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*The Diabetes Educator* 2009; 35; 818 originally published online Aug 17, 2009;
DOI: 10.1177/0145721709340929

The online version of this article can be found at:
http://tde.sagepub.com/cgi/content/abstract/35/5/818

Published by:
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On behalf of:
AADE

American Association of Diabetes Educators

# The Effect of Weight Reduction Interventions for Persons With Type 2 Diabetes

## A Meta-analysis From a Self-regulation Perspective

Sasja D. Huisman, MSc, PhD

Véronique De Gucht, MSc, PhD

Elise Dusseldorp, MSc, PhD

Stan Maes, MSc, PhD

From Leiden University (Dr Huisman, Dr De Gucht, Dr Maes), and TNO Leiden (Dr Dusseldorp), Leiden, The Netherlands.

Correspondence to Sasja D. Huisman, MSc, PhD, Leiden University, Section of Clinical and Health Psychology, Wassenaarseweg 52, PO Box 9555, 2300 RB Leiden, The Netherlands (shuisman@fsw.leidenuniv.nl).

*Acknowledgments:* This article was partially supported by the Netherlands Organization for Scientific Research grant 451-02-058 to the third author.

DOI: 10.1177/0145721709340929



### Purpose

The main purpose of this article was to investigate the value of a self-regulation approach for weight reduction interventions in patients with type 2 diabetes. In addition, the potentially moderating effect of other intervention characteristics was explored.

### Methods

In a meta-analysis of 34 studies, overall effect sizes were calculated for weight and A1C. The focus of the analysis was, however, on the moderating effect of intervention characteristics, especially whether interventions that score high on self-regulation produce stronger effects.

### Results

The overall effect sizes (*d*) for weight loss in the short term (<6 months) were low and even lower in the longer term (>6 months). The overall effect sizes for A1C outcomes were higher and remained stable in the longer term. Interventions that scored high on self-regulation characteristics produced significantly better effects on both weight and A1C outcomes. Furthermore, "goal reformulation" increased the effect on weight outcomes whereas "emotion regulation" increased the effect on A1C. With respect to the other intervention characteristics, only the "inclusion of a patient's partner or relative" increased the effect on weight loss.

## Conclusions

This meta-analysis underlines the importance of a self-regulation approach for weight reduction interventions in diabetes patients, in particular, for A1C outcomes. However, more research is needed to fully understand the relationship among self-regulation, weight, and A1C.

Since most patients with type 2 diabetes are overweight (BMI > 25), weight reduction is an essential step in the treatment of diabetes type 2. Weight loss improves the insulin absorption and decreases high blood glucose levels, which in turn reduce the risk of serious diabetes complications such as cardiovascular damage, retinopathy, neuropathy, or nephropathy.[1-3] Different interventions have therefore tried to achieve both weight loss and a decrease in A1C in overweight patients with diabetes.[4-13] However, the outcomes of these interventions are somewhat disappointing in the sense that reported weight loss effects are often small and decrease even further in the long term.[4,13] Some studies do not even report weight loss.[10-11] The intervention effects on A1C levels appear somewhat higher and less susceptible to relapse,[7-8] but some studies report a lack of effects on A1C levels as well.[6]

During the past few years a number of (systematic) reviews and meta-analyses have tried to assess the overall effect of nonsurgical and nonpharmacological weight reduction interventions in patients with type 2 diabetes[14-17] on weight and A1C. In general, it was found that behavior therapy and psychoeducation generated no effects on weight,[14-17] whereas positive effects on A1C[15] and stress outcomes[16] were found. Differences in the approach and methodology of these meta-analyses make it difficult to draw firm conclusions on the effects of interventions on weight loss and A1C in patients with type 2 diabetes. Substantial differences were found not only in the number of studies that were included in the various meta-analyses but also in the inclusion criteria that were used for the selection of the studies. Some meta-analyses specifically selected randomized controlled trials,[15-17] whereas other meta-analyses also included 1 group pretest/posttest designs.[14] Some meta-analyses primarily focused on intervention effects on A1C and provided only limited data on effects on weight.[15-16] Furthermore, although some meta-analyses described intervention characteristics such as "frequency of contact," "type of interventions,"[15-16] or "behavioral strategies,"[17] none of them were grounded in sound psychological theory. Furthermore, no moderator analyses were conducted to examine whether specific intervention characteristics moderated the overall effect sizes and as a consequence it remains unclear whether the effectiveness of existing interventions can be increased by focusing on specific education or behavior change components or principles. As already stated, identifying and categorizing existing intervention principles and mechanisms that are effective ingredients of diabetes self-management programs directed at weight control and A1C requires a sound theoretical framework, from which a taxonomy of intervention principles can be derived.[18]

Self-regulation theory provides such a framework. Self-regulation can be defined as a sequence of actions and/or steering processes to attain a personal goal.[19] A basic premise of self-regulation is that motivation to change behavior results from the wish to reduce a perceived discrepancy between one's actual and desired state.[20] Along this premise, it is assumed that all behavior is goal-directed and that goal related processes, such as goal setting, feedback and emotion regulation facilitate goal attainment.[21,22] This goal attainment process consists of at least the following 3 phases: (1) a phase of goal selection and goal setting; (2) a phase of active goal pursuit; and (3) a phase of goal attainment, maintenance, or disengagement.[19] In the goal selection and goal setting phase, goal ownership plays a key role. Usually, health related intervention targets such as weight loss, quitting smoking, or engaging in physical exercise are set for the individual, rather than by the individual, without relating these targets to the individual's preexisting personal goals. As a consequence, other personal goals are frequently in conflict with the attainment of externally set health targets, resulting in disengagement from the target. Deci and Ryan[23] have repeatedly demonstrated that autonomous regulation, which is setting and pursuing personally relevant health goals, produces notable effects in terms of life-style changes, medication adherence, and disease management outcomes.[24-26] Next to goal ownership, the value of goal setting and planning for diabetes self-care behaviors such as diet and physical exercise have been well-documented.[27,28]

The transition from the first phase to the active goal pursuit phase is facilitated by both cognitive and affective processes.[19] Positive and negative affects function as positive and negative reinforcers of goal pursuit.[29] The cognitive processes that facilitate goal achievement are categorized into three types: (1) feedback mechanisms, which refer to the ability to evaluate and monitor goal progress on the basis of results; (2) feed forward mechanisms, which consist of expectations with regard to the outcome of goal pursuit as well as efficacy expectations, and (3) activation of control processes, such as control over distracting emotions, being able to focus on goal-related information, being able to motivate oneself, and using failure as an opportunity for learning.[29]

The importance of feedback mechanisms, such as the self-monitoring of nutrition and exercise behavior and keeping track of progress with regard to weight loss, is used in many weight reduction interventions.[6,8,30-33] Moreover, for most insulin-dependent patients with diabetes the self-monitoring of blood glucose levels has become a daily routine. Feed forward mechanisms in health interventions are usually represented by a focus on self-efficacy mechanisms. Self-efficacy has been frequently shown to relate to the adoption and performance of various health behaviors, such as adherence to medication,[34] physical exercise,[35] and diabetes self-care.[36] Furthermore, self-efficacy has been proven to be an important mediator of successful weight loss behaviors.[37,38] To our knowledge, the activation of control processes have not been linked to weight loss in existing studies.

Maintaining weight loss is one of the biggest challenges for both patients and health care providers. Numerous weight reduction interventions have shown the relative simplicity of losing weight in the short term and the extreme difficulty of maintaining weight loss in the longer term. Preventing patients from relapsing to old behaviors and habits is a prerequisite for every successful weight reduction intervention.[39,40]

While many weight reduction interventions included at least one or several of these self-regulation aspects, a systematic categorization of these principles is needed to identify effective intervention components. For this purpose, in a review on self-regulation, physical health, and illness, Maes and Karoly[19] described 14 principles that proved to be effective for the self-management of health problems.

In the present meta-analysis, the objective was to explore the value of self-regulation for weight reduction interventions in patients with type 2 diabetes. The main research questions of this meta-analysis were:

1. Do (specific) self-regulation principles increase the overall effect of weight reduction interventions on weight loss and/or A1C?
2. Do other intervention characteristics, including length of intervention or number of sessions, moderate the overall effect of weight reduction interventions on weight loss and/or A1C?

## Methods

Web of Science, Pubmed, and WebSPIRS were searched for relevant articles on weight reduction interventions in patients with diabetes type 2. Keywords that were used in different combinations for this search were: diabetes (type 2/II), behavioral interventions, weight, self-regulation, self-management, weight reduction, weight change, meta-analysis, and review. Reference lists from selected studies were screened for other relevant studies. In addition, experts in the field were contacted in an effort to obtain relevant unpublished material. The literature search was limited to randomized controlled trials published in English between 1990 and 2005. Furthermore, the following inclusion criteria were defined: a nonsurgical/nonpharmacological intervention in an outpatient setting or included at least 1 nonsurgical/nonpharmacological condition; interventions were carried out in adults with type 2 diabetes; the number of participants in the intervention and control group was more than 10; data specified the weight (loss) and A1C of participants before and after treatment, which permitted the calculation of effect sizes. All studies were subjected to the Cochrane Depression, Anxiety, and Neurosis Criteria for the quality assessment of psychological randomized controlled trials.[41,42] No exclusion criteria were applied concerning the use of medication in patients. This selection procedure yielded 34 studies (5469 patients in total) that met all the criteria and were included in the final meta-analysis (see Figure 1).

Study features were independently rated by 2 health psychologists. The average agreement between the 2 coders across the moderator variables was 84% (average Cohen's kappa = 0.7). The self-regulatory principles were coded according to the definitions of the self-regulation principles for interventions.[19] Self-regulation principles were coded as not present = 0, present to some extent = 1, and present to a great extent = 2. The total amount of self-regulation was calculated by adding the scores (0-2) of the various self-regulation principles. Then, a median

Table 1

Study and Intervention Characteristics

| Author | Subjects | Self-Regulation Principles[a] | Focus | IND/GR | Channel | Session | LENG | MSPO |
|---|---|---|---|---|---|---|---|---|
| Agurs-Collins, et al[30] | 64 overweight African-Americans, aged 55-79 years, with diabetes type 2 | GS (2), FE (1), REL (1), SM (2), AC (1) | Diet and exercise | Individual and group | Face to face | 19 sessions × 1½ h | 26 wk | 3, 6 mo |
| Ash, et al[4] | 51 overweight men with diabetes type 2 <70 years | SM (1) | Diet | Individual | Face to face and phone | 7 sessions | 12 wk | 12 wk, 18 mo |
| Campbell, et al[5] | 70 subjects with diabetes type 2, BMI ≥ 25 | GS (1), OW (1), PL (1), RE (1), AC (2), TA (1) | Diet | Group | Face to face | 13½ h in 11 wk | 11 wk | 1, 3, 6 mo |
| Campbell, et al[6] | 59 diabetes type 2 patients in behavioral program | GS (1), OW (1), PL (1), FE (1), EF (1), EM (1), CO (1), SM (1), GR (1), TA (1) | Diet and exercise | Individual | Face to face and phone | >6 sessions × 1 h | 52 wk | 3, 6, 12 mo |
| D'Eramo-Melkus, et al[7] | 82 diabetes type 2 patients, 21-65 years, 20%-75% of desirable weight | GS (1), OW (1), FE (1), CO (1), SM, SR | Diet | Individual and group | Face to face | 13 sessions × 2 h | 11 wk | 3, 6 mo |
| DiLoreto, et al[8] | 182 patients with type 2 diabetes in behavioral program | GS (1), OW (2), FE (2), EF (2), RE (1), CO (1), SM (2), GR (1), AC (2) | Exercise | Individual | Face to face and phone | 8 sessions × ¼-½ h | 104 wk | 2 y |
| Franz, et al[43] | 179 men and women 38-76 years, diabetes type 2 | GS (1), OW (1), PL (1), FE (1), SM (2), TA (1) | Diet | Individual | Face to face | 3 sessions × ½-1 h | 6 wk | 6 wk, 6 mo |
| Glasgow, et al[46] | 102 persons >60 years with diabetes type 2 | GS (2), OW (2), PL (1), FE (1), EF (1), EM (1), REL (1), CO (1), SM (2), AC (2) | Diet and exercise | Group-based | Face to face | 10 sessions and exercise sessions | 12 wk | 3, 6 mo |
| Goldhaber-Fiebert, et al[9] | 75 adults with diabetes type 2 | GS (2), OW (2), PL (1), FE (1), EF (1), SM (2) | Diet and exercise | Individual and group | Face to face | 11 sessions + 36 exercise × 1-1½ h | 12 wk | 12 wk |

*(continued)*

Table 1 (continued)

| Author | Subjects | Self-Regulation Principles[a] | Focus | IND/GR | Channel | Session | LENG | MSPO |
|---|---|---|---|---|---|---|---|---|
| Goudswaard, et al[47] | 54 patients (39-75 years) taking maximal dosages of oral hypoglycemic agents | GS (1), OW (1), FE (1), CO (1), SM (2), AC (1) | Diet and exercise | Individual | Face to face | 6 sessions × ¼-¾ h | 26 wk | 3, 6, 18 mo |
| Keyserling, et al[48] | 200 African-American women ≥40 years with diabetes type 2 | GS (1), OW (1), EF (1), SM (2) | Diet and exercise | Individual and group | Face to face and phone | 7 sessions × 1½ h | 26 wk | 6, 12 mo |
| Kirk, et al[12] | 70 inactive diabetes type 2 patients | GS (1), FE (1), EF (1). REL (1), CO (1), SM (2), AC (1), TA (1) | Exercise | Individual | Face to face and phone | 1 session × ½ h | 13 wk | 6 mo |
| Kirk, et al[10] | 70 inactive people with type 2 diabetes | GS (1), PL (1), FE (1), REL (1), CO (1), AC (1) | Exercise | Individual | Face to face and phone | 1 sessions × ½ h | 39 wk | 6, 12 mo |
| Kirkman, et al[49] | 275 veterans with type 2 diabetes | GS (1), PL (1), FE (1), REL (1) | Diet and exercise | Individual | Phone | Only phone calls | 52 wk | 12 mo |
| Ligtenberg, et al[11] | 58 patients with type 2 diabetes | GS (1), FE (1), EF (1), SM (1) | Exercise | Individual and group | Face to face and phone | 18 sessions × 50 min | 26 wk | 6, 12, 26 wk |
| Mayer-Davis, et al[13] | 152 persons with diabetes living in rural communities | GS (1), OW (1), SM (1) | Diet and exercise | Individual | Face to face | 26 sessions × 1 h | 52 wk | 3, 6, 12 mo |
| Nadeau, et al[50] | 48 subjects with diabetes type 2 | GS (1), PL (1), SM (1) | Diet | Individual | Face to face | — | 35 wk | 4, 8 mo |
| Pascale, et al[51] | 44 obese women with NIDDM | GS (1), FE (2), EF (1), EM (1), CO (1), SM (2), AC (1) | Diet and exercise | Group | Face to face | 20 sessions | 16 wk | 16 wk, 1 y |
| Redmon, et al[52] | 59 overweight or obese individuals with type 2 diabetes | GS (1), PL (1) | Diet and exercise | Individual | Face to face | 3-6 sessions | 52 wk | 1 y |

*(continued)*

Table 1 (continued)

| Author | Subjects | Self-Regulation Principles[a] | Focus | IND/GR | Channel | Session | LENG | MSPO |
|---|---|---|---|---|---|---|---|---|
| Rickheim, et al[53] | 170 subjects with type 2 diabetes | GS (1), OW (2), FE (2), EF (1), RE (1), EM (1), REL (1), CO (1), SM (2) | Diet | Individual and group | Face to face | 4 sessions × 1-3 h | 26 wk | 6 mo |
| van Rooijen, et al[45] | 157 type 2 diabetes female subjects | GS (1), FE (2), EF (1), SM (2) | Exercise | Individual and group | Face to face | 6 sessions × ¾ h | 12 wk | 12 wk |
| Samaras, et al[54] | 26 nonexercising NIDDM patients | GS (1), OW (2), FE (1), EF (2), SM (2) | Exercise | Group | Face to face | 6-12 sessions × 1 h | 26-52 wk | 6 mo, 1 y |
| Sone, et al[55] | 2205 patients with previously diagnosed type 2 diabetes | GS (2), FE (1), SM (2) | Diet and exercise | Individual | Phone | Only phone calls × ¼ h | 156 wk | 3 y |
| Trento, et al[56] | 120 patients < 80 years with NIDDM | GS (1), FE (1), EF (1) | Diet and exercise | Group | Face to face | 4 sessions × 1 h | 52 wk | 1 y |
| Trento, et al[57] | 112 type 2 patients | GS (2), FE (2), EF (1), EM (1), CO (1), SM (2), AC (1) | Diet and exercise | Group | Face to face | 8 sessions | 104 wk | 2y |
| Trento, et al[44] | 56 patients with type 2 diabetes and 56 controls | GS (2), PL (1), FE (2), EF (2), EM (1), CO (1), SM (2), AC (2) | Diet and exercise | Group and individual | Face to face | 15 sessions | 208 wk | 4 y |
| Tudor-Locke, et al[58] | 47 overweight/obese sedentary individuals from diabetes center | GS (1), OW (2), PL (1), FE (2), SM (2), TA (1) | Exercise | Group and individual | Face to face and phone and mail | 4 sessions | 16 wk | 16, 24 wk |
| Uusitupa, et al[59] | 86 patients with type 2 diabetes, aged 40-64 years | GS (2), OW (1), PL (1), SM (1) | Diet and exercise | Group and individual | Face to face | 6 sessions | 52 wk | 3, 9, 15, 27 mo |
| Vanninen, et al[60] | 45 male newly diagnosed type 2 diabetes patients | GS (2), PL (1), EF (1), SM (2) | Diet and exercise | Group and individual | Face to face | 6 sessions | 52 wk | 1 y |

*(continued)*

Table 1 (continued)

| Author | Subjects | Self-Regulation Principles[a] | Focus | IND/GR | Channel | Session | LENG | MSPO |
|---|---|---|---|---|---|---|---|---|
| Vanninen, et al[60] | 33 female newly diagnosed type 2 diabetes patients | GS (2), PL (1), EF (1), SM (2) | Diet and exercise | Group and individual | Face to face | 6 sessions | 52 wk | 1 y |
| Varroud-Vial, et al[61] | 340 patients with type 2 diabetes | GS (2), PL (1), FE (1), SM (1) | Diet and exercise | Individual | Face to face | — | 52 wk | 1 y |
| Wing, et al[31] | 49 obese patients with diabetes and obese spouses | GS (1), EM (1), REL (1), SM (2), SR (1), AC (2) | Diet and exercise | Group | Face to face | 20 sessions × 1 h | 20 wk | 20 wk, 1 y |
| Wing, et al[32] | 36 obese patients with type 2 diabetes | GS (2), OW (1), PL (1), EF (1), EM (1), CO (1), SM (1), AC (1) | Diet and exercise | Group | Face to face | 25 sessions × 1 h | 20 wk | 20, 72 wk |
| Wing, et al[33] | 93 overweight persons with type 2 diabetes, 30-70 years | GS (2), PL (1), FE (1), EM (1), REL (1), SM (2) | Diet and exercise | Group | Face to face | 52 sessions | 52 wk | 1, 2 y |

Abbreviations: AC, Anticipatory Coping; CO, Control over Competing goals; EC, Emotion Control; EF, Goal Efficacy; FE, Feedback; GR, Goal Reformulation; GS, Goal-setting; OW, Goal Ownership; PL, Planning; RE, Realistic outcome expectancies; REL, Relapse prevention; SM, Self-monitoring; SR, Self-reinforcement; TA, Tailoring; IND/GR, Individual or Group-based Intervention; LENG, Length of intervention; MSPO, Measurement points in study.

[a] Self-regulation principles present at least to some extent.

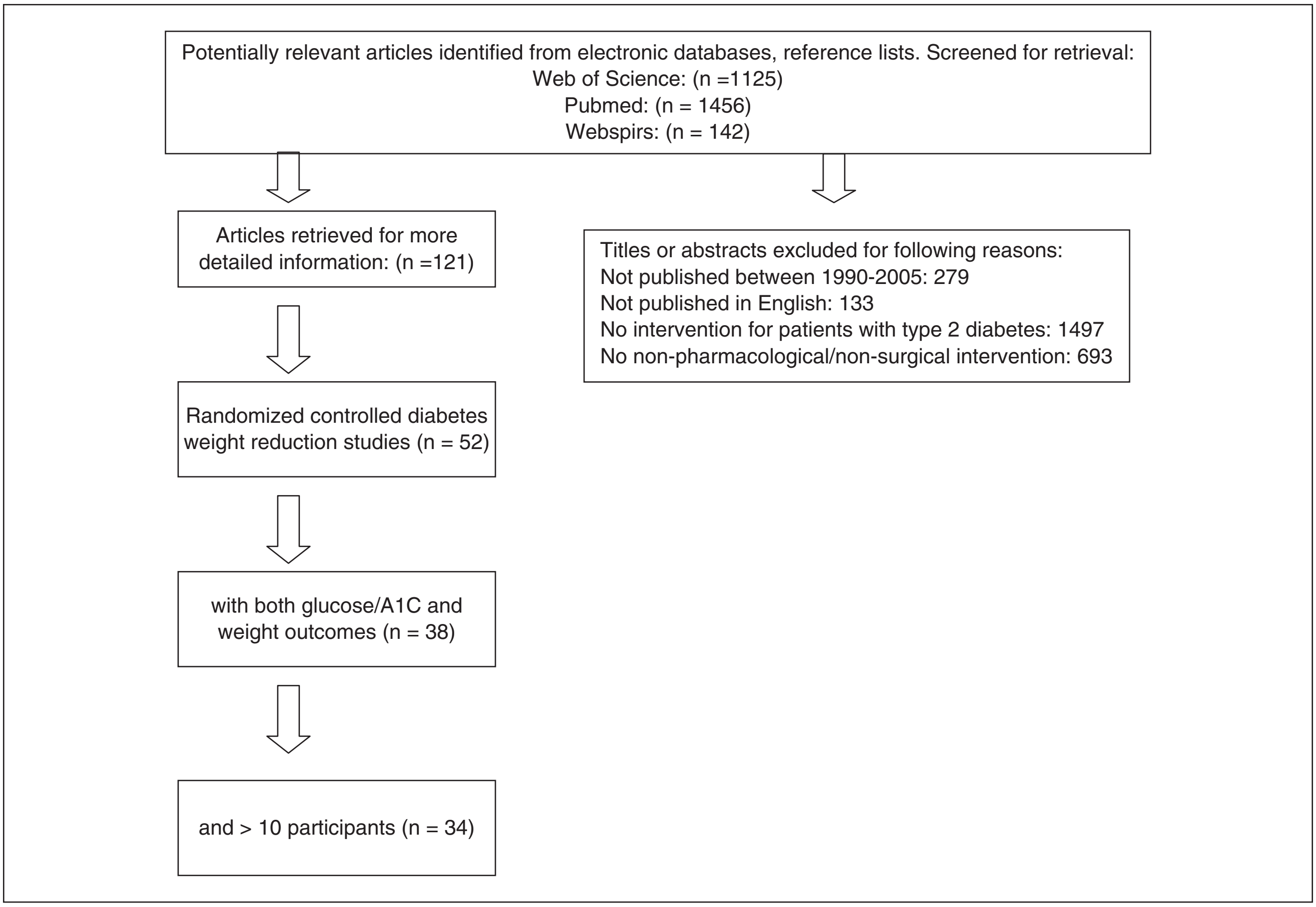


**Figure 1.** Systematic flow diagram of included studies.

split divided the total self-regulation scores into a high score (above the median) and a low score (below the median).

Since many interventions were provided by various types of health care workers, the professions of the various providers were coded as either present or absent (yes/no).

The studies were coded for data that permitted the computation of effect sizes. Pretest and posttest weight, BMI, and A1C scores and change scores in weight, BMI, and A1C were screened and coded. The measurement point in time for all posttest data and change-scores was also coded. Measurement points up to 6 months were defined as short-term measurements. Measurement points above 6 months were defined as long-term measurements.

Finally, when a study compared 2 similar interventions to a control group (eg, 2 different types of a diet), the intervention containing the highest number of self-regulation principles was selected as the experimental group.

## Statistical Analyses

Standardized mean difference effect size estimates (*d*) were calculated using Borenstein, Rothstein, and Cohen's Comprehensive Meta-Analysis Program (CMA, version 2.2).[43] Pretest/posttest scores for weight and A1C (raw means and standard deviations) were used to compute the study effect sizes. The mean differences were standardized by the posttest standard deviation (see formula 1 in Appendix). If studies reported standard errors instead of standard deviations, standard deviations were computed by multiplying the standard error with the square root of the number of subjects in the specific group. When studies reported change data only, we used the change scores (mean changes and standard deviations, or mean changes and paired *P* values) to compute the study effect sizes, assuming a pretest/posttest correlation of 0.50 (see formula 2 in the Appendix). Since only 1 study reported a

Table 2

Population Effect Size Estimates for Weight Reduction Interventions in Patients With Type 2 Diabetes

| Outcome | Measurement Period | k | d | 95% CI | | Q |
|---|---|---|---|---|---|---|
| Weight | Short | 25 | 0.18[c] | 0.08 | 0.27 | 35.98[a] |
| | Long | 21 | 0.06[a] | 0.00 | 0.13 | 24.63 |
| | Combined | 36 | 0.08[b] | 0.03 | 0.14 | 44.21 |
| A1C | Short | 23 | 0.35[c] | 0.20 | 0.50 | 47.95[c] |
| | Long | 18 | 0.34[c] | 0.14 | 0.54 | 88.90[c] |
| | Combined | 32 | 0.35[c] | 0.21 | 0.49 | 129.73[c] |

Abbreviations: CI, confidence interval; d, weighted average standardized mean difference; k, number of studies; Q, test of homogeneity.
[a] $P < .05$.
[b] $P < .01$.
[c] $P < .001$.

pretest/posttest correlation, we could not compute an average pretest/posttest correlation.

The population effect sizes (ie, the weighted average effect size *d*) were also computed with CMA for the short term and long term separately, and for the combined term. The combined term consisted of the study effect size for the longest term available. *Q*-statistics were computed to test the null hypothesis of homogeneity of a specific set of study effect sizes. For a heterogeneous set, the random effect estimates with the 95% confidence intervals were reported, while for a homogeneous set the fixed effect estimates with the 95% confidence intervals were reported. To improve the power of the analyses, moderator analyses were conducted only for the study effect sizes of the combined term. Again, the *Q*-statistic was computed to test the homogeneity of the specific subset of study effect sizes. Depending on the homogeneity of the subset either the random population effect sizes with the 85% confidence intervals or the fixed population effect sizes with the 85% confidence intervals was reported. Calculating the 85% confidence intervals served as a significance test for the moderator effect under a random error model.[44] A significantly different effect size in moderator subsets was indicated by nonoverlapping 85% confidence intervals.

## Results

A total of 34 studies were included in the meta-analysis[4-13,30-33,45-63](see Table 1). The average length of the intervention was 43.8 weeks (SD = 42.9) with a minimum of 6 weeks[45] and a maximum of 208 weeks.[46] The posttest measurements varied from 12 weeks[9,47] to 4 years,[46] with an average of 58.5 weeks (SD = 41.7). Almost all studies primarily used face-to-face contacts to provide patients with information regarding weight loss and changes in A1C-levels. Therefore, this variable was not included in the moderator analyses.

## Population Effect Sizes for Weight and A1C

In Table 2, the population effect sizes for weight and A1C in the short and the long term are presented. Significant effects were found for all measurement periods on both weight and A1C.

The average population effect size estimate for weight (25 studies) in the short term was 0.18. This is only a small effect according to Cohen's effect size classification.[64] In the longer term (>6 months) the effect size decreases even further to 0.06. In general, the population effect size estimates for A1C were found to be higher and also more heterogeneous than for weight. For A1C the average population effect size estimate in the short term was 0.35, which can be considered a medium effect. Surprisingly, this effect did not decrease over time. The medium effect size remained 0.34, even in the longer term (>6 months).

## Moderator Effects

Moderators were examined for the longest available term (see statistical analyses). The total amount of self-regulation

Table 3

Moderator-Analyses with Self-regulation Principles to Explain Differential Effects on Weight and A1C

| Outcome | Self-Regulation Principle | *k* | N | *d* | 85% CI | | *Q* | Moderator/Trend |
|---|---|---|---|---|---|---|---|---|
| Weight | Self-regulation high/low | | | | | | | Moderator |
| | Low (<7 sr points) | 17 | 3488 | 0.04 | –0.01 | 0.08 | 17.669 | |
| | High (≥7 sr points) | 18 | 1520 | 0.17[c] | 0.10 | 0.24 | 16.513 | |
| A1C | Self-regulation high/low | | | | | | | Moderator |
| | Low (<7 sr points) | 15 | 3315 | 0.127[c] | 0.08 | 0.18 | 65.274[c] | |
| | High (≥7 sr points) | 17 | 1459 | 0.470[c] | 0.39 | 0.55 | 35.198[b] | |
| Weight | Goal setting | | | | | | | |
| | Not at all | 3 | 231 | 0.15 | –0.047 | 0.346 | 0.68 | |
| | To some extent | 21 | 2250 | 0.19[c] | 0.120 | 0.258 | 21.72 | |
| | Very much | 12 | 3025 | 0.01 | –0.039 | 0.066 | 12.97 | |
| A1C | Goal setting | | | | | | | |
| | Not at all | 1 | 58 | 0.29 | –0.09 | 0.67 | 0.00 | |
| | To some extent | 19 | 1691 | 0.34[b] | 0.18 | 0.49 | 77.13[c] | |
| | Very much | 12 | 3025 | 0.40[c] | 0.24 | 0.55 | 48.51[c] | |
| Weight | Goal ownership | | | | | | | |
| | Not at all | 23 | 3773 | 0.06 | 0.011 | 0.105 | 28.16 | |
| | To some extent | 6 | 546 | 0.08 | –0.050 | 0.200 | 2.25 | |
| | Very much | 7 | 725 | 0.21 | 0.097 | 0.313 | 10.56 | |
| A1C | Goal ownership | | | | | | | |
| | Not at all | 20 | 3564 | 34[c] | 0.21 | 0.48 | 85.90[c] | |
| | To some extent | 5 | 485 | 0.17 | 0.04 | 0.31 | 9.12 | |
| | Very much | 7 | 725 | 0.49[c] | 0.29 | 0.68 | 16.73[c] | |
| Weight | Planning | | | | | | | Trend |
| | Not at all | 23 | 3698 | 0.22[c] | 0.133 | 0.300 | 37.97[a] | |
| | To some extent | 13 | 134 | 0.04 | –0.042 | 0.118 | 5.43 | |
| | Very much | | | | | | | |
| A1C | Planning | | | | | | | |
| | Not at all | 21 | 3645 | 0.38[c] | 0.23 | 0.52 | 112.74[c] | |
| | To some extent | 11 | 1129 | 0.36[c] | 0.28 | 0.45 | 11.02 | |
| | Very much | | | | | | | |
| Weight | Feedback | | | | | | | |
| | Not at all | 14 | 946 | 0.20[b] | 0.102 | 0.29 | 9.21 | |
| | To some extent | 14 | 3223 | 0.02 | –0.034 | 0.067 | 14.86 | |
| | Very much | 8 | 875 | 0.20[b] | 0.098 | 294 | 10.85 | |
| A1C | Feedback | | | | | | | |
| | Not at all | 11 | 712 | 0.29 | 0.03 | 0.55 | 52.08[c] | |
| | To some extent | 14 | 3223 | 0.34[c] | 0.22 | 0.46 | 37.20[c] | |
| | Very much | 7 | 839 | 0.51[c] | 0.30 | 0.69 | 20.54[b] | |
| Weight | Goal efficacy | | | | | | | Moderator |
| | Not at all | 20 | 3587 | 0.04 | –0.008 | 0.069 | 23.09 | |
| | To some extent | 13 | 1001 | 0.13[a] | 0.040 | 0.224 | 13.04 | |
| | Very much | 3 | 456 | 0.29[b] | 0.150 | 0.422 | 1.29 | |

*(continued)*

Table 3 (continued)

| Outcome | Self-Regulation Principle | k | N | d | 85% CI | | Q | Moderator/Trend |
|---|---|---|---|---|---|---|---|---|
| A1C | Goal efficacy | | | | | | | |
| | Not at all | 16 | 3317 | 0.32[b] | 0.17 | 0.47 | 72.75[c] | |
| | To some extent | 13 | 1001 | 0.36[c] | 0.21 | 52 | 32.82[c] | |
| | Very much | 3 | 456 | 0.51[a] | 0.16 | 0.84 | 6.82[b] | |
| Weight | Realistic outcome expectancies | | | | | | | |
| | Not at all | 33 | | 0.07[a] | 0.026 | 0.112 | 38.84 | |
| | To some extent | 3 | | 0.19[a] | 0.064 | 0.325 | 3.64 | |
| | Very much | | | | | | | |
| A1C | Realistic outcome expectancies | | | | | | | |
| | Not at all | 30 | 4342 | 0.32[c] | 0.22 | 43 | 104.20[c] | |
| | To some extent | 2 | 432 | 0.68[c] | 0.24 | 1.12 | 9.77[b] | |
| | Very much | | | | | | | |
| Weight | Emotion control | | | | | | | |
| | Not at all | 24 | 3991 | 0.08[b] | 0.036 | 0.127 | 30.13 | |
| | To some extent | 12 | 1053 | 0.08 | –0.010 | 0.169 | 14.08 | |
| | Very much | | | | | | | |
| A1C | Emotion control | | | | | | | Moderator |
| | Not at all | 21 | 3757 | 0.25[b] | 0.14 | 0.37 | 68.79[c] | |
| | To some extent | 11 | 1017 | 0.55[c] | 0.41 | 0.70 | 21.59[a] | |
| | Very much | | | | | | | |
| Weight | Relapse prevention | | | | | | | |
| | Not at all | 28 | 4501 | 0.08[b] | 0.033 | 0.120 | 36.12 | |
| | To some extent | 8 | 543 | 0.12 | -0.006 | 0.243 | 7.88 | |
| | Very much | | | | | | | |
| A1C | Relapse prevention | | | | | | | Trend |
| | Not at all | 25 | 4277 | 0.29[c] | 0.18 | 0.41 | 92.49[c] | |
| | To some extent | 7 | 497 | 0.59[c] | 0.38 | 0.80 | 14.96[a] | |
| | Very much | - | - | - | - | - | - | |
| Weight | Control over competing goals | | | | | | | Trend |
| | Not at all | 23 | 3879 | 0.06 | .009, | .102 | 31.69 | |
| | To some extent | 13 | 1165 | 0.17[b] | 0.081 | 0.251 | 9.85 | |
| | Very much | | | | | | | |
| A1C | Control over competing goals | | | | | | | Trend |
| | Not at all | 19 | 3609 | 0.28[b] | 0.14 | 0.41 | 81.89[c] | |
| | To some extent | 13 | 1165 | 0.48[c] | 0.36 | 0.61 | 21.32[a] | |
| | Very much | | | | | | | |

*(continued)*

Table 3 (continued)

| Outcome | Self-Regulation Principle | *k* | N | *d* | 85% CI | | Q | Moderator/Trend |
|---|---|---|---|---|---|---|---|---|
| Weight | Self-monitoring | | | | | | | |
| | Not at all | 6 | 48483 | 0.10 | –0.041 | 0.232 | 1.13 | |
| | To some extent | 8 | 2 | 0.13 | 0.026 | 0.227 | 7.47 | |
| | Very much | 22 | 3728 | 0.16[b] | 0.078 | 0.242 | 35.04[a] | |
| A1C | Self-monitoring | | | | | | | |
| | Not at all | 4 | 267 | 0.74 | 0.33 | 0.69 | 31.41[c] | |
| | To some extent | 7 | 815 | 0.32[c] | 0.22 | 42 | 11.58 | |
| | Very much | 21 | 3692 | 0.34[c] | 0.21 | 0.46 | 79.20[c] | |
| Weight | Self-reinforcement | | | | | | | Trend |
| | Not at all | 33 | 4941 | 0.08[b] | 0.034 | 0.117 | 38.86 | |
| | To some extent | 3 | 103 | 0.35 | 0.060 | 0.638 | 3.54 | |
| | Very much | | | | | | | |
| A1C | Self-reinforcement | | | | | | | Trend |
| | Not at all | 30 | 4707 | 34[c] | 0.23 | 0.44 | 124.42[c] | |
| | To some extent | 2 | 67 | 0.71[b] | 0.33 | 1.09 | 1.94 | |
| | Very much | | | | | | | |
| Weight | Goal reformulation | | | | | | | Moderator |
| | Not at all | 34 | 4634 | 0.06[a] | 0.017 | 0.102 | 37.61 | |
| | To some extent | 2 | 410 | 0.33[c] | 0.181 | 0.472 | 0.18 | |
| | Very much | | | | | | | |
| A1C | Goal reformulation | | | | | | | |
| | Not at all | 30 | 4364 | 0.35[c] | 0.24 | 0.46 | 126.134[c] | |
| | To some extent | 2 | 410 | 0.41[c] | 0.26 | 0.56 | 0.425 | |
| | Very much | | | | | | | |
| Weight | Anticipatory coping | | | | | | | Trend |
| | Not at all | 21 | 3722 | 0.03 | –0.010 | 0.085 | 25.64 | |
| | To some extent | 11 | 786 | 0.21[b] | 0.100 | 0.313 | 9.52 | |
| | Very much | 4 | 536 | 0.21[a] | 0.089 | 0.33 | 2.08 | |
| A1C | Anticipatory coping | | | | | | | Trend |
| | Not at all | 20 | 3705 | 0.28[b] | 0.14 | 0.41 | 97.842[c] | |
| | To some extent | 9 | 594 | 0.47[c] | 0.34 | 0.59 | 10.870 | |
| | Very much | 3 | 475 | 0.47[c] | 0.33 | 0.60 | 3.593 | |
| Weight | Tailoring | | | | | | | |
| | Not at all | 30 | 4536 | 0.09[b] | 0.042 | 0.128 | 40.90 | |
| | To some extent | 6 | 508 | 0.05 | –0.081 | 0.178 | 3.16 | |
| | Very much | | | | | | | |
| A1C | Tailoring | | | | | | | |
| | Not at all | 27 | 4327 | 0.34[c] | 0.23 | 0.45 | 104.325[c] | |
| | To some extent | 5 | 447 | 0.42[a] | 0.12 | 0.72 | 18.558[c] | |
| | Very much | | | | | | | |

Abbreviations: *k*, number of studies; *d*, weighted average standardized mean difference; CI, confidence Interval; *Q*, test of homogeneity,
[a] $P < .05$.
[b] $P < .01$.
[c] $P < .001$.

principles included in the interventions moderated the effect for both weight and A1C, which indicated that the effect of weight reduction interventions can be increased by including more self-regulation principles (Table 3). With respect to the specific self-regulation principles that were examined, "goal reformulation" was a significant moderator for weight, and "emotional control" was a significant moderator for A1C. These effects were in the expected direction. Although the overlapping confidence intervals of the other self-regulation principles indicated that from a strictly methodological perspective these could not be seen as real moderators, trends of moderation were found with regard to "discussing competing goals," "positive reinforcement" and "anticipatory coping" on weight and A1C outcomes. For A1C, these moderating effects were even stronger than for weight outcomes. "Relapse prevention" showed a moderating trend for A1C only. An unexpected negative trend was found for the effect of "planning" on weight. Interventions that did not include "planning" had significantly higher effect sizes than interventions that did include "planning."

Finally, as far as the other study characteristics were concerned, only "involvement of a partner or relative" in an intervention moderated the effect size for weight (Table 4). Interventions that included a patient's partner or relative had significantly higher effect sizes than interventions that did not take into account a patient's partner or relative. None of the other intervention features, such as the focus of treatment, individual treatment versus group treatment, the length of the intervention, or the number of sessions moderated the effect on either weight or A1C outcomes.

## Conclusion and Discussion

The purpose of this meta-analysis was two-fold. The first objective was to explore whether the inclusion of self-regulation principles increased the overall effectiveness of weight loss interventions on both weight and A1C. Second, the moderating influence of other specific intervention characteristics on the effect sizes of weight and A1C was examined.

The overall intervention effect on weight was small, both in the short and the longer term, which confirms the findings of previous meta-analyses.[14-17] Clark[65] described the failure of obesity treatments to achieve significant and long-lasting weight loss and suggested that weight loss as a major intervention goal in diabetes type 2 patients might be a bridge too far. Clark stated that for motivational reasons, intervention targets in diabetes type 2 patients should ideally be formulated in terms of behavioral actions related to weight management rather than in terms of pounds or kilos. For A1C, a medium effect size was found, both in the short and the longer term, a finding that corresponds with the effect sizes found for A1C in some other meta-analyses.[15-16]

With regard to the main purpose of this meta-analysis, self-regulation principles seem indeed to increase outcome effects. A moderating effect of the total amount of self-regulation principles was found for both weight and A1C. This moderating effect was stronger for A1C than for weight outcomes. With respect to specific self-regulation principles, it was found that "goal reformulation" moderated weight loss effects and that "emotion regulation" moderated the effect on A1C outcomes. The moderating effect of "goal reformulation" is in line with the results of studies showing that trying to achieve unrealistic weight loss goals is related to goal disengagement[66] and low compliance to surgical aftercare in bariatric surgery patients.[67] In general, goal adjustment has been found to be an important mechanism in the self-regulation of health outcomes.[68,69] The finding that "emotional control" moderates intervention effects on A1C corresponds with findings indicating that emotions play a key role in the self-management of diabetes.[70,71] Whittemore and colleagues[72] demonstrated that fear of diabetes complications and concerns over health are important emotions in many type 2 diabetes patients. Van der Ven and colleagues[73] suggested the use of cognitive-behavioral strategies to reduce negative emotions and thus enhance diabetes self-care behaviors and glycemic outcomes, including A1C.

In addition, moderating trends were found for "discussing competing goals," "positive reinforcement," and "anticipatory coping" on both weight and A1C outcomes. A moderating trend of "relapse prevention" was found for A1C only. All moderating trends were stronger for A1C than for weight outcomes. A negative moderating trend of "planning" was found for weight outcomes. This could be explained from a theoretical point of view as "planning" is only expected to be beneficial in the initial phase (short term) of behavior change, and no longer in the long term. The moderator analyses in the present study could not be conducted for the short term and the longer term separately, but only for the longest available term, which may have been responsible for this unexpected result.

Table 4

Moderator Analyses With Intervention Features to Explain Differential Effects on Weight and A1C

| Outcome | Self-Regulation | *k* | N | *d* | 85% CI | | *Q* | Moderator/Trend |
|---|---|---|---|---|---|---|---|---|
| Weight | Partner/family involved | | | | | | | Moderator |
| | Not involved | 24 | 3885 | 0.04 | –0.01 | 0.09 | 23.53 | |
| | Involved | 11 | 1159 | 0.21[c] | 0.12 | 0.29 | 9.48 | |
| A1C | Partner/family involved | | | | | | | |
| | Not at all | 22 | 3771 | 0.30[c] | 0.17 | 0.43 | 103.47[c] | |
| | To some extent | 10 | 1003 | 0.46[c] | 0.33 | 0.58 | 13.37 | |
| Weight | Focus of treatment | | | | | | | |
| | Diet | 7 | 557 | –0.01 | –0.13 | 0.12 | 1.45 | |
| | Exercise | 7 | 742 | 0.20[b] | 0.10 | 0.31 | 3.71 | |
| | Combination | 21 | 3727 | 0.06 | 0.02 | 0.11 | 29.72 | |
| A1C | Focus of treatment | | | | | | | |
| | Diet | 5 | 459 | 0.37 | 0.07 | 0.67 | 18.89[c] | |
| | Exercise | 7 | 742 | 0.31[c] | 0.20 | 0.41 | 2.30 | |
| | Combination | 20 | 3571 | 0.39[c] | 0.24 | 0.54 | 102.08[c] | |
| Weight | Individual vs group | | | | | | | |
| | Individual | 12 | 3373 | 0.04[a] | 0.04 | 0.22 | 19.786[a] | |
| | Group | 10 | 659 | 0.16[a] | 0.04 | 0.27 | 10.881 | |
| | Combination | 13 | 1009 | 0.13[a] | 0.04 | 0.22 | 5.388 | |
| A1C | Individual vs group | | | | | | | |
| | Individual | 10 | 3180 | 0.41[b] | 0.22 | 0.60 | 65.72[c] | |
| | Group | 9 | 589 | 0.39[c] | 0.26 | 0.51 | 11.33 | |
| | Combination | 13 | 1003 | 0.29[a] | 0.11 | 0.47 | 45.38[c] | |
| Weight | Length of intervention | | | | | | | |
| | ≤26 wk | 17 | 1244 | 0.12[a] | 0.04 | 0.20 | 16.520 | |
| | 27-52 wk | 14 | 1298 | 0.14[b] | 0.06 | 0.22 | 10.097 | |
| | >52 wk | 4 | 2493 | 0.02 | –0.05 | 0.26 | 8.573[a] | |
| A1C | Length of intervention | | | | | | | |
| | ≤26 wk | 15 | 1137 | 0.37[b] | 0.21 | 0.52 | 42.65 | |
| | 27-52 wk | 13 | 2279 | 0.32[b] | 0.13 | 0.50 | 48.24[c] | |
| | >52 wk | 4 | 1356 | 0.42[a] | 0.16 | 0.68 | 25.76[c] | |
| Weight | Number of contact Sessions | | | | | | | |
| | ≤6 sessions | 15 | 3156 | 0.03 | –0.03 | 0.08 | 14.652 | |
| | 7-15 sessions | 10 | 977 | 0.22[b] | 0.13 | 0.31 | 7.504 | |
| | >15 sessions | 8 | 505 | 0.21[a] | 0.08 | 0.33 | 6.190 | |
| A1C | Number of contact sessions | | | | | | | |
| | ≤6 sessions | 14 | 3000 | 0.35[b] | 0.17 | 0.53 | 77.15[c] | |
| | 7-15 sessions | 8 | 879 | 0.42[b] | 23 | 0.62 | 21.23[b] | |
| | >15 sessions | 8 | 505 | 0.27[b] | 0.10 | 0.36 | 12.54 | |

*(continued)*

Table 4 (Continued)

| Outcome | Self-Regulation | *k* | N | *d* | 85% CI | | *Q* | Moderator/Trend |
|---|---|---|---|---|---|---|---|---|
| Weight | Intervals between sessions in weeks | | | | | | | |
| | ≤2 wk | 15 | 1138 | 0.16[b] | 0.07 | 0.24 | 12.98 | |
| | >2 and ≤10 wk | 9 | 561 | 0.21[a] | 0.08 | 0.33 | 8.58 | |
| | >10 wk | 7 | 792 | 0.19[b] | 0.09 | 0.30 | 2.83 | |
| A1C | Intervals between sessions in weeks | | | | | | | |
| | ≤2 wk | 13 | 1060 | 0.31[c] | 0.19 | 0.43 | 19.35 | |
| | >2 and ≤10 wk | 9 | 561 | 0.18 | -0.08 | 0.43 | 33.15[c] | |
| | >10 wk | 7 | 792 | 0.66[a] | 0.38 | 0.95 | 36.32[c] | |

Abbreviations: *k*, number of studies; *d*, weighted average standardized mean difference; CI, confidence Interval; *Q*, test of homogeneity.
[a] $P < .05$.
[b] $P < .01$.
[c] $P < .001$.

With regard to the second research question, namely whether intervention characteristics, other than self-regulation, moderate the overall effect on weight loss and changes in A1C, only the inclusion of a patient's partner or relative in the intervention proves to have a moderator effect on weight. With the exception of the meta-analysis by Gary and colleagues,[15] none of the previous meta-analyses were able to detect moderating influences of specific intervention characteristics on weight or A1C outcomes. Gary and colleagues[15] demonstrated that interventions focusing on exercise generated larger effects on A1C (glycohemoglobin) than interventions focusing on diet. This finding could, however, not be confirmed by the present meta-analysis.

When interpreting the results of the present meta-analysis, some limitations should be taken into account. First, no unpublished studies were included in the meta-analysis. Despite our efforts to obtain unpublished studies from experts in the field, none of the experts were able to provide us with extra, unpublished data. Second, although there were some exceptions to the rule, most studies did not clearly describe the theoretical background and content of the intervention that was used, which sometimes hampered the categorization of intervention characteristics.

## Implications for Clinical Practice and Research

In spite of the limitations described above, the results of the moderator analyses clearly indicate that self-regulation principles are potentially powerful ingredients of interventions targeted at weight loss and a decrease in A1C in patients with diabetes. The development and evaluation in a randomized controlled trial of a comprehensive self-regulation intervention has the potential of increasing our knowledge regarding the importance of self-regulation for diabetes care.

## Appendix

Formula 1 and 2 were used to compute the standardized mean differences between the treatment group (T) and control group (C) of the change in weight or A1c from pretest to posttest. Formula 1 was applied if a study reported raw pretest and posttest means of the two groups, denoted with $M_{preT}$, $M_{postT}$, $M_{preC}$, $M_{postC}$, and raw pretest and posttest standard deviations, denoted with $S_{preT}$, $S_{postT}$, $S_{preC}$, $S_{postC}$. The sample sizes are denoted with $n_T$ and $n_C$

Formula 1: $$d_{change} = \frac{(M_{preT} - M_{postT}) - (M_{preC} - M_{postC})}{S_{post-pooled}}.$$

The standardization was done by the pooled post score standard deviation, where

$$S_{post-pooled} = \sqrt{\frac{(n_T - 1)S^2_{postT} + (n_C - 1)S^2_{postC}}{n_T + n_C - 2}}.$$

Formula 2 was applied if a study reported only change scores from pretest to posttest for the treatment and control group, denoted with $M_{changeT}$, $M_{changeC}$, and the standard deviations of the change, denoted with $S_{changeT}$, $S_{changeC}$.

Formula 2: $$d_{change} = \frac{M_{changeT} - M_{changeC}}{S_{post-pooled}}$$

To compute the pooled post score standard deviation, we assumed a pre-posttest correlation of 0.50. In this case, the posttest standard deviations are equal to the change score standard deviations:

$$S_{postT} = \frac{S_{changeT}}{\sqrt{2(1 - r_{prepost})}} = \frac{S_{changeT}}{\sqrt{2^*0.50}} = S_{changeT}$$

The standard error (SE) of $$d_{change} = \sqrt{\left(\frac{1}{n_T} + \frac{1}{n_C} + \frac{d^2_{change}}{2(n_T + n_C)}\right)}.$$

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