Acta Kinesiologica 19 (2025) Issue.1
DOI. 10.51371/issn.1840-2976.2025.19.1.1
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Original Investigation

MASimplified: A User-Friendly Web-Based Tool for Conducting Pairwise Meta-Analysis and Visualization Using R-Shiny and Metafor R Packages

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Background: A meta-analysis is a fundamental method for synthesizing evidence across studies comparing two or more interventions, playing a pivotal role in healthcare decision-making and evidence-based research. While essential, existing software tools often require programming expertise, they are not cost-free, limiting accessibility for many researchers and clinicians.
Purpose: To present a MASimplified, a user-friendly web application designed for conducting a pairwise meta-analysis. The tool enables researchers with no programming background to conduct analyses via an intuitive point-and-click interface, generate publication-ready visualizations, and interpret results in real time. Leveraging R's meta and metafor packages for statistical computations and the Shiny framework for interface development, the MASimplified was built as a freely accessible web app. The platform requires only a standard internet browser, eliminating installation barriers. Key features include conducting a pairwise meta-analysis, subgroup analysis, automated forest plots, funnel plots, risk-of-bias assessments and conducting a meta-regression analysis.
Conclusions: MASimplified successfully streamlines the entire pairwise meta-analysis workflow, from data input to result interpretation. An illustrative example (detailed in the current manuscript) demonstrates its functionality, showcasing outputs such as pooled effect estimates, heterogeneity metrics, meta-regression analysis and visualizations. The app is publicly available at https://arminparavlic.shinyapps.io/MASimplified/. MASimplified empowers non-specialists to conduct rigorous pairwise meta-analyses, enhancing the transparency and clinical relevance of evidence synthesis. By bridging the gap between advanced statistical methods and user-friendly implementation, the tool strengthens capacity for informed decision-making in research and practice. We hope this initiative inspires further development of accessible tools using open-source technologies like Shiny, fostering broader engagement with specialized analytic methods.

Keywords: meta-regression, linear model, loess, sensitivity analysis, funnel plot, forest plot

Introduction

Systematic reviews with meta-analysis have become a cornerstone of evidence-based research, offering robust insights by synthesizing data across studies. Recognized as one of the highest tiers of evidence in medicine and related fields, meta-analyses are now indispensable tools in disciplines ranging from kinesiology and sports science to clinical medicine[1–3]. For instance, a PubMed search for the term "meta-analysis" yields 319,309 articles published between 1966 and 2023 (Figure 1)[4], with over 75% (242,253 articles) published in the last decade alone. This exponential growth underscores the method's critical role in modern research.
Despite its prominence, conducting a meta-analysis remains

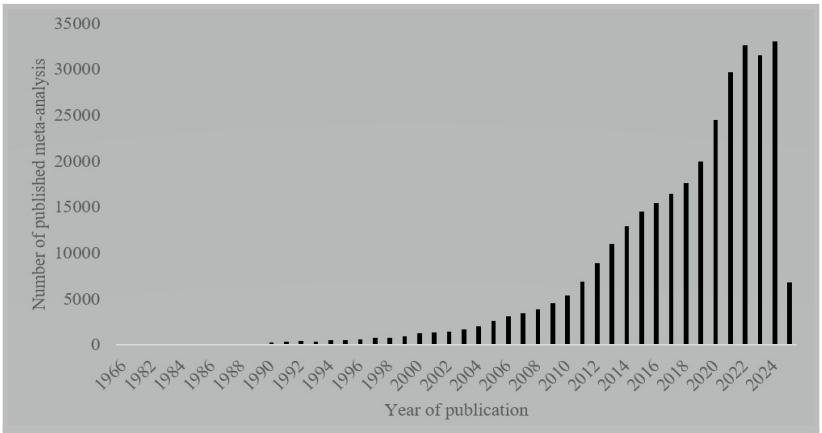

Figure 1. Number of articles published between 1966 and 2023 containing the term 'meta-analysis' in the PubMed database (n = 319,309).

challenging for many researchers, students, and practitioners. Specialized statistical expertise and familiarity with complex software are often required, creating barriers to entry. Commercial tools like SPSS (1,320/year)[5], STATA (160-720/year)[6], and Comprehensive Meta−Analysis (195–$495/year)[7] impose significant financial costs, limiting accessibility for individuals and institutions with constrained budgets. While free alternatives like Review Manager (RevMan)[8] and R's metafor package[9] exist, they fall short in addressing the full spectrum of user needs. RevMan, though user-friendly and tailored for Cochrane reviews, lacks advanced analytical capabilities such as meta-regression—a critical tool for investigating heterogeneity and identifying predictors of the observed effect. Meanwhile, R packages like the Metafor offer greater flexibility but demand programming proficiency, steepening the learning curve for non-statisticians.

These limitations highlight an unmet need: a cost-free, intuitive software that bridges the gap between simplicity and analytical rigor. Existing tools either prioritize accessibility at the expense of advanced features (e.g., RevMan) or require technical expertise to unlock their full potential (e.g., R). As meta-analytic methodologies evolve - particularly in exploring source of heterogeneity and potential moderators - researchers increasingly require software that integrates user-friendliness with sophisticated methods like meta-regression and publication bias assessment through funnel asymmetry plot[10] or Egger's regression tests[11].

To bridge this gap, MASimplified is introduced - a novel user-friendly web-based tool developed using R-Shiny and the Metafor R package. MASimplified enables users to perform meta-analyses efficiently without requiring advanced programming expertise. This paper presents a comprehensive overview of the features, development, and applications of MASimplified. For detailed guidance on interpreting meta-analysis results, readers are directed to other publications that thoroughly explain this topic[9,11,12].

How the MASimplified tool was created

MASimplified was developed using **R-Shiny[13]**, a framework that allows the creation of interactive web applications. The core analysis functions rely on the **Metafor** R package[9], which is widely used for conducting meta-analyses through R studio. Key aspects of the tool's development include:

User Interface: Built using R-Shiny to provide an intuitive, point-and-click experience.

Data Processing: Supports CSV file uploads, ensuring compatibility with common spreadsheet formats.

Analysis Engine: Utilizes the Metafor package for summarizing the main effect, heterogeneity metrics, publication bias assessments and meta-regression analysis.

Visualization: Generates high-quality forest plots, funnel plots, and other graphical outputs using ggplot2[14].

Export Options: Allows users to download results in various formats, including PNG, JPG, TIFF, and CSV. Moreover, the MASimplified interface enables users to choose among different quality of figures i.e., 300, 400, 500 and 600 drops per inch (dpi), respectively.

Implementation

MASimplified structure

1. Home page which welcomes user to the Meta-Analysis Simplified and informs you to navigate using the menu.
2. Load Data. Allows user to upload data in csv format.
3. Data Analysis. Allows user to conduct pairwise meta-analysis.
4. Publication Bias Assessment. Allows user to investigate the publication bias utilizing both the graphical and statistical approach.
5. Subgroup Meta-Analysis. Here the user can further investigate the sources of heterogeneity within studies included in the meta-analysis utilizing categorical variable.
6. Meta-Regression Analysis. Allows user to investigate the sources of heterogeneity within studies included in the meta-analysis and predictors of the observed effect size.
7. User Guide. Here we presented a basic guide on how to use the MAS app.

How to use MASimplified and conduct your first meta-analysis with this tool

Data Upload

Users begin by uploading an **Excel CSV file** containing study data, including effect sizes, standard errors, and other study characteristics which will be used for conducting subgroup meta-analysis (consisting of categorical variables) or meta-regression analysis (consisting of continuous variables) (Figure 2). The important notice for user when creating its data are as follows:

- Columns where a study labels are defined must be named "**id**".
- Effect size column must be named "**es**".
- Standard error column must be named as "**se**".

In case user would like to experience the full potential of the app and investigate moderators of the effect by utilizing subgroup meta-analysis or meta-regression analysis, an additional study characteristic must be added to the original dataset. To be recognized from the app all categorical variables must use prefix "**CAT**" which stands for categorical, whereas continuous variables must use prefix "**COV**" which stands for covariance. More information about conducting subgroup MA and meta-regression analysis can be found in the following text.

An example of dataset is available in the author's GitHub repository (https://github.com/ArminParavlic/MAS-Meta-Analysis-Simplified/blob/main/data.csv)[15]. This dataset represents a subset of data originally published in *Sports Medicine*[16].

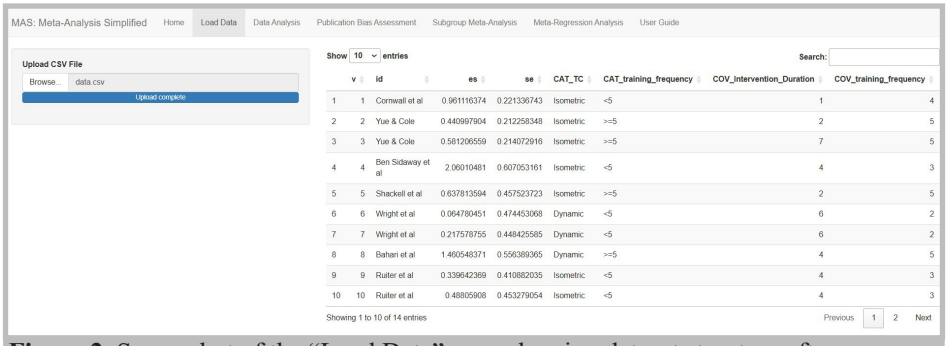

Figure 2. Screenshot of the "Load Data" page showing dataset structure after uploading.

Conducting meta-analysis

On a Data Analysis page, users can perform pairwise meta-analysis by selecting either fixed-effect and random-effects models (Figure 3, Step A). Sensitivity analyses are supported through the exclusion of individual studies, enabling researchers to evaluate the robustness of pooled effect estimates; selecting "None" retains all studies for the primary analysis (Figure 3, Step B). After configuring parameters, users initiate the meta-analysis by selecting "Run Meta-Analysis" (Figure 3, Step C). MASimplified generates forest plots to visualize individual study outcomes and pooled effect estimates. Graphical results can be exported in PNG, JPG, or TIFF formats (Figure 3, Step D) and different quality of figures (Figure 3, Step E) as forest plot (Figure 3, Step F), while numerical data, including effect sizes and confidence intervals, are downloadable as CSV files (Figure 3, Step G).

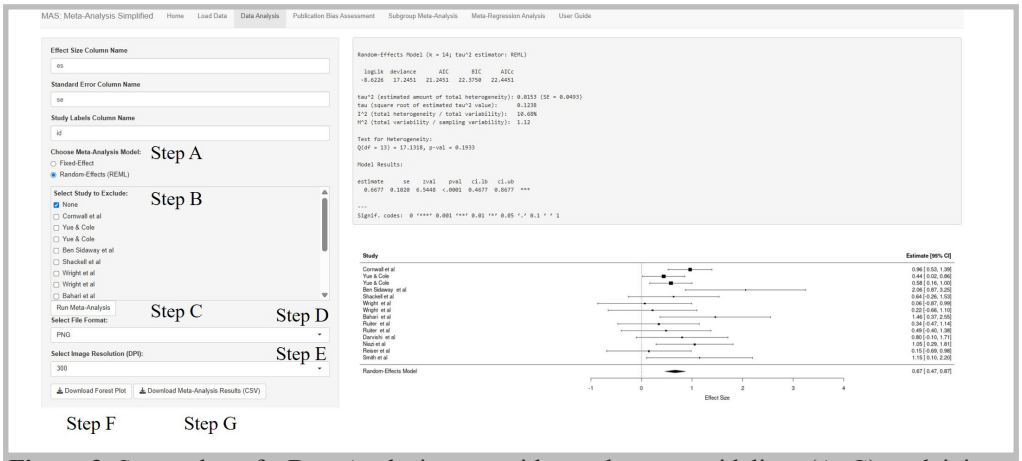

Figure 3. Screenshot of a Data Analysis page with step-by-step guidelines (A–G) explaining its main features. Detailed descriptions of each step are provided in the manuscript text.

Assessing Publication Bias

Publication bias is evaluated on the Publication Bias Assessment page using funnel plots and Egger's regression test (Figure 4). Funnel plots are downloadable in standard image formats (PNG, JPG, TIFF), and statistical results from Egger's test, including intercept estimates and p-values, are exportable as CSV files.

Subgroup Meta-Analysis

To investigate heterogeneity, the Subgroup Meta-Analysis page allows stratification by categorical variables. For example, in the provided dataset, users can analyze subgroups based on variables such as CAT_TC (time of contraction) or CAT_training_frequency (Figure 5). After selecting a variable (Figure 5, Step A), and initiating the analysis (Figure 5, Step B), subgroup-specific pooled estimates and heterogeneity statistics (e.g., I^2) are displayed. Results are exportable via the Download Subgroup Results (CSV) function (Figure 5, Step C).

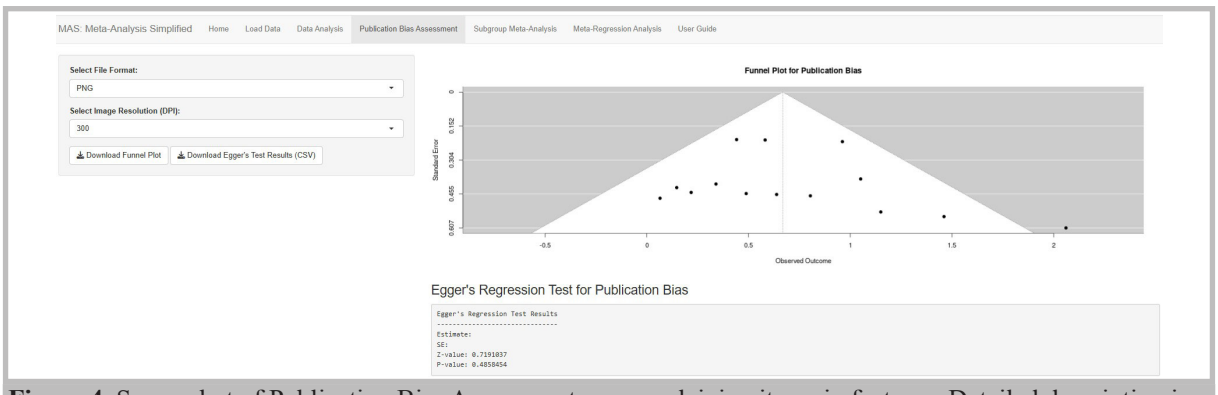

Figure 4. Screenshot of Publication Bias Assessment page explaining its main features. Detailed description is provided in the manuscript text.

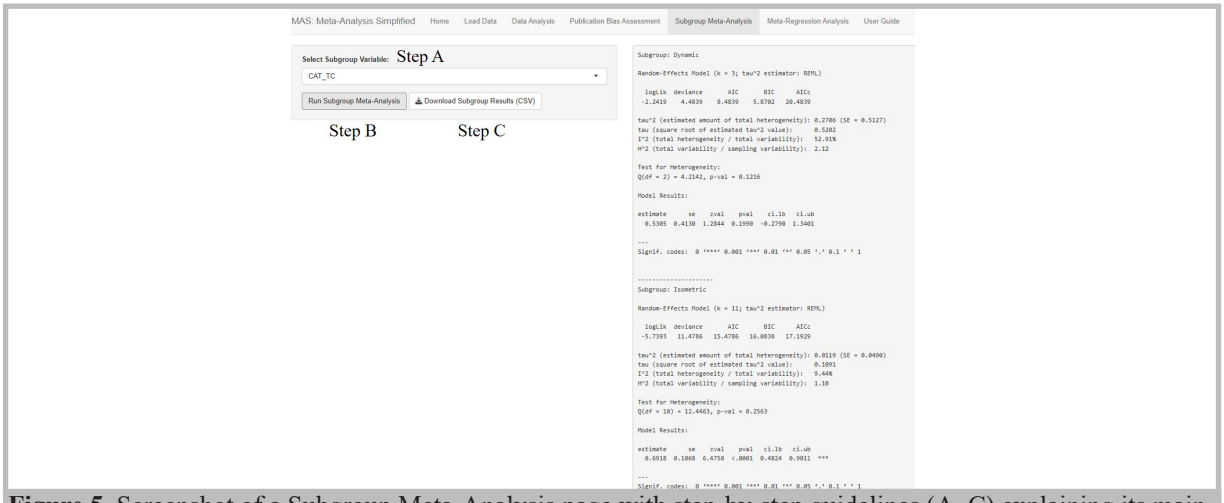

Figure 5. Screenshot of a Subgroup Meta-Analysis page with step-by-step guidelines (A–C) explaining its main features. Detailed descriptions of each step are provided in the manuscript text.

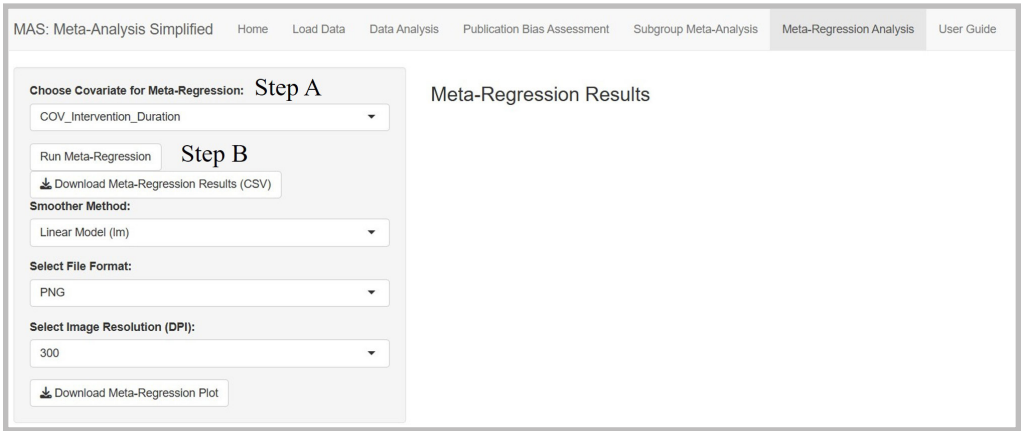

Figure 6. Screenshot of a Meta-Regression Analysis page with step-by-step guidelines (A–B) explaining how to choose covariate and run meta-regression analysis. Detailed descriptions of both steps are provided in the manuscript text.

Meta-Regression Analysis

Continuous covariates are analysed on the Meta-Regression Analysis page. Following a primary meta-analysis, users select covariates (e.g., dosage, follow-up duration) to assess their influence on effect sizes (Figure 6, Step A). After running the meta-regression (Figure 6, Step B), regression coefficients, confidence intervals, and significance values are displayed (Figure 7). Results are downloadable as CSV files, and meta-regression plots (e.g., bubble plots) are exportable in standard image formats (Figure 7, Steps A and E). An additional feature allows users to choose between a linear model and a LOESS regression model for the graphical representation of regression analysis (Figure 7, Step B). The results are displayed in Figure 8 (linear model) and Figure 9 (LOESS model).

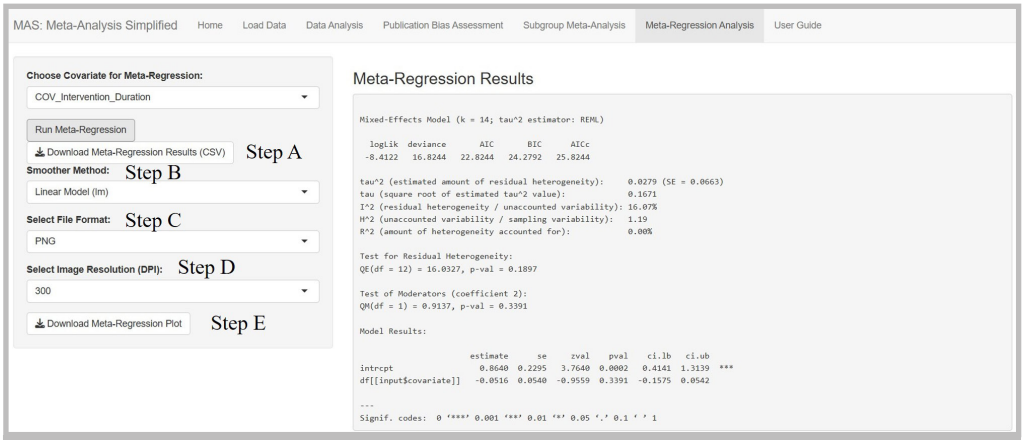

Figure 7. Screenshot of a Meta-Regression Analysis page with step-by-step guidelines (A–E) explaining how to export results from a meta-regression analysis. Detailed descriptions of both steps are provided in the manuscript text.

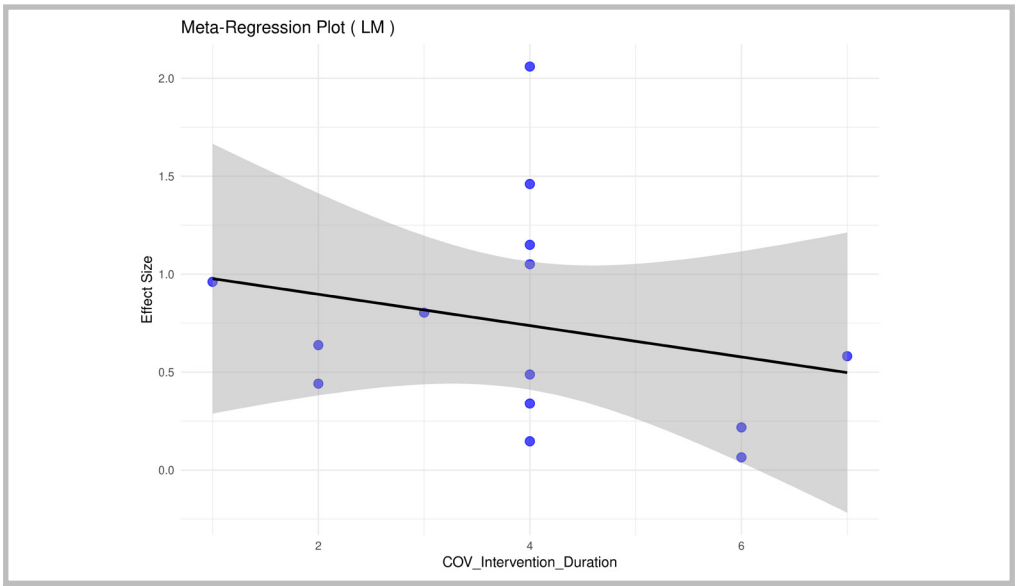

Figure 8. Meta-regression plot with linear model

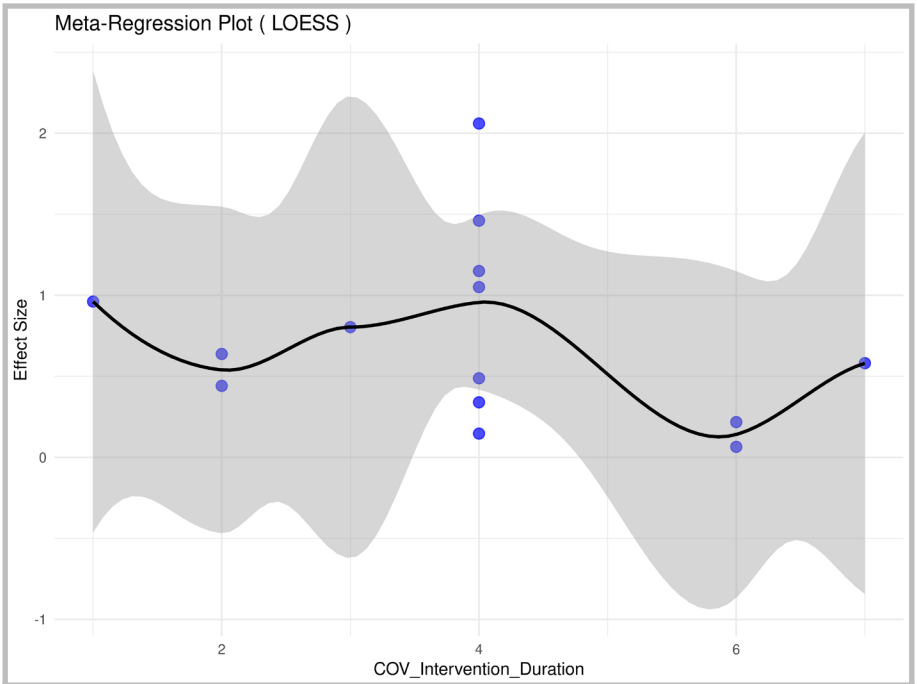

Figure 9. Meta-regression plot with LOESS model.

Limitations of the Current Version of the MASimplified Online Tool

While MASimplified provides a user-friendly platform for conducting methodologically rigorous pairwise meta-analyses and incorporates essential analytical features, its current version has several limitations. First, the tool is exclusively designed for pairwise meta-analyses and does not support other meta-analytic frameworks, such as multilevel meta-analysis, network meta-analyses, or Bayesian approaches. Researchers requiring advanced methodologies beyond pairwise comparisons would need to employ alternative software. Second, although the tool generates standard graphical outputs (e.g., forest plots, funnel plots, bubble plots), users cannot customize these visualizations (e.g., adjusting axis labels, modifying scales, or altering stylistic elements), which may limit their utility for publication-ready figures, when more complex amendments are needed.

These limitations reflect deliberate prioritization of simplicity and accessibility in the initial development phase. Future updates aim to expand the tool's analytical scope to include additional meta-analysis frameworks and introduce flexible graphical customization options to enhance interpretability and adaptability for diverse research contexts.

Practical applications

MASimplified is a streamlined, web-based tool enabling researchers to conduct rigorous pairwise meta-analyses efficiently. Its integrated features—including forest plots, funnel plots, Egger's regression test for bias, sensitivity analyses, and meta-regression—support critical appraisal of effect estimates, exploration of heterogeneity, and assessment of publication bias. While currently limited to pairwise comparisons, the tool is ideal for rapid hypothesis testing, educational purposes, or preliminary analyses in evidence synthesis. Clinicians, students, and researchers without advanced statistical software can leverage its intuitive interface to derive reproducible results, with outputs suitable for internal reports and or publication in scientific journals.

Conclusions

MASimplified is a user-friendly tool designed to democratize access to meta-analysis by eliminating technical barriers. With its intuitive interface, comprehensive features, and free accessibility, MASimplified provides an ideal solution for researchers, students, and decision-makers seeking to conduct rigorous meta-analyses efficiently. Educators can seamlessly integrate this platform into curricula, enabling students to build foundational knowledge in evidence synthesis without requiring coding expertise or financial investment. By offering a streamlined, open-access platform for meta-analysis, MASimplified holds significant potential to advance evidence-based decision-making and foster methodological literacy across diverse scientific disciplines.

Availability and requirements

- Project Name: Meta-Analysis Simplified (MAS)
- Project Home Page: https://arminparavlic.shinyapps.io/MASimplified/
- Operating System(s): Platform independent.
- Web Browser Types: No limitation for existing browsers
- Programming Language: R Studio, R Shiny
- License: Free license.
- Restrictions to Use by Non-Academics: None.

Acknowledgments

NA

Informed Consent Statement

Not applicable.

Ethical Committee approval

Not applicable.

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Topic

Sport Science

Conflicts of interest

The author have no conflicts of interest to declare.

Funding

No funding was received for conducting this research. However, the research is a part of a projects funded by University of Ljubljana, Development Fund titled “The role of physical Activity in Cardiovascular disease risk reducTiOn for Non-communicable diseases. Do non-responders to exercise really exist?” (project ID: 005-1/2023, principal investigator: assist. Prof. Armin Paravlic) and “The role of physical Activity in Cardiovascular disease risk reducTiON – On the way to personalized exercise prescription (ACT-ON)” (project ID: 802-15/2023-5, principal investigator: assist. Prof. Armin Paravlic). This research also took place within the kinesiology of mono-structured, poly-structured, and conventional sports research and infrastructure program funded by the Slovenian Research Agency (ARIS) (project No. P5-0147).

Author-s contribution

The author confirms being the sole contributor of this work and has approved it for publication.

References

1. Berlin JA, Golub RM. Meta-analysis as evidence: Building a better pyramid. *Jama*. 2014;312(6):603-605.
2. Paul M, Leibovici L. Systematic review or meta-analysis? Their place in the evidence hierarchy. *Clin Microbiol Infect*. 2014;20(2):97-100.
3. Mulimani PS. Evidence-based practice and the evidence pyramid: A 21st century orthodontic odyssey. *Am J Orthod Dentofac Orthop*. 2017;152(1):1-8.
4. PubMed. Accessed February 27, 2025. https://pubmed.ncbi.nlm.nih.gov/?term=meta-analysis&size=100&filter=pubt.meta-analysis&filter=pubt.review&filter=pubt.systematicreview&timeline=expanded
5. Pricing - IBM SPSS Statistics. Accessed February 27, 2025. https://www.ibm.com/products/spss-statistics/pricing
6. Buy Stata | Stata Prof+ Plan purchases (educational). Accessed February 27, 2025. https://www.stata.com/order/new/edu/profplus/dl/
7. Academic/Non-Profit Pricing | CMA. Accessed February 27, 2025. https://meta-analysis.com/pages/academic_rates?cart=B9UA14630907
8. Review Manager (RevMan) | Cochrane Training. Accessed February 27, 2025. https://test-training.cochrane.org/online-learning/core-software-cochrane-reviews/review-manager-revman
9. Viechtbauer W. Conducting Meta-Analyses in R with the metafor Package. *J Stat Softw*. 2010;36(3):1-48.
10. Sterne JAC, Sutton AJ, Ioannidis JPA, et al. Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. *BMJ*. 2011;343(7818).
11. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ*. 1997;315(7109):629-634.
12. Borenstein M, Hedges L V., Higgins JPT, Rothstein HR. *Introduction to Meta-Analysis*. Vol 19.; 2009.
13. Chang W, Cheng J, Allaire J, Sievert C, Schloerke B, Xie Y, Allen J, McPherson J, Dipert A BB. Shiny: Web Application Framework for R. Published online 2025. https://shiny.posit.co/
14. Hadley Wickham. ggplot2: Elegant Graphics for Data Analysis. *J R Stat Soc Ser A Stat Soc*. 216AD;174(1):245-246.
15. Paravlić AH. MAS-Meta-Analysis-Simplified/data.csv at main · ArminParavlic/MAS-Meta-Analysis-Simplified. Accessed March 1, 2025. https://github.com/ArminParavlic/MAS-Meta-Analysis-Simplified/blob/main/data.csv
16. Paravlic AH, Slimani M, Tod D, Marusic U, Milanovic Z, Pisot R. Effects and Dose–Response Relationships of Motor Imagery Practice on Strength Development in Healthy Adult Populations: a Systematic Review and Meta-analysis. *Sport Med*. Published online 2018.

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Received: 03.03.2025.
Accepted: 24.03.2025.
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