0.20); $I^2 = 30.1\%$



Khademioore, Sahar, et al. "Effects of digital health counseling and behavioral interventions on weight management during pregnancy and postpartum: A systematic review and meta-analysis of randomized controlled trials." *Plos one* 20.9 (2025): e0331913.

PART 2

Fixed-Effect vs. Random-Effects Models

Understanding Heterogeneity

Why do different studies get different results?

Within-Study Variability (variance)

Random sampling error within each study. Shown by the confidence interval width.

Smaller studies → wider CIs
Larger studies → narrower CIs

Between-Study Variability (heterogeneity)

True differences in effects across studies due to:
- Different populations
- Different interventions
- Different settings
- Different outcome measures

How Do We Measure Heterogeneity?

I^2 (I-squared)

% of variability due to heterogeneity
- 0-40%: Low
- 30-60%: Moderate
- 50-90%: Substantial
- 75-100%: Considerable

Q-statistic & p-value

Tests if heterogeneity exists
- $p < 0.10$ suggests significant heterogeneity
- Low power with few studies

Visual inspection

In the forest plot:
- Overlapping CI
- Direction of point estimate

Understanding Heterogeneity

Why do different studies get different results?

Within-Study Variability

Between-Study Variability

Fixed and random effects models make different assumptions about these.

Study	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Risk Ratio MH, Random, 95% CI
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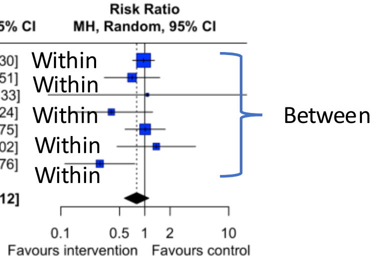


Fixed-Effect vs. Random-Effects

Fixed-Effect Model

Assumption:

There is ONE true effect size that all studies are estimating.

Implication:

- Differences are only due to sampling error
- $\tau^2 = 0$ (no between-study variance)
- Larger studies dominate the pooled estimate

When to use:

- Studies are very similar
- Same population, intervention, outcome
- You want to estimate THIS specific effect

Random-Effects Model

Assumption:

True effects VARY across studies. We estimate the MEAN of a distribution of effects.

Implication:

- $\tau^2 > 0$ (between-study variance exists)
- Smaller studies get more weight compared to FE
- Confidence intervals are typically wider

When to use:

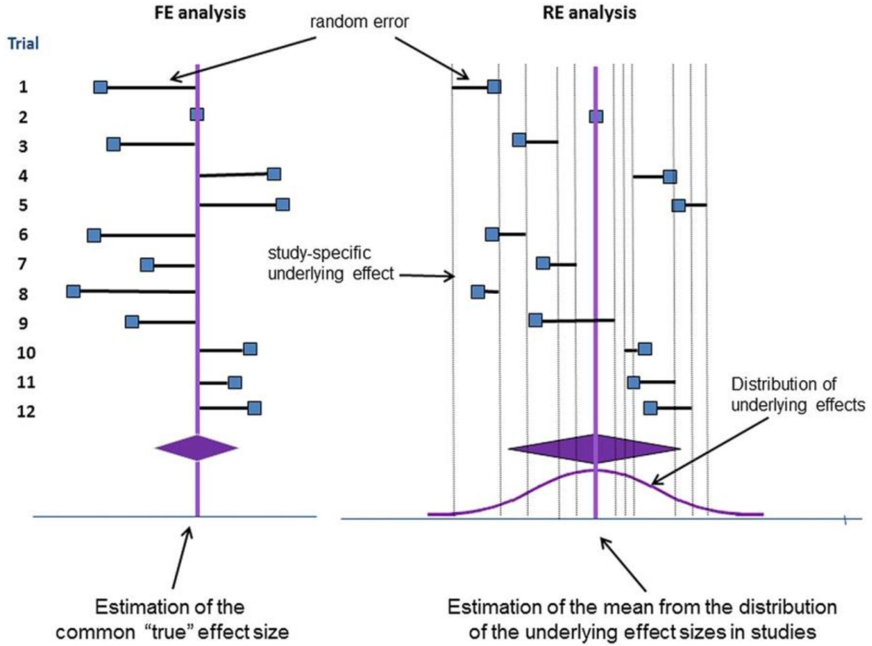
- Studies differ in populations/methods
- You want to estimate the average treatment effect
- Most common choice in practice

In practice, random-effects is often the safer default choice, unless you have strong reasons to assume all studies estimate the exact same effect.

Fixed-Effect vs. Random-Effects

Fixed-Effect Model

Random-Effects Model



Adriani Nikolakopoulou, Dimitris Mavridis, Georgia Salanti - Demystifying fixed and random effects meta-analysis: Evidence Based Mental Health 2014;17:.

All studies estimate the SAME true effect. Variation is due to sampling error only.

Studies estimate DIFFERENT (but related) true effects. We estimate the mean of this distribution.

PART 3

Weighting method and effect measure

How Are Studies Weighted?

Core Principle: Inverse Variance Weighting

Weight = 1 / Variance. Studies with smaller variance (more precise) get higher weight.

The pooled estimate is a weighted average. But how do we calculate the weights?

- Model (fixed or random)
- Type of outcome/Effect measure (MD, RR, OR)

How Are Studies Weighted?

The pooled estimate is a weighted average. But how do we calculate the weights?

Common Weighting Methods:

Method	Model	Best For	Notes
Inverse Variance	Both	All effect measures (MD, SMD)	Most general method
Mantel-Haenszel	Both	Dichotomous (RR, OR)	Good with sparse data
Peto	Fixed	OR (rare events)	Special case for rare events
DerSimonian-Laird	Random	General use	Default in some software
Restricted Maximum Likelihood (REML)	Random	General use	More accurate τ^2 estimate

Effect Measures: Dichotomous Outcomes

When your outcome is yes/no, event/no event (e.g., death, disease, cure)

Risk Ratio (RR)

Ratio of risks between groups

RR = 0.75 means 25% lower risk in treatment group

Best for: Cohort studies, RCTs

Odds Ratio (OR)

Ratio of odds between groups

OR = 0.5 means half the odds in treatment group

Best for: Case-control, cross-sectional studies

Risk Difference (RD)

Absolute difference in risks

RD = -0.10 means 10% absolute reduction

Best for: When absolute effect size matters

RR and OR are similar when events are rare (<10%). For common events, they can differ substantially!

Effect Measures: Continuous Outcomes

When your outcome is measured on a continuous scale (e.g., blood pressure, weight, pain score)

Mean Difference (MD)

The absolute difference between the mean values of two groups.

Use when: All studies use the SAME measurement scale

Example: "Treatment reduced systolic BP by 5.2 mmHg compared to control"

Standardized Mean Difference (SMD)

The difference divided by the pooled standard deviation.

Use when: Studies use DIFFERENT scales for the same construct

Example: "Treatment had an SMD of 0.5 (moderate effect) on depression across different scales"

PART 4

Hands-On Practice with R

Using the meta package

Data Requirements

Continuous Outcomes

For metacont() you need:

- Mean in treatment group
- Mean in control group
- SD in treatment group
- SD in control group
- Sample size (n) in each group

Dichotomous Outcomes

For metabin() you need:

- Events in treatment group
- Total n in treatment group
- Events in control group
- Total n in control group

Example Data Format (CSV):

```
study,       events_t, n_t, events_c, n_c
Smith2020,   52,       135, 53,       133
Jones2021,   10,       65,  12,       55
Lee2022,     37,       865, 18,       425
```

Data Requirements

Example Data Format (CSV):

author	event.e	n.e	event.c	n.c	BMI
Feng (2023)	52	135	53	133	Overweight/obese
Gonzalez-Plaza (2022)	10	65	12	55	Overweight/obese
Herring (2016)	1	27	1	29	Overweight/obese
Kennedy (2018)	4	114	10	114	Any BMIs
Olson (2018)	37	865	18	425	Any BMIs
Teoule (2024)	7	49	5	48	Any BMIs
Uria-Minguito (2023)	5	102	17	101	Any BMIs

author	mean.e	sd.e	n.e	mean.c	sd.c	n.c	BMI
Chen (2022)	6.34	5.66	37	7.43	4.99	43	Overweigh
Coughlin (2020)	11.4	4.5	13	12	4.5	13	Any BMI
Dahl (2018)	11.34	8.16	47	10.46	7.53	40	Any BMI
Feng (2023)	8.5	4.07	135	10	5.93	133	Any BMI
Gonzalez-Plaza (20	7.6	5.5	60	10.1	6.4	53	Overweigh
Herring (2016)	8.7	6.6	27	12.3	6.4	29	Overweigh

The meta Package in R

The meta package provides a comprehensive toolkit for meta-analysis in R

Key Functions:

`metabin()`	Binary/dichotomous outcomes	*Events and totals per group*
`metacont()`	Continuous outcomes	*Means, SDs, and sample sizes*
`metagen()`	Generic effect sizes	*Pre-calculated effects and SEs*
`forest()`	Create forest plots	*Visualize meta-analysis results*
`funnel()`	Create funnel plots	*Assess publication bias*

```
Installation:  install.packages("meta")   then   library(meta)
```

Running Your First Meta-Analysis

```r
# Load the package
library(meta)

# Read your data
data <- read.csv("my_studies.csv")

# Run meta-analysis (binary outcomes)
ma_result <- metabin(
  event.e = events_t,  # Events in treatment
  n.e = n_t,           # Total in treatment
  event.c = events_c,  # Events in control
  n.c = n_c,           # Total in control
  studlab = study,     # Study labels
  data = data,
  sm = "RR",           # Risk Ratio
  method = "MH",       # Mantel-Haenszel
  random = TRUE        # Include random-effects
)
```

View results: `summary(ma_result)`

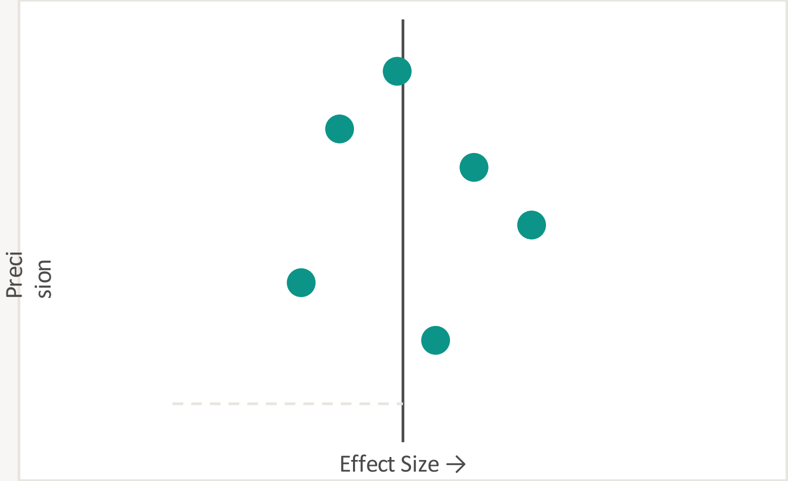
Create forest plot: `forest(ma_result)`

💡 See the hands-on R Markdown file for complete working examples!

Checking for Publication Bias

Publication bias occurs when studies with "positive" or significant results are more likely to be published than those with null or negative findings.

The Funnel Plot



Interpreting the Funnel Plot

Symmetric funnel:

No evidence of bias. Small studies scatter evenly around the pooled estimate.

Asymmetric funnel:

Suggests possible publication bias. "Missing" studies on one side.

Statistical tests:

- Egger's test: metabias(ma_result)
- Need ≥10 studies for reliable results

Let's Practice!

Open the R Markdown file and follow along

In the hands-on session, you will:

✓ Load and explore meta-analysis data
✓ Run fixed-effect and random-effects meta-analyses
✓ Create and interpret forest plots
✓ Assess heterogeneity and publication bias

Key Takeaways

1. Meta-analysis combines results from multiple studies to get a pooled estimate with greater precision
2. Choose your effect measure based on outcome type (continuous vs. binary) and study designs
3. Random-effects models are generally safer when studies differ in populations or methods
4. Always assess heterogeneity (I^2, Q-test) to understand how consistent results are
5. Check for publication bias using funnel plots (and Egger's test if ≥10 studies)
6. The meta package in R provides all the tools you need for a basic meta-analysis

📖 For deeper learning: "Doing Meta-Analysis with R" (free online) - bookdown.org/MathiasHarrer/Doing_Meta_Analysis_in_R/

Resources & Further Learning

Essential Resources

- Cochrane Handbook — training.cochrane.org/handbook
- Doing Meta-Analysis with R (Free) — cran.r-project.org/web/packages/meta/meta.pdf
- meta package documentation

R Packages for Meta-Analysis

meta - General meta-analysis (today's focus)
metafor - Comprehensive meta-analysis framework
netmeta - Network meta-analysis
dmetar - Companion to "Doing Meta-Analysis with R"

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Thank You!

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Questions? Let's discuss!