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A meta-analysis of the past 25 years of weight loss research using diet, exercise or diet plus exercise intervention

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OBJECTIVE: The therapeutic effectiveness of diet, exercise, and diet plus exercise for weight loss in obesity was determined.
DATA SOURCES: All human research reported in English, published in peer-reviewed scientific journals within the past 25 y was reviewed.
STUDY SELECTION: Acceptance criteria ($n = 493$ from > 700 studies) were that a therapeutic intervention of diet, exercise or diet plus exercise was employed, specifically for weight reduction in obese adult humans and that weight change was reported numerically. Only aerobic exercise studies were included, while drug, hormone and surgical treatments were excluded.
DATA EXTRACTION: All data were extracted by the same investigator from the original research report. Except for gender and program type, all extracted data were numerical.
DATA SYNTHESIS: ANOVA, with a Newman–Keuls post hoc test, was used to determine differences among programs ($P < 0.05$). One analysis was performed on the group mean data and one based on effect sizes. Analyses were repeated using initial body weight, initial percent body fat and program length, as covariates.
RESULTS: Primarily, subjects aged 40 y have been studied (39.5 ± 0.4 y, mean ± s.e.m.) who are only moderately obese (92.7 ± 0.9 kg, 33.2 ± 0.5 body mass index (BMI), 33.4 ± 0.7% body fat); for short durations (15.6 ± 0.6 weeks). Exercise studies were of a shorter duration, used younger subjects who weighed less, had lower BMI and percentage body fat values, than diet or diet plus exercise studies. Despite these differences, weight lost through diet, exercise and diet plus exercise was 10.7 ± 0.5, 2.9 ± 0.4* and 11.0 ± 0.6 kg, respectively. However, at one-year follow-up, diet plus exercise tended to be the superior program. Effect size and covariate analyses revealed similar program differences.
CONCLUSION: Weight loss research over the past 25 y has been very narrowly focused on a middle age population that is only moderately obese, while the interventions lasted for only short periods of time. The data shows, however, that a 15-week diet or diet plus exercise program, produces a weight loss of about 11 kg, with a 6.6 ± 0.5 and 8.6 ± 0.8 kg maintained loss after one year, respectively.

Keywords: weight loss; meta-analysis; effect size; diet; exercise; weight control; obesity

Introduction

Most weight-loss programs are experimental and lack the validation through scientific research that is demanded with other medicinal practices.[1,2] Since diet and exercise are the most frequently cited methods for both men and women attempting weight loss,[1] the purpose of this research was not to validate any one particular weight-loss program, but rather to determine how efficacious general diet and exercise programs were in reducing obesity.

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Methods

Literature search

The literature search began with a computer search of *Medline* (US National Library of Medicine) which is inclusive of *Index Medicus*. Extensive cross-referencing and manual searches were also performed. All research reported in English, published in peer-reviewed scientific journals and conducted within the past 25 y was reviewed (1969–1994). The first requirement for acceptance of a study into the meta-analysis, was that one of the primary study interventions had to be weight-loss therapy. The reason for this criteria was to eliminate studies where weight loss was an unexpected result of the intervention rather than a primary focus of the intervention. This distinction eliminated the necessity for making subjective decisions about inclusion/exclusion for a study where weight loss was accidental or not clearly an expected outcome.

The second requirement for acceptance of a study into the meta-analysis was that the intervention had to be either diet (D), exercise (E) or diet plus exercise (DE). The D intervention had to include some type of calorie restriction or reduced energy intake and only E studies using aerobic exercise were included. These acceptance criteria for the type of intervention kept the focus of the paper, which was to compare the effects of manipulating the energy balance through traditional D, E, or DE programs on body weight/composition. In other words, if a change in body weight/composition could not be linked to a clear reduction in energy intake and/or increase in energy expenditure through aerobic exercise, the study was not included in the data set.

Other criteria for study acceptance were that the subject sample had to be overweight (as defined by original author(s) or by our predetermined criteria of being either $\geq 120\%$ ideal body weight, body mass index (BMI) ≥ 27, or body fat $\geq 30\%$), aged ≥ 18 y and that a numerical value was given for weight change during the program. Studies that reported data in figures only, where no numerical values could be extracted, were excluded. Drug therapy, hormone therapy, and surgery treatment studies were not included. Behavioral and health education programs that did not include a D, E or DE component were excluded. Additional information was incorporated into the analyses from accepted studies that either reported data directly or reported data that could be converted to values for: duration of the intervention, change in percentage body fat, change in weight of body fat or follow-up data for any dependent variable over at least one year.

A total of 493 study groups from the > 700 papers reviewed, met the minimal inclusion criteria. Sample sizes in the study groups analyzed ranged from 3–2869, with the average number per experimental group being 33 ± 6 (mean $\pm$ s.e.m.). However, the distribution of sample size for the groups analyzed was skewed to the left, with only 21 of the 493 study groups having a sample size of ≥ 100 subjects. The median as well as the mode for the sample size distribution was 12, with the frequency of 12 subjects per group occurring in 50 of the 493 groups. Only 26% of the sample populations were men, while 46% were women and 28% of the studies reported having either both genders within a group or did not report group gender at all. Data for control groups were not recorded nor analyzed, but the literature review revealed that less than half of the research studies included separate control groups. Diet programs were used in 269 of the research reports, E programs in 90 reports and DE in 134 reports.

The average degree of obesity, determined by BMI, was 33.2 ± 0.5, with a range 22.0–60.0; and for percentage body fat the average was 33.4 ± 0.7, with a range 13.0–52.0. The variance for initial adiposity levels among samples in the D, E and DE groups would not have affected the analyses performed for several reasons. First, the standard deviations among the D, E and DE groups was evenly distributed. Second, the coefficient of variation among sample groups was between 15% and 29%. Finally, in no case was the standard deviation for a sample group larger than the mean.

The age of the subjects for the inclusion studies ranged from 18–68 y. None of the participants in any of the studies reported having metabolic diseases, illness or were taking medications that may have affected weight loss. The actual weight change reported ranged from a gain of 2 kg to a loss of 55 kg. Length of the intervention ranged from 2–90 weeks.

Coding of variables

The second step in the analysis was to code the data from all of the studies that met the criteria for inclusion. Objectivity and reliability were maintained during the coding process because all of the variables coded (except gender and program type) were numerical values. Coding for gender does not lend itself to subjective interpretation, whereas coding for the type of program might. Consequently, subjective coding for program type was avoided by strict adherence to predetermined guidelines. Program types were defined as D, E or DE. Guidelines for coding program type were subsequently based on a strict dichotomy. In other words, if exercise was prescribed for a particular weight-loss program, then exercise was coded as part of that program. Similarly, if a calorie restricted diet regimen of any type was prescribed for weight loss, then the program was coded for diet accordingly. All studies were coded by the same investigator (WCM).

All studies that were coded for exercise utilized an aerobic type of exercise protocol,[3] where the duration of exercise ranged from 14–120 min and the frequency of exercise was 2–7 d/week. The mode of exercise in a majority of the studies was either walking, jogging or a combination of walk-jog.

Quantifying findings

Conceptually, meta-analysis converts the findings of a given study into data points called effect sizes (ES). These ES represent a common measure of treatment effectiveness. The ES of a single variable for an individual study represents the magnitude of treatment effect for that variable in that particular study. Thus, results from studies utilizing different methodologies can be equilibrated and compared by calculating each study's ES for the variable in question. ES for the dependent variables in each of the studies included in this meta-analysis were calculated by dividing the mean change in a variable measured for a group by the standard deviation (s.d.) for that group

(ES $= \Delta \overline{X} \div$ s.d.). Hence, the larger the ES for a particular group, the more consistent the effectiveness of treatment for that group. Once ES were calculated, statistical analyses were than performed on the ES.

Notwithstanding the strength of the meta-analysis using study ES as individual data points, many studies in the literature reviewed did not report the variance data necessary to compute ES. Other investigators have encountered this same problem and have consequently used the actual group mean as the ES in order to have enough data points to proceed with their analyses.[4,5] The choice of using the actual group mean versus a calculated ES for a meta-analysis is somewhat a matter of preference and depends upon the variance in group results and/or the variance in the number of subjects per group studied.[5] For comparison purposes, however, we performed both types of analyses, one on the actual group mean and one on the ES. Hence, if the results from the two types of analyses concur, one should be extremely confident in the findings, regardless of their personal position on the use of ES for analysis. If the results from the two analyses differ, one should favor the ES analysis due to the fact that it is more valid for the studies included in this meta-analysis.

Statistical analysis

Initially, the ANOVA was used to compare subject demographics and program lengths as well as determine differences in weight-loss success among the general program types of D, E and DE. The possibility that the initial subject profile may affect weight loss outcome variables was eliminated by performing two ANCOVAS where initial body weight and initial percentage body fat were used as covariates. Moreover, another ANCOVA was used where length of program intervention was taken as the covariate. All of these analyses were performed on both the actual group mean data and the ES data. If significance differences were found, then the Newman–Keuls post hoc test was employed. Significance was declared at the $P < 0.05$ level. All values are reported as mean $\pm$ s.e.m.

Results

Table 1 contains the demographic data for subjects participating in the respective D, E and DE programs. It is evident that studies investigating the effectiveness of exercise alone on weight loss, have sample populations that are different from those used in the D and DE studies. Subjects in the E studies were younger (36 *vs* 40 y), weighed less (83 *vs* 96 kg), had lower initial BMI values (26 *vs.* 35), and had a lower initial percentage body fat (28% *vs* 37–38%) than those in the D and DE studies. These differences for subject characteristics persisted even when the group demographic data for the genders were compared separately for those studies where group gender could be identified ($n = 355$). In other words, both the women and the men in the E studies were characteristically different from those women and men in the D or DE studies (data not shown). Moreover, the length of intervention was 6–8 weeks longer for the E studies than for the D and DE studies.

When programs were compared for changes in body composition, the E programs were clearly less effective than the D or DE programs (Table 2). In particular, weight lost, weight of fat lost, reduction in percentage fat, BMI decrease and percentage of initial weight lost, for the E programs were only 20–60% of that seen in the D or DE programs. These differences were conspicuous regardless of whether the analysis on mean data was done with or without the covariates of initial body weight, initial percentage body fat or initial BMI. However, when group mean data for program types were compared for maintained weight loss at one year post-program, no differences were found. It must be noted, however, that the initial weight loss in the seven E studies that provided one-year maintenance data was 8.7 ± 2.1 kg, which was higher than the 2.9 ± 0.4 kg for the 90 E studies analyzed in the complete data set. Therefore, at one-year maintenance, the seven E study groups were able to maintain 70% of their initial weight loss. Initial weight loss for the D and DE subgroups that provided one-year maintenance data were not different from the D and DE study groups in the complete data set

Table 1 Subject demographics and program lengths.

Variable	*Diet*[a]	*Exercise*[a]	*Diet + exercise*[a]
Age	40.0 ± 0.5 (171)	36.5 ± 1.4* (63)	39.5 ± 0.7 (90)
Initial weight (kg)	96.4 ± 1.1 (196)	82.9 ± 2.4* (75)	96.3 ± 1.9 (114)
Initial BMI	34.9 ± 0.6 (87)	26.4 ± 1.5* (27)	34.8 ± 1.0 (56)
Initial percentage body fat	38.5 ± 0.9 (56)	28.5 ± 1.2* (55)	36.6 ± 1.0 (42)
Program length (weeks)	15.1 ± 0.8 (224)	20.9 ± 1.8* (76)	13.4 ± 0.7 (119)

BMI = Body mass index. Data are means ± s.e.m. *Significantly different from other program types (ANOVA). [a]Number in paranthesis represents the number of studies reporting data for that particular variable.

Table 2 Body composition changes in obese adults following diet, exercise or diet plus exercise intervention.

Variable	Diet (D)[a]	Exercise (E)[a]	Diet + exercise (DE)[a]
Weight lost (kg)	10.7 ± 0.5 (269)	2.9 ± 0.4*,**,***,**** (90)	11.0 ± 0.6 (134)
Fat lost (kg)	7.8 ± 0.7 (48)	3.3 ± 0.5*,**,***,**** (40)	9.0 ± 1.0 (33)
Percentage body fat decrease	6.0 ± 1.0 (46)	3.5 ± 0.5*,***,**** (56)	7.3 ± 0.8 (43)
BMI decrease	4.0 ± 0.4 (53)	0.8 ± 0.1*,**,***,**** (27)	4.2 ± 0.4 (43)
Percentage of initial weight lost (kg)	10.9 ± 0.4 (186)	3.6 ± 0.4*,**,***,**** (69)	10.8 ± 0.6 (103)
Weight loss maintained at one year[b]	6.6 ± 0.5 (91)	6.1 ± 2.1 (7)	8.6 ± 0.8 (54)

BMI = Body mass index. Data are means ± s.e.m. *Significantly different from other program types when ANOVA was run without covariates. **Significantly different from other program types when analysis was run with initial body weight as a covariate. ***Significantly different from other program types when analysis was run with intitial percentage body fat as a covariate. ****Significantly different from other program types when analysis was run with initial BMI as a covariate. [a]Number in paranthesis represents the number of studies reporting data for that particular variable. (This number may have varied for the covariate analyses if a study did not report data for the covariate in question.) [b]Not enough studies included data for a covariate analysis using initial percentage body fat or initial BMI as the covariate.

Table 3 Effect sizes (ES) for body composition changes in obese adults following diet, exercise or diet plus exercise intervention[a].

Variable	Diet (D)[b]	Exercise (E)[b]	Diet + exercise (DE)[b]
ES kg lost	5.1 ± 0.5*,** (141)	2.1 ± 0.5*** (34)	5.5 ± 0.7*,** (68)
ES kg fat lost	5.5 ± 1.2 (29)	2.1 ± 0.7 (16)	7.9 ± 1.6* (16)
ES percentage body fat decrease	4.8 ± 0.8** (20)	3.0 ± 1.1**** (16)	7.4 ± 2.5*,**,**** (15)
ES BMI decrease	2.2 ± 0.5 (8)	0.7 ± 0.9 (7)	3.7 ± 2.0 (10)

BMI = Body mass index. Data are means ± s.e.m. *Significantly different from E when ANOVA was run without covariates. **Significantly different from E when analysis was run with initial body weight as a covariate. ***Significantly different from other groups when analysis was run with intitial BMI as a covariate. ****Significantly different from D when analysis was run with initial body weight as a covariate. [a]Numbers were too small for ES analyses for percentage of initial weight lost and weight loss maintained at one year. [b]Number in paranthesis represents the number of studies reporting data for that particular variable. (This number may have varied for the covariate analyses if a study did not report data for the covariate in question.)

(D = 9.0 ± 0.8 *vs* 10.7 ± 0.5; DE = 11.8 ± 1.0 *vs* 11.0 ± 0.6, respectively). Similar to the E groups, the D and DE groups maintained 73% of their initial weight loss at one year after. Therefore, the overall result for weight-loss comparisons among program types remains; that there was no difference in maintenance of weight loss among D, E and DE groups after one year.

The ES analysis also revealed that E programs were least effective in producing body compositional changes (Table 3). This was particularly true for weight lost and reduction in percentage body fat. The ES values for the D and DE programs revealed that these programs were twice as effective as the E programs (Table 3). However, some of the ES analyses were weakened or not performed, due to a small number of studies reporting variance for changes in the dependent variables (Table 3).

When length of the intervention was taken into account as a covariate, E programs were still least effective in altering body composition when compared to D and DE. For example, average weight loss in the D and DE programs was about 1.0 kg/week compared to 0.2 kg/week for the E programs. The finding that E programs did not produce as great a change in body composition as the D and DE programs was rather consistent, whether the analyses were performed with or without covariates on either the group mean data (Table 4) or ES data (Table 5).

Discussion

Descriptive data

The data that describes the different program types and the subject demographics reveal two important idiosyncrasies about the weight loss research conducted over the past 25 y. First of all, the research has been very narrowly focused. Variance among studies within each program type for the variables of age; initial body weight, BMI and percentage body fat is small (Table 1). This indicates that most of the weight loss research has been conducted on the same small subset of the obese population, namely, the moderately obese aged 40 y. Furthermore, therapeutic

Table 4 Body composition changes per week in obese adults following diet, exercise or diet plus exercise intervention.

Variable	*Diet (D)*[a]	*Exercise (E)*[a]	*Diet + exercise (DE)*[a]
Weight lost/week (kg)	0.98 ± 0.06 (222)	0.20 ± 0.04*,** (75)	1.00 ± 0.06 (116)
Fat lost/week (kg)	0.78 ± 0.07 (46)	0.22 ± 0.03*,** (40)	0.75 ± 0.07 (32)
Percentage body fat decrease/week	0.44 ± 0.07 (45)	0.27 ± 0.04*** (54)	0.56 ± 0.06 (43)
BMI decrease/week	0.37 ± 0.04 (53)	0.05 ± 0.01*,** (26)	0.48 ± 0.05 (43)
Percentage initial weight lost/week (kg)	1.03 ± 0.07 (176)	0.22 ± 0.04*,** (67)	0.98 ± 0.05 (102)
Weight loss/week maintained at one year (kg)[b]	0.46 ± 0.04 (84)	0.32 ± 0.14 (7)	0.82 ± 0.13*,**** (52)

BMI = Body mass index. Data are means ± s.e.m. *Significantly different from other program types when ANOVA was run without covariates. **Significantly different from other program types when analysis was run with either initial body weight, initial percentage body fat or initial BMI, as a covariate. ***Significantly different from DE when analysis was run without covariates. ****Significantly different from other program types when analysis was run with initial body weight as a covariate. [a]Number in paranthesis represents the number of studies reporting data for that particular variable. (This number may have varied for the covariate analyses if a study did not report data for the covariate in question.) [b]Not enough studies included data for a covariate analysis using initial percentage body fat or initial BMI as the covariate.

Table 5 Effect sizes (ES) for body composition changes per week in obese adults following diet, exercise or diet plus exercise intervention[a].

Variable	*Diet (D)*[b]	*Exercise (E)*[b]	*Diet + exercise (DE)*[b]
ES Weight lost/week (kg)	0.52 ± 0.06 (135)	0.13 ± 0.03*,**,***,**** (34)	0.61 ± 0.11 (68)
ES Fat lost/week (kg)	0.50 ± 0.08 (29)	0.18 ± 0.06*,**** (16)	0.61 ± 0.13 (16)
ES Percentage body fat decrease/week	0.47 ± 0.08 (25)	0.25 ± 0.09*,** (16)	0.63 ± 0.20 (16)
ES BMI decrease/week	0.21 ± 0.07 (8)	0.05 ± 0.03 (7)	0.73 ± 0.51 (7)

BMI = Body mass index. Data are means ± s.e.m. *Significantly different from other program types when ANOVA was run without covariates. **Significantly different from other program types when analysis was run with initial body weight as a covariate. ***Significantly different from other program types when analysis was run with intitial percentage body fat as a covariate. ****Significantly different from other program types when analysis was run with initial BMI as a covariate. [a]Numbers were too small for ES analyses for percentage initial weight lost and weight loss maintained at one year. [b]Number in parenthesis represents the number of studies reporting data for that particular variable. (This number may have varied for the covariate analyses if a study did not report data for the covariate in question.)

intervention for this overweight individual has only lasted for 13–21 weeks. The second idiosyncrasy in the literature is that the studies investigating weight loss due to exercise alone, were conducted on a completely different sample than those dealing with D or DE. These E studies, like the D and DE studies, used a very narrowly defined sample population, which to many scientists cannot even be considered obese.[1,6–9]

Although the inclusion criteria for study acceptance called for an obese population, only one of the obesity defining parameters (BMI, percentage body fat, 120% ideal weight, author defined) needed to be met for inclusion. It is possible that in many of the E studies only one of the criteria was met for study acceptance, while the other criteria were not. This could well have been the case for studies where the author(s) definition of obesity was the acceptance criteria. Using an author-defined criteria for obesity is not unprecedented in meta-analytical research in obesity;[5] and may be better than having no exclusion criteria at all for obesity, as other meta-analyses have done.[4,5,10] Nonetheless, caution is warranted when interpreting comparative differences among program types. It may be that exercise is a more effective intervention strategy for individuals who are more obese[4,5] or older than those included in the narrowly-defined population defined by this meta-analysis.

Program effectiveness

The results from this meta-analysis, which are more definitive than any individual study, indicate superiority of the use of D or DE in reducing obesity during the period of treatment (Tables 2–5). This conclusion is supported by the covariate analyses, where initial body weight, BMI and percentage body fat are used as covariates, as well as the ES analyses. Depending upon the variable measured, the D and DE programs produced a three-to-five fold greater change in body composition than the E programs. By piecing together the data from three earlier meta-analyses, one might foresee this conclusion. For example, Ballor and Poehlman[11] found that D programs resulted in a 10–12 kg weight loss, while DE programs produced a 9 kg weight loss. These numbers compare to our value of about 11 kg for D and DE. Data from two other meta-analyses[4,5] indicate that weight loss through E was only 1–2 kg, which is similar to our value of 2.9 kg. However, one must realize that piecing together data from three separate meta-analyses may not be the most appropriate way to make group comparisons for D, E and DE effectiveness, because the inclusion/exclusion criteria for each of these meta-analyses was different. One must also realize that the meta-analysis on the effects of exercise on body composition performed earlier[5] was done on relatively normal weight men (15–21% fat) and women (25–28% fat). Furthermore, the number of data points in these three earlier meta-analyses was 25,[4] 87,[5] and 53;[11] compared to 493 in the current study. Therefore, we feel that the data from this study unite and solidify any pieces of data that have been previously reported in the literature, either by review[1] or by meta-analysis.[4,5,11]

As previously mentioned, expected weight loss for a 3–4 month weight-loss program is about 11 kg (< 1 kg/week), with the ability to maintain about 70% of this loss after one year. These expectations represent an initial weight reduction of 11% of original body weight which dwindles to a 7–9% reduction after one year. These values fall within the generally accepted guidelines for rate of reduction, which are 1 kg/week or 1–2% of body weight/week, but slightly higher than more recent recommendations calling for rates of about 0.5 kg/week.[12] However, it must be remembered that these data were derived from a moderately obese population and that a weight loss of less than 10 kg in a severely obese individual may be negligible and discourage adoption of a new healthier lifestyle.[12]

There is some weak evidence for the continued superiority of DE intervention over D and E after a one-year follow-up (see Table 4, weight lost/week maintained at one year). When these values from the subgroup of studies providing one-year data, are compared to their own initial values for weight loss per week, the DE programs maintained 77% of their initial weight loss, while values for the D and E programs were 56% and 53%, respectively.

The conclusion that no data exists for long- term clinical trials evaluating various methods for voluntary weight control[1] is supported by this search. We found no E studies reporting data for maintenance up to 2 y post intervention and only a handful of D or DE studies reporting follow-up data 3 or 4 y post intervention. Hence, no analyses could be performed to compare program effectiveness beyond one year. Nevertheless, the average weight loss of the 16 D and DE studies that followed subjects for 3 y was 6–7 kg (data not shown).

There was no way of statistically estimating the potential bias for publishing studies that favor successful intervention. Although some of the studies included in the meta-analysis, reported negligible weight loss and even weight gain following intervention, we must assume that the bias, if any, would favor successful intervention. This assumption of the tendency to favor successful intervention in the published literature may be supported by the inclusion criteria which required the main focus of an accepted study to be weight-loss therapy. If one assumes that the tendency to publish only successful intervention strategies was evenly distributed across program types (D, E and DE), then the program comparison analyses would not have been affected. However, if one could include in the meta-analysis the research that was not published because of an inability to produce an effect, then this would lower the mean values for the dependent variables as well as diminish the ES values. The result would then be that D, E and DE programs are even less effective in reducing adiposity than reported here.

Recommendations

With the above limitations to the data base in mind, we have statistically evaluated the past 25 y of weight loss research and recommend that the pursuance of research take a different direction. We recommend that further investigations into diet and exercise therapy for the obese be directed at the severely obese and the elderly obese, who are at highest risk for obesity-linked complications. More research on these two obese subgroups will help determine if all the obese respond similarly to weight-loss intervention. We further suggest that long-term studies be performed to assess the effectiveness of exercise alone on body composition.

With respect to clinical application, we conclude that either a D or DE program would be most beneficial on a short-term basis. We suggest, however, that due to the small amount of maintenance data in the literature, that clinicians consider an exercise component as part of the intervention and/or follow-up.

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