

RANDOM EFFECTS META-REGRESSION USING WEIGHTED LEAST SQUARES (CASE STUDY: EFFECTIVENESS OF ACCEPTANCE AND COMMITMENT THERAPY IN REDUCING DEPRESSION)

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Abstract: Meta-analysis is a statistical method for synthesizing quantitative data from multiple related studies, yet heterogeneity among studies often complicates interpretation. Meta-regression extends this approach by incorporating study-level covariates to explain variations in outcomes. With the global increase in depression, Acceptance and Commitment Therapy (ACT) has attracted attention as an effective psychological intervention. Therefore, a deeper understanding of the factors that influence its effectiveness across studies is needed. However, to date, only a few meta-analyses have quantitatively examined moderator variables that influence ACT outcomes using a random effects meta-regression approach. This study aims to fill this gap. This study estimated the model parameters using the Weighted Least Squares (WLS) method. Thirty-three published studies testing the effectiveness of ACT in reducing depression were collected from PubMed, Google Scholar, and Science Direct. The homogeneity test results showed significant heterogeneity, supporting the use of a random effects model. The combined effect size of -0.321 indicates that ACT significantly reduces depression levels compared to the control group. Meta-regression analysis revealed that variation in effect size was significantly influenced by differences in the average age of patients and duration of therapy. These findings provide new insights into the conditions and characteristics that make ACT therapy more effective.

1. INTRODUCTION

Meta-analysis is a statistical method used to quantitatively synthesize the results of various studies in order to obtain a more accurate estimate of the effect size of a relationship. In practice, heterogeneity or variation in results between studies often arises. This condition is normal because empirical data collected from separate studies generally have fundamental differences, such as in the selection of subjects, sample size, research location, and the definition and measurement of outcome variables. To understand and explain the sources of this variation, a meta-regression approach is used, which is a statistical method in meta-analysis that aims to evaluate the extent to which study characteristics (e.g., study design, population, duration, or type of intervention) influence

the effect size between studies. Different from conventional meta-analysis, which only calculates the combined average of all studies, meta-regression allows for the analysis of the relationship between effect size and study covariates through regression models, therefore providing a deeper understanding of the factors that cause differences in research results (Mathur, M. & VanderWeele, T., 2022).

As with regular regression models, estimating the meta-regression parameters is a necessary step to meet the requirements of the Best Linear Unbiased Estimator (BLUE). However, different from conventional regression data, the data used in meta-analysis exhibit substantial heterogeneity because each study contributes an effect size with a different sampling variance and level of precision. The assumption of homoscedasticity required by the Ordinary Least Squares (OLS) method is therefore violated. Using OLS in this context treats all studies as equally reliable, which leads to inefficient and biased parameter estimates since studies with larger standard errors exert the same influence as those with more precise estimates (Sebayang & Yuniarto, 2017). To address this methodological issue, the Weighted Least Squares (WLS) approach is more appropriate for estimating meta-regression parameters. WLS assigns weights inversely proportional to each study's variance, allowing studies with greater precision to contribute more to the estimation process. This method accounts for heterogeneity and ensures that parameter estimates remain consistent, efficient, and unbiased under the BLUE framework (Stanley & Doucouliagos, 2017). Thus, WLS provides a more robust and statistically valid approach for modelling the relationship between study-level covariates and effect sizes in meta-regression.

Although many meta-regression studies have been conducted, few have explored the detailed processes involved in modeling and parameter estimation. For example, Esmaeili et al. (2023) used meta-regression to analyze global mortality rates from COVID-19 in hospitalized elderly patients, using moderators such as gender, year of publication, GDP, and continent. Their results showed that these factors explained most of the heterogeneity in the pooled estimates, but the study did not discuss the details of model construction and parameter estimation. Inspired by this gap, this study proposes a comprehensive exploration of meta-regression estimation using the WLS approach, applied to secondary data on an urgent social issue: mental health. Depression affects more than 300 million people worldwide (WHO, 2019), and psychological interventions such as counseling are essential treatments (Bai et al., 2019). Among these methods, Acceptance and Commitment Therapy (ACT) has emerged as a promising method. ACT, as a cognitive-behavioral therapy approach, utilizes acceptance, mindfulness, and behavioral change techniques to reduce experience avoidance and increase psychological flexibility (Aravind et al., 2024).

Many studies have evaluated the effectiveness of ACT in reducing depression. For example, Anggraeni & Budiarto (2020) found ACT to be effective and acceptable in reducing depression in people living with HIV/AIDS, while Ahmadsaraeri et al. (2017) reported its benefits for individuals with type II diabetes. However, conflicting evidence also exists: Williams et al. (2023) argued that standard cognitive therapy is more effective than ACT, and Parling et al. (2016) found ACT to be less effective in certain cases. These conflicting results suggest the influence of moderator factors. In fact, individual differences—such as patient age (Collins & Corna, 2018) and therapy session duration (Yun et al., 2025)—can influence response to ACT.

Using meta-regression, this study aims to explain the heterogeneity in ACT outcomes and measure how moderators such as age and therapy duration influence its effectiveness. The goal is not only to measure the average effect, but also to understand under what

conditions ACT works best.

2. LITERATURE REVIEW

2.1. Weighted Least Square

The WLS method is in principle almost the same as OLS, except that in the WLS method, the weighting of an appropriate factor is carried out and then OLS is used on the later weighted data so that the parameter estimates obtained from the WLS method are BLUE. In general, the steps of parameter estimation with the WLS method are as follows:

1. Determination of Weighting

The first stage in WLS is to determine the weight for each observation in the regression. This weight describes the level of uncertainty or reliability of the data. Usually, weights are assigned based on domain information or relevant statistical analyses (Borenstein et al., 2021).

2. Minimize the weighted sum of squared residuals.

The squared residual is the difference between the observed value and the value predicted by the regression model. In WLS, each residual is multiplied by the square root of its weight before summing (Stanley & Doucouliagos, 2017).

2.2. Meta-Analysis

Meta-analysis is a statistical procedure used to combine the results of several independent studies examining the same topic. This method provides a quantitative summary of evidence by combining the effect sizes from various studies, allowing researchers to estimate the overall direction of the effect, as well as explore the variability among study results (Borenstein et al., 2021).

- Effect Size

The utilization of effect size as a quantitative measure in meta-analysis serves the purpose of summarizing the outcomes of a study, indicating the extent of the association between variables within each study (Retnawati et al., 2018). In the field of meta-analysis, various effect size calculations are available. However, for this study, the analysis is restricted to employing the Standardized Mean Difference (SMD). This choice is made due to the fact that the primary study's reported summary data is based on the mean and standard deviation values of two distinct groups. When various studies employ different instruments, such as psychological tests, to evaluate outcomes, the measurement scale will vary across studies. To ensure meaningful comparisons, it is necessary to combine standardised mean differences (Boreinstein, 2021). The effect size value (y_i) for the i -th study is estimated as follows:

$$y_i = \frac{\bar{Y}_1 - \bar{Y}_2}{S_{pooled}} \quad (1)$$

with

$$S_{pooled} = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}} \quad (2)$$

where $\bar{Y}_1$ and $\bar{Y}_2$ indicate their respective mean scores, n_1 and n_2 represent the sample sizes of the experimental and control groups, and s_1 and s_2 denote the standard deviations of the experimental and control groups. In this study, the group that received the ACT intervention is considered the "experimental" group, while the "control" group is the group that did not receive the intervention. While the variant of y_i is written as follows:

$$var(y_i) = \frac{n_1+n_2}{n_1n_2} + \frac{(y_i)^2}{2(n_1+n_2)} \quad (3)$$

- Fixed Effect Model

Fixed effect models and random effect models are the two categories of meta-analysis models. The fixed effect meta-analysis model postulates that there is a single effect size that is provided by all of the studies in the meta-analysis. An equation with the fixed effect meta-analysis model is provided.

$$y_i = \theta + \varepsilon_i; i = 1, 2, \dots, k \quad (4)$$

where $\varepsilon_i \sim N(0, \sigma_i^2)$. y_i is the effect size of each study obtained from equation (1) with variance σ_i^2 is the variance in the study obtained from equation (3) and θ is pooled effect size parameter or the population effect size obtained from the following formula:

$$\hat{\theta} = \frac{\sum_{i=1}^k w_i y_i}{\sum_{i=1}^k w_i} \quad (5)$$

with y_i is the effect size value for the i -th study and w_i is the weight given to each study is the inverse of the variance of each study.

- Random Effect Model

The random effect meta-analysis model is given in the following equation.

$$y_i = \theta^* + u_i + \varepsilon_i; i = 1, 2, \dots, k \quad \hat{\theta} = \frac{\sum_{i=1}^k w_i y_i}{\sum_{i=1}^k w_i} \quad (6)$$

Where u is other variations due to specific effects. In the fixed effect model, there is only one source of variation, which is the sample variance σ^2 . In contrast, there are two sources of variation in the random effect model, namely the sample variance and the inter-study variance component or called heterogeneity. In other words, in the random effect model, it is not only the population effect size θ^* that is estimated using the same formula as in the fixed effects model (Equation 5), but also the variance between studies, $\tau^2 = \text{var}(u)$.

- Heterogeneity

Between-study heterogeneity is the degree to which effect sizes in a meta-analysis actually differ from one another. Heterogeneity can result from random variations in effect sizes, systematic differences between studies, or both. The following is how to apply the Dersimonian & Laird (Blazquez, et al., 2023) approach to examine heterogeneity between observations:

$$Q = \sum_{i=1}^k (w_i y_i^2) - \frac{(\sum_{i=1}^k (w_i y_i))^2}{\sum_{i=1}^k w_i} \quad (7)$$

with $w_i = 1/\sigma_i^2$. Reject H_0 if $Q > \chi_{(k-1; \alpha)}^2$. This means that the population effect size variance is heterogeneous or the population effect size is not the same in all studies. Furthermore, parameter estimation is carried out by the method introduced by Dersimonian & Laird (Blazquez et al., 2023) as follows:

$$\hat{\tau}^2 = \max \left(0, \frac{Q - (k-1)}{(\sum_{i=1}^k w_i) - \frac{\sum_{i=1}^k w_i^2}{\sum_{i=1}^k w_i}} \right) \quad (8)$$

where, τ^2 is variance between studies, k show the number of studies and Q is the heterogeneity test statistic shown in equation (7).

In determining the proportion of variance between studies that can reflect real differences or heterogeneity in effect size, the following statistics are required:

$$I^2 = \max \left\{ 0, \frac{Q - (k-1)}{Q} \right\} \times 100\% \quad (9)$$

Equation (8) has a scale between 0 and 100%. According to Borensten (2021), I^2 values at 25% are considered to have low heterogeneity, while values at 50% are considered to have moderate heterogeneity and values between 75% have high heterogeneity.

2.3. Random Effect Meta Regression

The random effect meta regression model is a model that uses one or more covariates and aims to identify which covariate variables affect the effect size. The random effect model assumes that heterogeneity between studies causes the true effect size of the study to differ. The random effect meta regression model with more than one covariate variable can be written as follows (Nakagawa et al., 2012):

$$y_i = \beta_0 + \beta_1 x_{i1} + \dots + \beta_p x_{ip} + u_i + \varepsilon_i; i = 1, 2, \dots, k \quad (10)$$

with $u_i \sim N(0, \sigma_u^2)$ and $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$.

y_i shows the effect size value of the i -th study which in this study is shown by the standardized mean difference of each study. The regression coefficients in the random effect meta regression are estimated by WLS as follows:

$$\hat{\beta} = (\mathbf{X}^T \mathbf{V}_r^{-1} \mathbf{X})^{-1} \mathbf{X}^T \mathbf{V}_r^{-1} \mathbf{y} \quad (11)$$

$\mathbf{V}_r^{-1}$ is weights used in random effects meta-regression:

$$\mathbf{V}_r^{-1} = \begin{bmatrix} \frac{1}{\sigma_1^2 + \tau^2} & 0 & \dots & 0 \\ 0 & \frac{1}{\sigma_2^2 + \tau^2} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \frac{1}{\sigma_k^2 + \tau^2} \end{bmatrix}$$

In other words, $\mathbf{V}_r^{-1}$ is a diagonal matrix that contains the values of the weights in the random effects meta-regression, which is the inverse of the within-study variance summed with the between-study variance, $w_i^* = \frac{1}{\sigma_i^2 + \tau^2}$.

The parameters τ^2 are unknown so they need to be estimated first. The estimation can be done using the following DerSimonian-Laird method.

$$\hat{\tau}^2 = \frac{Q_{\text{residual}} - (k-p)}{\{\text{tr}[\mathbf{V}^{-1}] - \text{tr}[(\mathbf{X}^T \mathbf{V}^{-1} \mathbf{X})^{-1} \mathbf{X}^T (\mathbf{V}^{-1})^T \mathbf{V}^{-1} \mathbf{X}]\}} \quad (12)$$

Testing the parameter estimation of the random-effects meta-regression model involves simultaneous tests and partial tests to determine the relationship between all covariates and the effect size. Simultaneous testing is done using the following hypothesis:

$$H_0: \beta_1 = \beta_2 = \dots = \beta_p = 0$$

$$H_1: \text{at least there is } \beta_i \neq 0, i = 1, 2, \dots, p$$

The test statistics used are as follows:

$$Q_{\text{model}} = \sum_{i=1}^k w_i (\hat{y}_i - \bar{y}_w) \quad (13)$$

where, $\hat{y}_i = \mathbf{X}(\mathbf{X}^T \mathbf{V}_r^{-1} \mathbf{X})^{-1} \mathbf{X}^T \mathbf{V}_r^{-1} \mathbf{y}$ and $\bar{y}_w = \frac{\sum_{i=1}^k w_i^* y_i}{\sum_{i=1}^k w_i^*}$ with $w_i^* = \frac{1}{\sigma_i^2 + \tau^2}$.

The critical region is to reject H_0 if $Q_{\text{model}} > \chi_{(p-1; \alpha)}^2$ with p is the number of covariates included in the model. If we reject H_0 , then there are covariates that affect the effect size. Next is a partial test on each regression coefficient parameter using the following hypothesis:

$$H_0: \beta_j = 0$$

$$H_1: \beta_j \neq 0, j = 1, 2, \dots, p$$

The test statistic used follows the distribution of z.

$$Z = \frac{\hat{\beta}_j}{SE(\hat{\beta}_j)}, j = 1, 2, \dots, p \quad (14)$$

Reject H_0 if $|Z|$ is larger than $Z_{\alpha/2}$, where α is the level of significance used. If the decision taken is Reject H_0 then the parameter affects the random effect meta regression model partially

2.4. Goodness of Fit Test in Meta Regression

In meta-regression analysis, the evaluation of model adequacy or goodness of fit is essential to determine whether the inclusion of moderator variables effectively explains between-study heterogeneity. Among various heterogeneity measures, the between-study variance (τ^2) is considered the most informative indicator for assessing model improvement. A reduction in τ^2 after adding moderators indicates that these covariates account for part of the heterogeneity, resulting in a better-fitting model (Borenstein et al., 2021).

3. MATERIAL AND METHOD

3.1. Data Sources

The secondary data used in this study, which addresses ACT and depression, was taken from studies that have already been published. The data used in this study came from searches conducted online in the Science Direct, Google Scholar, and PubMed databases. According to the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-analyses) 2020 guidelines, the studies that will be included in the meta-analysis must first be chosen. Clear inclusion and exclusion criteria should be used to screen the studies that are included in the meta-analysis.

1. Inclusion Criteria

- a. There are two keywords consisting of "ACT" and "depression".
- b. Patients were diagnosed with depression using a professional scale.
- c. Treatment intervention consisted of ACT without other types of treatment.
- d. Research with RCT study design.
- e. The research is in full text.
- f. English language research.
- g. Research published in the range of 2010-2023.

2. Exclusion Criteria

- a. Research that has an operational definition that is different from that intended in this study
- b. Duplicated research or previously published research Research that does not have enough data to analyze.

3.2. Research Variable

The definitions of the covariate variables used are

- Effect Size (Y): The effect size value is obtained from the standardized mean differences of each previous study.
- Patient Age (X_1): Patient age variable is the average age of patients obtained from demographic information in each study with units of years.
- Length of therapy (X_2): The length of therapy sessions in the intervention refers to the total length of time the patient receives ACT intervention and is calculated in weeks.

3.3. Methods

The steps of meta regression analysis in this study are as follows:

1. Collect data from research results related to the effectiveness of ACT in reducing depression. Searches were conducted in electronic databases including PubMed, Google Scholar, and ScienceDirect, using keywords such as “Acceptance and Commitment Therapy,” “ACT,” “depression”, and” RCT”.
2. Perform data selection with PRISMA 2020 guidelines. This procedure involved four main stages: (a) Identification: collecting all potentially relevant studies from the databases; (b) Screening: removing duplicates and excluding studies that did not meet the inclusion criteria; (c) Eligibility: evaluating full-text articles based on methodological quality and relevance to ACT outcomes and depression; and (d) Inclusion: selecting studies reporting sufficient quantitative data to calculate effect sizes.
3. Calculate the effect size (Standardized Mean Differences) and variance of each research data according to Equations (1) and (3).
4. Conduct a heterogeneity test according to Equation (7). If the decision taken in the heterogeneity test is to reject H_0 , the next step is to conduct a random effect analysis.
5. Perform random-effect meta-analysis. A random effects model was applied to obtain a pooled effect size that accounted for variance both within and between studies according to Equation (5).
6. Estimate the parameters of random effects meta-regression analysis using the WLS method according to Equation (11).
7. Testing the significance of random effect meta regression model parameters simultaneously and partially
8. Testing Goodness of Fit by comparing the between-study variance (τ^2) before and after including moderator variables.
9. Conclusions.

4. RESULTS AND DISCUSSION

Articles in the PubMed database were identified as many as 1627 articles. In the Science Direct and Google Scholar databases, 113 and 121 articles were identified. The total number of articles obtained from the three databases was 1861 articles. Furthermore, 48 duplicate articles were found, and 1616 articles did not discuss ACT or depression. 62 articles were not available in full text, 74 articles whose research design was not an RCT, 10 articles that were systematic reviews or meta-analyses, 2 articles found were not available in English, and 16 articles that could not be analyzed because they did not have enough data. After applying the PRISMA 2020 guidelines, 33 research articles were included in the meta-analysis. Figure 1 shows the article selection process using PRISMA 2020 guidelines.

The first step in conducting the meta-analysis was to determine the effect size (y_i) and its corresponding variance (v_i) for each study, calculated using equations (1) and (3). A total of 33 studies were included in the analysis. The distribution of individual study effect sizes and their 95% confidence intervals is presented in Figure 2. The plot shows that most studies reported negative SMD, indicating that depression levels were generally lower in the experimental group (patients receiving ACT) compared to the control group. Overall, the direction and magnitude of the effect sizes demonstrate consistent evidence of ACT's effectiveness in reducing depression.

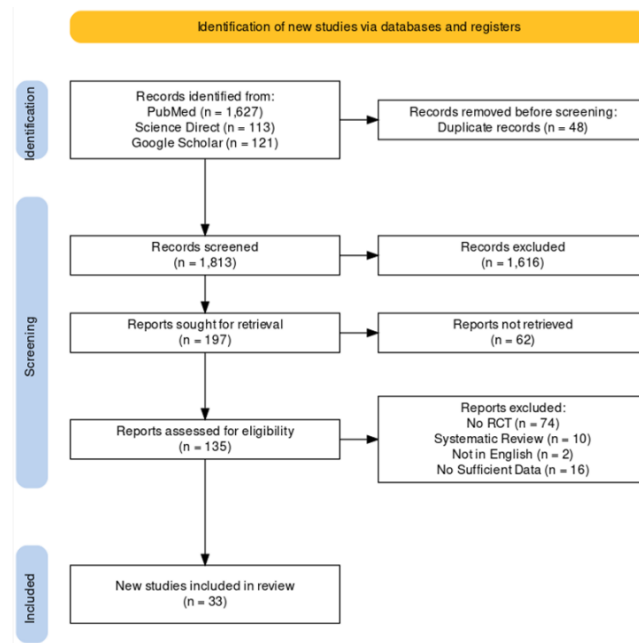


Figure1. Flowchart of Article Selection with PRISMA 2020

At this stage, we can see the results of the heterogeneity test on the effectiveness of ACT in reducing depression levels.

Table 1. Q Value

	Coefficient	Degree of freedom
Q	431.39	32

Based on Table 1, the test statistic value is obtained Q is 431.39. At the 5% significance level, we found $\chi^2_{(33-1;0.05)} = 46.19$ which means it is smaller than the value if $Q = 431.39$ so reject, which indicates that there is heterogeneity in the study population's effect size variance. This test's conclusion is that it has been demonstrated that the random effect model should be used instead of the fixed effect model.

The parameter estimation in the random-effects meta-analysis was performed using the WLS method. In this approach, each study was assigned a weight based on the inverse of its within-study variance, so that studies with higher precision contributed more strongly to the overall estimate. This weighting process minimizes the weighted sum of squared residuals and accounts for heterogeneity among studies. The estimation was carried out iteratively until the parameter values stabilized, producing unbiased and efficient estimates of the pooled effect size. The results of the estimation are presented in Table 2.

Table 2. Random Effect Meta-Analysis Results

Coefficient	Std. Error	Z-value	P-value	CI 95%
-0.321	0.1561	-2.0572	0.0397	-0.6269; -0.0152

Based on Table 2, the value of $|Z|$ is 2.0572 which is larger than $Z_{(0.05/2)} = 1.96$ so reject H_0 . This indicates that the random effect model parameters have a significant effect. The random effect meta-analysis model obtained can be written as follows.

$$\hat{y} = -0.321$$

According to the value, there is an average of 0.321 difference in depression levels between the experimental and control groups. It can be concluded that ACT is effective in reducing the level of depression because the negative value shows that the ACT intervention can reduce the level of depression as seen by the decrease in the level of depression in the

experimental group when compared to the control group. The between-study variance and a few other measures of heterogeneity are then estimated by the random effects model and are as follows.

Table 3. Random Effect Meta-Analysis Heterogeneity Measure

Heterogeneity	Value
τ^2	0.7265
τ	0.8524
I^2	92.58%

Table 3 provides information on several measures of heterogeneity. Variance between studies τ^2 estimated using the Dersimonian Laird method which is obtained at 0.7265 with a standard deviation between studies (τ) is 0.8524. I^2 shows that the heterogeneity is high at 92.58, which means that 92.58% of the total variability of the observed effect sizes can be attributed to heterogeneity among the effect size populations.

The distribution of the individual study effect sizes and their confidence intervals is illustrated in Figure 2. The plot visually demonstrates the degree of heterogeneity among studies and the overall pooled effect obtained from the random-effects model.

The forest plot (Figure 2) illustrates that most studies reported negative effect sizes, indicating a reduction in depression levels in the ACT group compared to the control group. The confidence intervals of individual studies vary in width, reflecting differences in sample size and precision. The overall effect size (-0.321) lies to the left of zero, confirming that ACT has a significant effect in reducing depression.

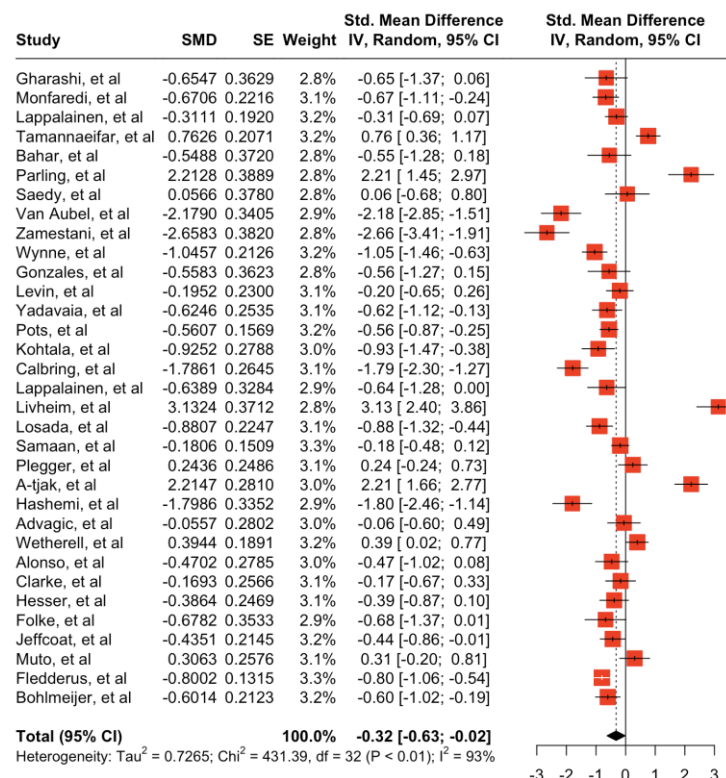


Figure 2. Forest Plot

The random-effects analysis revealed substantial heterogeneity among the 33 studies, prompting further examination using meta-regression. This analysis incorporated two covariates, average patient age (X_1) and therapy duration (X_2) to explain variations in effect size. Parameter estimation was performed using the Weighted Least WLS method, which

assigns weights inversely proportional to total variance (within- and between-study). This approach minimizes the weighted residuals and yields efficient, unbiased estimates under heterogeneity. The resulting coefficients, summarized in Table 4, represent the relationship between these covariates and the effect size across studies.

Table 4. Random Effect Meta Regression Analysis Results

	Estimate	SE	Z	P-value	CI 95%
Intercept	-0.8472	0.5368	-1.5787	0.1144	-1.8995; 0.2047
X ₁	-0.0205	0.0101	-2.0275	0.0426	-0.0403; -0.0007
X ₂	0.1634	0.0444	3.6848	0.0002	0.0765; 0.2504

Before modelling, it is necessary to conduct several tests, namely simultaneous tests and partial tests. The simultaneous test results are given as follows.

Table 5. Simultaneous Testing Results

Source of Variant	Q	df	P-value
Model (Q_{model})	16,2440	2	0,0001

Based on the results of simultaneous testing on Table 5 with a significance level of 5% obtained $\chi^2_{(2;0.05)} = 3.48$ which means it is smaller than the value of $Q_{Model} = 16.2440$ so reject H_0 which means there is at least one covariate that affects the effect size. If simultaneous testing has been carried out, the next step is to conduct a partial test of each covariate.

Partial test results with a significance level of 5%, with a value of $Z_{(0.05/2)} = 1.96$ compared to value of $|Z| = 2.0275$ for X_1 , and 3.6848 for X_2 results in a value greater than 1.96 so that the test results in rejecting H_0 , which means that the two variables individually affect the effect size.

All tests have been identified, the next step is random effect meta regression modelling which is given as follows:

$$\hat{y} = -0,8472 - 0,0205X_1 + 0,1643X_2$$

The model can be interpreted as follows:

- The coefficient of -0.0205 on the average age variable shows that the greater the average age of the patient, the lower the effect size value. In other words, the higher the patient's age, the smaller the difference in depression levels between the experimental and control groups.
- The coefficient of 0.1643 on the variable length of therapy sessions shows that the longer the length of therapy sessions, the higher the effect size value. In other words, the longer the patient receives ACT intervention, the greater the difference in depression level with the control group. This means that ACT is more effective.

The model's goodness of fit was assessed using the between-study variance (τ^2) as the primary indicator. The τ^2 value from the random-effects model was 0.7265, indicating high heterogeneity among studies. After including the moderator's average patient age and therapy duration, the residual τ^2 decreased to 0.51, suggesting that these covariates explained of the between-study heterogeneity and improved the model's overall fit.

This study found that ACT significantly reduces depression (pooled effect size = -0.321, $p < 0.05$), consistent with recent meta-analyses reporting similar effects (Ye et al., 2023; Han et al., 2022; Borenstein et al., 2021). However, unlike previous research that mainly focused on pooled estimates, this study addressed the methodological gap by applying meta-regression using the WLS method to examine study-level moderators (Stanley & Doucouliagos, 2017). The results showed that patient age and therapy duration

significantly influenced ACT's effectiveness, highlighting the contextual nature of treatment outcomes. These findings reinforce the importance of incorporating moderator analyses to enhance model accuracy and interpretability in psychological intervention research.

5. CONCLUSION

The meta-analysis results indicated significant heterogeneity among the 33 included studies ($I^2 = 92.58\%$), with a combined effect size of -0.321 , suggesting that ACT effectively reduces depression levels compared to control groups. The subsequent meta-regression analysis showed that this heterogeneity could be partially explained by study-level moderators, specifically the average age of patients and the duration of therapy sessions, both of which significantly affected ACT's effectiveness. Furthermore, the decrease in between-study variance (τ^2) from 0.7265 to 0.51 demonstrates an improvement in the model's goodness of fit.

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