Effects of Exercise, Diet, and a Combination of Exercise and Diet in Overweight and Obese Adults – A Meta-Analysis of the Data

Bettina Schaar[1], Corinna Moos-Thiele[*,1] and Petra Platen[2]

[1]*Institute of Rehabilitation and Sport for the Disabled, German Sport University Cologne, Germany*

[2]*Department of Sports Medicine and Sports Nutrition, Faculty of Sports Science, Ruhr University Bochum, Germany*

Abstract: The objective of the following meta-analysis was to determine what kind of treatment, or combination of treatments, has the greatest effect on weight loss in overweight and obese adults.

A systematic search was conducted of the available literature published between 1993 and 2006 that covered randomized controlled trials on overweight and obese subjects who underwent treatment consisting of physical exercise and/ or changes in diet. The scope of the search thus incorporated seven relevant databases.

Using 6,545 key word combinations, the electronic search yielded a total of 36,869 abstracts. 13 relevant studies with a total of 826 subjects (BMI > 25; 17 - 68 years of age) met the meta-analysis criteria. The courses of treatment included "diet (d)", "physical exercise (pe)", "diet and physical exercise (dpe)", and "no intervention (ni)". The results confirmed the hypothesis that the combined intervention "dpe" had the greatest effect with regard to weight loss. The single treatments "pe" and "d" also led to weight loss, with "d" having a significantly greater effect than "pe".

The main reason for the small sample size of thirteen studies out of 36,819 was that the experimental design and/or procedures of most studies were inadequate. A common error was a failure to assign subjects randomly to the different treatment groups. The results of our meta-analysis indicate that a combination of diet and physical exercise is the best form of treatment to induce weight loss in overweight individuals in the first weeks, followed by physical exercise to maintain weight loss.

Keywords: Overweight, obesity, physical activity, diet, adult.

1. INTRODUCTION

Excess weight and obesity and the resulting risk factors are major contributing factors to skyrocketing health-care costs. Between 3.9 and 10.33 billion euros are spent in Germany each year on treating obesity, which can lead to serious health problems such as diabetes, hypertension, and coronary heart disease. In a study incorporating data from medical examinations of men born in 1974 routinely conducted to assess fitness for military service, the German Federal Ministry of Health found that 154 out of 1000 men were slightly to moderately overweight and 15 were severely obese [1]. The prevalence of obesity has also increased dramatically in the U.S. during the last decade. An estimated 97 million American adults are overweight or obese, making obesity the nation's second most common cause of preventable death [2].

2. REVIEW OF REVIEWS

Before an evaluation of a new meta-analysis, a review of established meta-analyses is used to show the necessity of an additional evaluation. The questioning of the review of reviews amounted to the investigation of meta-analyses, which evaluated the effects of dietary advices and or exercise interventions for obese subjects. The search of the secondary review took place in seven selected databases: *Cochrane Reviews der Cochrane Library, Digital Dissertations, EMBASE, MEDLINE, Psycinfo, Psyndex und SPORT Discus*. As result of the research, 22 publications could be identified in the following journals: *Advances in Therapy, British Journal of Nutrition, Coronary Artery Disease, The Cochrane Collaboration, European Journal of Clinical Nutrition, Exercise and Sport Sciences Reviews, Health Technology Assessment, International Journal of Obesity, Journal of the American Dietetic Association, Journal of the American College of Nutrition, The Journal of the American Osteopathic Association, Journal of Human Nutrition and Dietetics, Journal of Science and Medicine in Sport, Journal of Sports Medicine, Medicine & Science in Sports & Exercise, Obesity Reviews und Official Journal of the American College of Sports Medicine.* The precise inspection of the reviews showed that one health technology assessment [3], 15 meta-analyses [4-18] and six descriptive reviews [19-24] were detected. Further consideration resulted in the exclusion of the descriptive reviews. In total, six to 70 studies in one publication with 41 to 123,423 subjects were included. The samples had a mean age of older than 18 years and the mean BMI was higher than 25 kg/m^2, except for the controls which had normal BMIs (<25 kg/m^2). The treatments of the studies lasted from one day to 90 weeks. Table **1** shows all included reviews during 1993 and 2006. The results of the review of reviews showed that the search

*Address correspondence to this author at the German Sport University Cologne, Am Sportpark Müngersdorf 6, D-50933 Cologne, Germany; Tel: ++49-173-5195471; Fax: ++49-221-49827460; E-mail: comoos@freenet.de

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Table 1. Meta-Analyses During the Time Period of 1993 to 2006 (k = 14)

Author / Year of Publication	Superior Treatment, Study - k (Subjects - n)	Age (Years)	KG (kg) BMI (kg/m^2)	Duration of Treatment and Dropout	Databases / Period of Time	Method	Conclusion
Only Diets, Nutrition Replacements, Medication or Surgeries							
Anderson *et al*., 2004 [3]	no i. I_1: meal replacements: 4 (579) I_2: energy-restricted diets (to 1500 kcal/d): 6 (200) I_3: low energy diets (800 to 1500 kcal/d): 10 (365) I_4: very low energy diets (< 800 kcal/T): 19 (1,968) I_5: soy very low energy diets (800 kcal/T Sojaprodukte):8 (333)	> 20	> 25 kg/m^2	8-24 weeks 11-47 hours directly supported by the physician, lessons took part in the clinic Dropout: 0-73 %	1 DB (Medline and handsearch) 1980 to 2001	M: random effects model	Meal replacements and energy-restricted diets seem to have the same effects, low energy diets and very low energy diets show the greatest body weight reduction after 24 weeks, soy very low energy diets have after 8 weeks the highest weight reduction.
Avenell *et al*., 2004 [4]	26 (no i.) I_1: low-fat diet I_1: low-calorie diet I_2: very low-calorie diet I_3: protein sparing modified fasts	> 18	> 28 kg/m^2	12 month - 5 years Dropout: 0-40 %	13 DB (Medline, Embase, Biosis, CAB Nutrition Abstracts and Reviews, CCTR, PsycInfo, Science Citation Index, British Library Inside, CINAHL, HealthSTAR, AMED, SPORTDiscus, UK National Research Register and handsearch) 1966 to 05/2001	M: fixed effect model	Low-fat diets show the greatest weight reduction. Little evidence supports the use of the other diets in obese adults. Long-term follwo-up in RCTs is needed to evaluate further effects.
Douketis *et al*., 2005 [5]	44 (19,273) I_1: diet: 16 (5,698) I_2: medication: 19 (9,953) I_3: surgery: 9 (3,622)	D: 40-59 M: 40-58 S: 34-49	D: 78-116 kg M: 87-102 kg S: 110-142 kg	D: 3-18 month weight-reduction and 12-36 month weight stabilisation M: after 1 to 2 years S: after 2 to 3 years Dropout: no i.	3 DB (Medline, Healthstar, CCTR and handsearch) 1966 to 09/2003	M: random effects model	Diets reduced the body weight after 2 to 4 years by 5 kg; medication after 1 to 2 years by 5 to 10 kg and sugeries after 2 to 4 years by 25 to 75 kg body weight.
Schrauwen & Westerterp, 2000 [6]	no i. I_1: high-fat diet: no i. I_2: low-fat diet: no i.	no i.	alle Gewicht sklassen	1-9 days dropout: no i.	no i.	M: no i.	High-fat diets lead to the development of obesity. The compareson of high-fat and low-fat diets shows that high-fat diets produce positive leptin levels. A body weight reduction is impossible.

(Table 1) contd…..

Author / Year of Publication	Superior Treatment, Study - k (Subjects - n)	Age (Years)	KG (kg) BMI (kg/m^2)	Duration of Treatment and Dropout	Databases / Period of Time	Method	Conclusion
Diet and Physical Activity							
van Baak, 1999 [7]	no i. I_1: diet: no i. I_2: diet and physical activity: no i.	> 18	> 25 kg/m^2	12 weeks dropout: no i.	no i.	M: no i.	The meta-analysis gives no clear answer to the question whether exercise training increases fat utilization at rest, during exercise or over 24 h in obese subjects.
Curioni & Lourenço, 2005 [8]	6 (407) I_1: diet: 6 (142) I_2: diet and physical activity: 6 (265)	21-65	> 25 kg/m^2 83.5-106.0 kg	Intervention: 10-52 weeks follow-Up: 12-24 month dropout: 9-24 %	3 DB (CCTR, Medline, Lilacs) until 03/2003	M: fixed effect model und Mantel Haenszel odds ratio	Interventions with diet and physical activity reduced body weight by 20% more than the intervention only diet. This is partially sustained after 1 year. But also half of all subjects gained weight after 1 year.
Garrow & Summerbell , 1995 [9]	28 I_1: diet: no i. I_2: diet and physical activity: no i.	> 18	25 -38 kg/m^2	3-52 weeks dropout: no i.	1 DB (Medline and handsearch) 1966 to 1993	M: no i.	Aerobic exercise causes a modest loss in weight without dieting. Exercise provides some conservation of fat free mass during weight loss by dieting, probably in part by maintaining glycogen and water.
Only Physical Activity							
Blundell & King, 1999 [10]	70 (no i.) I_1: high intensity training with I_2: moderate intensity training I_3: controlls each with nutrition protocols	> 18	all weights	1 day to 44 weeks dropout: no i.	no i.	M: no i.	Evidence suggests that a high level of physical activity can aid weight control. This effect accrues either because of improving the matching of food intake to energy expenditure (regulation) or by raising expenditure so that it is difficult for people to eat themselves into a positive energy balance.
Miller *et al.*, 1997 [11]	493 (no i.) I_1: diet: no i. I_2: physical activity: no i. I_3: diet and physical activity: no i.	18 - 68 40.0±0.5 36.5±1.4 39.5±0.7	22 -60 kg/m^2 34.9±0.6 26.4±1.5 34.8±1.0	2-90 weeks dropout: no i.	1 DB (Medline) 1969 to 1994	ANOVA and Student-Neuman-Keul test	The population was very narrowly focussed on middle aged subjects that are only moderately obese. The interventions lasted for only short periods of time. Obese subjects profit from a treatment with "only physical activity" as well as from a treatment with "physical activity and diet" in evidence by body weight reduction and maintained loss after 1 year.
Ross, 1997 [12]	no i. (309) I_1: diet: 8 (205) I_2: physical activity: 2 (41) I_3: diet and physical activity: 3 (63)	> 18	no i.	2 weeks to 14 month dropout: no i.	no i.	M: no i.	Changes in waist circumference and sagittal diameter are well correlated with corresponding changes in visceral adipose tissue. Effects of diet- and exercise-induced weight loss on visceral adipose tissue from well controlled studies are required to advance current knowledge with respect to the effects of diet and exercise on the adipose tissue depot that conveys the greatest healteh risk. Evidence is not validated because of the small size of treatment groups.
Ross *et al.*, 2000 [13]	8 (496) I_1: diet: 8 (244) I_2: physical activity: 8 (252)	> 18	> 25 kg/m^2	10-52 weeks (17-65 min/day added exercise) dropout: no i.	no i.	M: no i.	Daily exercise of about 30 to 60 minutes produces weight loss. This suggests that exercise without diet restriction is an effective strategy for reducing obesity and related co-morbidities. As the sports form, the authors suggest walking.

(Table 1) contd…..

Author / Year of Publication	Superior Treatment, Study - k (Subjects - n)	Age (Years)	KG (kg) BMI (kg/m^2)	Duration of Treatment and Dropout	Databases / Period of Time	Method	Conclusion
Only Physical Activity							
Wing, 1999	15 (1,644) I_1: physical activity: 10 (428) I_2: controlls: 10 (362) I_3: diet: 13 (402) I_4: diet and aerobic physical activity: 13 (402) I_5: diet and strength training: 4 (50)	no i.	> 25 kg/m^2	4-12 month Dropout: no i.	no i.	M: no i.	The meta-analysis consistently shows benefits of exercise for weight loss, but the effects are often modest. These effects may result from small sample sizes, short study duration, and poor adherence to the exercise prescriptions. Better ways of measuring exercise and promoting adherence to exercise are necessary for a detailed description of the doses and types of exercise, which promote long-term weight loss.
Diet, Physical Activity and Behavior Therapy							
Avenell *et al*., 2004a	27 (6,834) diet and: I_1: medic: 8 I_2: physical activity: 5 I_3: behavior therapy: 4 I_4: behavior therapy and physical activity: 7	> 18	> 25 kg/m^2	12-60 month Dropout: 5-64 %	13 DB (Medline, Embase, Biosis, CAB Nutrition Abstracts and Reviews, CCTR, PsycInfo, Science Citation Index, British Library Inside, CINAHL, HealthSTAR, AMED, SPORTDiscus, UK National Research Register and handsearch) 1966 to 05/2001	M: fixed effect model	Adding orlistat, sibutramine, exercise, or behavior modification to dietary advice can improve long-term weight loss. The greatest weight loss resulted from the combination of behavior modification or sibutramine and dietary advice. However, the other combinations resulted in additional weight loss after 12 months. Furthermore, 36 months of behavior modification and dietary advice caused additional weight reduction.
Shaw *et al*., 2006	36 (3,495) I_1: behavior therapy: 13 I_2: intensive behavior therapy: 17 I_3: behavior therapy and/ or diet and/ or physical activita: 8 I_4: controlls: 10	> 18	> 25 kg/m^2	1 training session to 36 month dropout: less than 20 %, to minimise the bias of the MA	5 DB (CCTR, Medline, PsychInfo, PsychLit, Embase) to 6/2003	M: fixed effect model	Overweight or obese people benefit from psychological interventions, particularly behavioral and cognitive-behavioral strategies, to enhance weight loss. Specially the combination of dietary and exercise strategies shows evidence of weight reduction. Other psychological interventions are less rigorously evaluated for their efficacy as weight loss treatments.
Diet and Physical Activity Follow-Up							
Fogelholm & Kukkonen-Harjula, 2000	31 (123,423) I_1: physical activity and weight gain I_2: Jojo-Effect after weight reduction by diet I_3: Jojo-Effect after weight reduction by physical activity	18-64	> 25 kg/m^2	15 weeks to 21 years Dropout: no i.	no i. 1980 to 2000	M: no i.	After an initial weight loss program, the following results are presented: Based on the studies, it seems that an actual increase in energy expenditure of physical activity of approximately 1,500-2,000 kcal/week was associated with improved weight maintenance. Nevertheless, adherence to a prescribed exercise program remains a big challenge and is a basic assumption for weight loss by exercise. Subjects without exercise training regained body weight by 0.28-0.33 kg per week.

BMI - Body Mass Index; D - diet; DB - database; h - hour; I - Interventions; k - number of studies; kcal - kilocalories; kg - kilograms; kg/m^2 - kilograms per squared meter; M - medication; MA - metaanalysis; min - minimum; n - number of subjects; S - sugery; no i. - no Information; d - day; e.g. - for example; % - percent; > - greater then.

period of the reviews took place up to the year 2003, so that in fact no publication from 2004 to 2006 was considered. Also the choice of databases differed from one to 13 databases. At the least, the questionings of the publications contrasted. Only five publications analyzed the interventions "exercise", "dietary advice" and/ or "only exercise" [5, 9, 10, 12, 16]. A detailed inspection of these meta-analyses showed that the intervention "only exercise" was mostly composed of overweight subjects (25 - 30 kg/m^2).

To be able to estimate the current state-of-the-art in meta-analysis, a new meta-analysis should be initiated and evaluated. The questioning should be phrased "Effects of physical exercise and/ or diet in overweight and obese subjects on reducing weight, fat and improving physical capacity" and all medicine, exercise and psychology relevant databases should be included in the extensive research. Also the inclusion of subjects with further diseases should be avoided.

3. META-ANALYSIS

Most studies found in our search for the meta-analysis evaluated weight loss programs according to their effectiveness, but the scientific procedures used were often insufficiently described [11]. The objective of this meta-analysis is to determine the general effectiveness of the different treatments "diet (d)", "physical exercise (pe)", "diet and physical exercise (dpe)", and "no intervention (ni)" for inducing weight loss in overweight and obese adults without any further illnesses by reviewing randomized controlled trials.

3.1. Methodology

This paper is a systematic review of all literature on physical exercise in overweight and obese adults without further orthopedic illnesses published in German and English between 1993 and 2006. We restricted our search to studies examining the effects of physical exercise, diet, or a combination of physical exercise and diet on overweight (BMI 25 - 29) and obese (BMI $\geq$ 30) adults compared to overweight and obese controls where no intervention was undertaken.

Eleven search words were drawn from the category "indications", seventeen from the category "populations", and 35 from the category "treatments". Thus a total of 6,545 word combinations were used to search the following databases: the Cochrane Controlled Trials Register (CCTR), Dissertation Abstracts, EMBASE, MEDLINE, Psyndex, Psycinfo, and Sport Discus. Out of the 36,819 abstracts found, two independent reviewers selected studies for inclusion in the meta-analysis based on the criteria described below. Effect size was calculated according to the Schmidt-Hunter method (random effects model calculation) using the meta-analysis software META Version 5.3 [23-25].

To lower the bias, only studies were considered for inclusion in this survey that examined the effects exercise, diet, or a combination of both in at least two concurrent treatment groups consisting of adults (ranging from 17 to 68 years of age) who had been diagnosed as overweight or obese and had a BMI over 25 [26]. Furthermore, studies had to be conducted as randomized controlled trials following the principles of evidence-based medicine. Also the intervention had to have two tests with a treatment in-between. All other studies were excluded. Follow-up and recidivism were not analyzed.

The following parameters were included in the meta-analysis: changes in weight, changes in absolute body fat, changes in body fat percentage, and/ or changes in aerobic capacity (maximal oxygen uptake). The independent variables were "d", "pe", "dpe", and "ni". The dependent variables were changes in weight, absolute body fat and body fat percentage, and aerobic capacity.

Two reviewers independently assessed the quality and eligibility of studies for inclusion in the meta-analysis to achieve an independent and double data collection. In a first step, a brief review of the abstracts reduced the number of potential candidates from 36,869 to 337. These 337 papers were read in full, and in many cases, the authors were contacted and asked to clarify their data, as studies frequently did not adequately describe the subjects or the method of randomization used. In the end, sixteen randomized controlled trails "RCTs" were identified that fulfilled the criteria described above, three of which were identical and therefore eliminated. Thus the meta-analysis includes a total of thirteen studies [27-39] (Fig. **1**).

3.2. Description of Sample

All studies included were designed in a pre/post testing format and were based on randomized, controlled trials. The papers, of which twelve were written in English and one in German, were published in the *Journal of Psychosomatic Research, Hypertension, Archives of Physical Medicine, Medicine & Science in Sport & Exercise, Journal of Aging and Physical Activity, International Journal of Obesity, Journal of the American College of Nutrition, Journal of the American Dietetic Association, Archives of Internal Medicine Journal of the American Medical Association, Ernaehrungs-Umschau,* and *Physiological Research* between 1995 and 2006. The thirteen primary studies included 826 adults between 17 and 68 years of age. Six studies included female subjects only and two studies exclusively male subjects; the overall gender distribution of the study subjects (BMI > 25) was 80% female and 20% male [26]. The duration of treatment ranged from four to 72 weeks; exercise frequency varied between two and five times per week. In five studies, the prescribed physical activity consisted of walking; exercise comprised a combination of walking, jogging, bicycle ergometer training, and strength training in six of the studies; two studies allowed subjects a choice between dancing and endurance training. The thirteen studies included a total of 34 different treatment groups. The studies monitored training intensity for the treatment "pe" in a variety of ways: according to heart rate intensity (50% to 90% of maximum heart rate) in five studies [27-31]; according to maximum heart rate reserve (HRR), with intensities from 50% to 80%, in three studies [32-34]; one study used heart rate reserve (HRR) and maximum oxygen uptake ($\dot{V}O_{2max}$) values [35]; one study monitored intensity on the basis of maximal wattage (W_{max}) [36]; and three studies relied on subjective parameters [37-39]. All primary studies reviewed demonstrated that diet and exercise, both alone and in combination, had positive effects, regardless of the duration of treatment, size of the sample, and

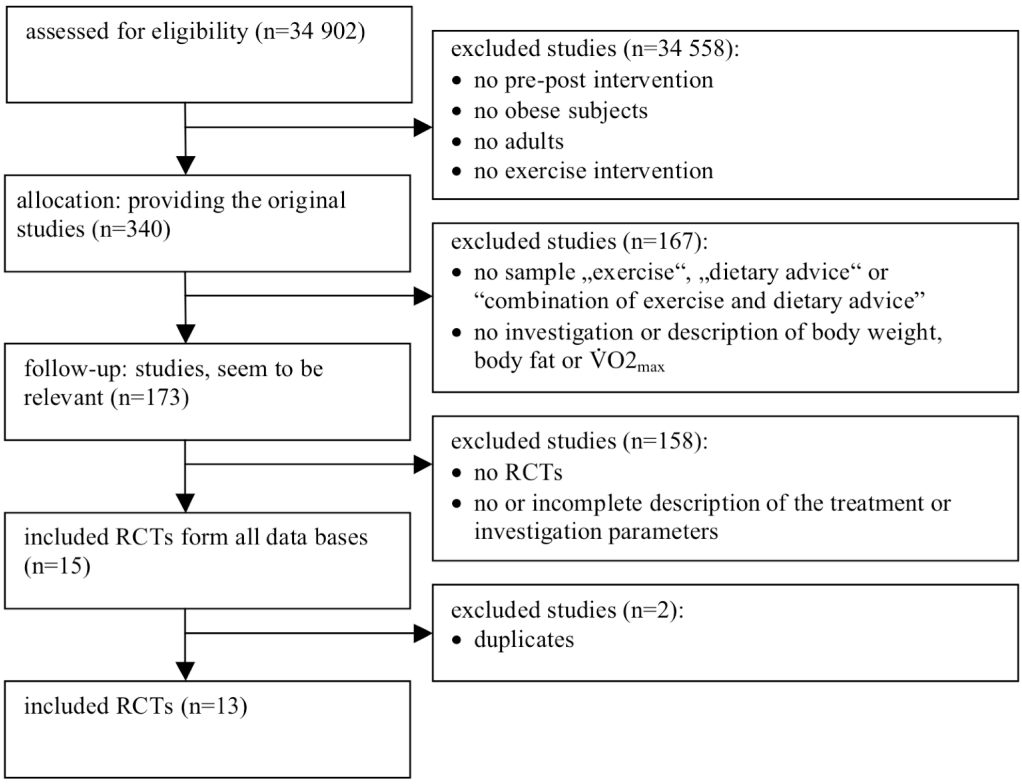

Fig. (1). QUOROM-Flowchart of included RCTs.

methodology used (Tables **2** and **3**). Nevertheless, the calculation of the meta-analysis can be performed with the random effect method by Schmidt & Hunter [23-25], which determines the effect sizes and compares the results afterwards.

3.3. Results

The effects of physical exercise only, changes in diet only, and physical exercise and changes in diet combined in overweight and obese adults were analyzed with regard to the question posed by the meta-analysis. The measurements were recorded before and after intervention and compared with the outcome when no intervention took place. A sub-analysis was not conducted because of the small size of the sample. The main finding was that a combination of changes in diet and physical exercise is most effective in inducing weight loss and changing body composition. The results for the primary outcome measure “change in weight (kg)” were: population effect size (r_g) = 0.4 (95% confidence interval [CI] = 0.39-0.41) for “d” (Table **4**); r_g = 0.47 (95% CI = 0.16-0.78) for “dpe” (Table **5**); r_g = 0.08 (95% CI = 0.07-0.07) for “pe” (Table **6**); and r_g = 0.02 (95% CI = 0.24-0.24) for the control group with “ni” (Table **7**). The results for the primary outcome measure “change in body fat (kg)” were: r_g = 0.39 (95% CI = 0.39-0.39) for “d”; r_g = 0.52 (95% CI = 0.52-0.52) for “dpe”; r_g = 0.21 (95% CI = 0.21-0.21) for “pe”; and r_g = -0.03 (95% CI = -0.03 - -0.03) for the control group with “ni”. The data sets can be regarded as significant, as the population effect sizes (r_g) were twice the residual standard deviation (SD_{res}), with the exception of the control group “ni”, where r_g = -0.03 (95% CI = -0.03 - -0.03). All data sets for body fat (kg) were homogeneous, as the Chi^2 test revealed no significant differences and the residual standard deviation (SD_{res}) was less than 25% of the population effect (r_g) [24, 25]. However, the data sets for weight (kg), body fat percentage, and maximal oxygen uptake were partly heterogeneous; therefore meta-analysis was not possible.

The figures produced by Binomial Effect Size Display (BESD) for weight loss with the intervention “d” were 0.30/0.70, i.e. the probability that in 100 individuals diet only will result in weight loss is 40% greater than the probability that no weight loss will result. For the intervention “pe”, BESD (0.46/0.54) indicated that the probability that physical exercise only will lead to weight loss in 100 individuals is only 8% higher than the probability that weight loss will occur when no intervention at all is undertaken. The data set for weight (kg) was heterogeneous for “dpe”. “ni” resulted in a mere 2% probability of weight loss (BESD: 0.49/0.51). The probability that body fat (kg) will be reduced by “d” is 40% (BESD: 0.30/0.70); 20% that a decrease will result from “pe” (BESD: 0.40/0.60); and 52% that absolute body fat will decrease as a result of “dpe” combined (BESD: 0.24/0.76). “ni” produced a negative effect of -4% (BESD: 0.52/0.48). The data set for body fat percentage was heterogeneous for “d” as well as “dpe”. The results indicated a 20% greater probability that body fat percentage will decrease as a result of “pe” than that no decrease will result (0.40/0.60); the probability of improvement as a result of “dpe” is 56% greater than that of no improvement (0.22/0.78); and the probability of improvement with “ni” (0.43/0.57) is 14% greater than no improvement. The probability of an increase in the parameter maximum oxygen uptake ($\dot{V}O_{2max}$) with “ni” was minus 22% (0.61/0.39). The data set for $\dot{V}O_{2max}$ was heterogeneous for

Table 2. Characteristics of Subjects in Studies Included in the Meta-Analysis

Study	Age (in Years)	Patients	BMI	Gender	Measurements
Berg *et al*. (2003; 2005) [38, 41]	35–65 TG_1: 49.2±7.72 TG_2: 45.6±7.01 TG_3: 47.4±7.63	TG_1: n=28 TG_2: n=28 TG_3: n=27	TG_1: 32.8±2.37 TG_2: 31.5±2.16 TG_3: 31.4±2.62	-	$W_{max,}$ BMI, body composition, profile of risk factors
Bond Brill *et al*. (2002) [39]	$TG_{1\ (CG)}$: 40.1±1.5 TG_2: 38.7±1.6 TG_3: 39.7±1.9	$TG_{1\ (CG)}$: n=16 TG_2: n=21 TG_3: n=19	$TG_{1\ (CG)}$: 32,79±1.48 TG_2: 35.27±1.76 TG_3: 33.76±1.37	f	$\dot{V}O_{2max,}$ hydrodensitometry body density, girth, hip-to-waist ratio
Bryner *et al*. (1997) [27]	TG_1: 24.9±4.6 TG_2: 24.2±6.0	TG_1: n=7 TG_2: n=8	> 25	f	$\dot{V}O_{2max,}$ hydrostatic weighing
Colak and Ozcelik (2004) [36]	TG_1: 38.3±10 TG_2: 37.5±8	TG_1: n=12 TG_2: n=12	TG_1: 36.1±3.6 TG_2: 39.8±5.4	21f/3m	W_{max}, BIA (leg-to-leg)
Donnelly *et al*. (2000) [35]	TG_1: 54.0±9.0 TG_2: 49.0±8.0	TG_1: n=11 TG_2: n=11	TG_1: 30.12±2.52 TG_2: 32.33±5.11	f	$\dot{V}O_{2max,}$ hydrostatic weighing, girth, hip-to-waist ratio
Donnelly *et al*. (2003) [33]	TG: 24.0±5.0 (f) 22.0±4.0 (m) CG: 21.0±4.0 (f) 24.0±4.0 (m)	TG_1: n=41 CG: n=33	TG: 28.7±3.2 (f) 29.7±2.9 (m) CG: 29.3±2.3 (f) 29.0±3.0 (m)	f	$\dot{V}O_{2max}$, hydrostatic weighing, CT
Gillett *et al*. (1996) [32]	64.4±3.0 TG_1: not specified TG_2: not specified CG: not specified	TG_1: n=63 TG_2: n=70 CG: n=31	32.0±4.0 TG_1: not specified TG_2: not specified CG: not specified	f	$\dot{V}O_{2max}$, skinfold thickness
Jakicic *et al*. (1999) [37]	TG_1: 37.2±6.2 TG_2: 36.7±4.6 TG_3: 37.5±5.5	TG_1: n=49 TG_2: n=51 TG_3: n=48	TG_1: 32.9±3.8 TG_2: 33.2±4.0 TG_3: 32.2±4.3	f	$\dot{V}O_{2max}$, girth, hip-to-waist ratio
Kraemer *et al*. (1999) [30]	TG_1: 40.0±6.3 TG_2: 37.8±8.5 TG_3: 39.9±6.4 CG: 30.3±7.4	TG_1: n=8 TG_2: n=11 TG_3: n=10 CG: n=6	TG_1: 33.1±4.3 TG_2: 31.3±3.1 TG_3: 29.2±2.9 CG: 27.9±2.3	m	$\dot{V}O_{2max}$, hydrostatic weighing
Leutholtz *et al*. (1995) [34]	TG_1: 43.5±7.8 TG_2: 39.8±7.3	TG_1: n=20 TG_2: n=20	> 25	33f, 7m	$\dot{V}O_{2max}$, BIA
Miller *et al*. (2002) [31]	TG: 53.0±11.0 CG: 54.0±8.0	TG: 22 CG: 23	TG: 32.8±5.4 CG: 34.2±6.2	28f, 17m	HR, RPE, BMI
Niemann *et al*. (2000) [29]	45.6±1.1 TG_1: not specified TG_2: not specified TG_3: not specified CG: not specified	TG_1: n=21 TG_2: n=26 TG_3: n=22 CG: n=22	33.1±0.62 TG_1: not specified TG_2: not specified TG_3: not specified CG: not specified	f	$\dot{V}O_{2max}$, hydrostatic weighing
Pritchard *et al*. (1997) [28]	TG_1: 42.3±4.5 TG_2: 43.6±18.0 CG: 44.9±6.5	TG_1: n=18 TG_2: n=21 CG: n=19	TG_1: 29.0±2.8 TG_2: 29.2±2.8 CG: 44.9±6.5	m	Index of activity, X-ray densitometer, DEXA

BIA - bioelectrical impedance plethysmography; BMI - Body Mass Index; HR - heart rate; HRR - heart rate reserve; kcal - kilocalorie; CG - control group; f - female; m - male; max – maximum; min - minutes; N - group (total); n - subgroup; TG - treatment group; $\dot{V}O_{2max}$ - maximum oxygen uptake.

the groups "d", "pe", and "dpe" [24, 25]; therefore, meta-analysis was not possible.

In summary, the interventions "d" and "dpe" had the greatest effect with regard to weight loss; the greatest decrease in absolute body fat and body fat percentage resulted through "dpe". A particularly noteworthy finding was the negative effect of "ni" on aerobic capacity.

3.4. Discussion

The large number of hits obtained in the databases is remarkable, though a high initial outcome was inevitable as the search was very detailed. The data were drawn from studies published between 1993 and 2006 that were

Table 3. Results Regarding the Effects of Exercise of the Studies Included in the Meta-Analysis

Study	Groups/Exercise	Intensity	Period of Time	Diet	Selected Results
Berg *et al.* (2003, 2005) [38]	TG_1: education TG_2: diet TG_3: diet and exercise; guided endurance exercise 60 min. 2 days/week (week 7-24)	self-selected	48 weeks	TG_1: no diet TG_2: minus 700 kcal/ day (week 7-24); additional nutrition substitution (soy-yogurt-honey-basis) TG_3: like TG_2 and exercise	BMI ↓ body weight ↓, (80% body fat) TG_1: systolic blood pressure ↓ (10 mmHg) TG_2: systolic and diastolic blood pressure (10/8 mmHg) ↓
Bond Brill *et al.* (2002) [39]	TG_1: diet TG_2: diet and walking- 30 min 5 days/ week TG_3: diet and walking- 60 min 5 days/ week	self-selected	12 weeks	1200 – 1400 kcal daily, fat 35 g/ day	BMI ↓ Body fat ↓ Body fat % ↓ FFM ↑ TG_2 / TG_3 waist circumference ↓, $\dot{V}O_{2max}$ ↑
Bryner *et al.* (1997) [27]	TG_1: 40-55 min, 4 days/ week, walking or jogging TG_2: 40-55 min, 4 days/ week, walking or jogging CG: 4 weeks without intervention	TG_1: 60-70 % HR_{max} TG_2: 80-90 % HR_{max}	16 weeks	self-selected	TG_1:$\dot{V}O_{2max}$ ─, Body fat % ─ TG_2: $\dot{V}O_{2max}$ ↑, Body fat % ↓ BMI ─
Colak and Ozcelik (2004) [36]	TG_1: diet TG_2: diet and exercise 35-45 min. 3 days/week	TG_2: 50-70 % W_{max}	4 weeks	1200-1600 kcal daily, 120 mg orlistat 3 times/ day	BMI ↓ body weight ↓ TG_2: maximal work rate (26,6%) ↑
Donnelly *et al.* (2000) [35]	TG_1: 30 min, 3 days/ week, treadmill exercise in the laboratory TG_2: 2 times per day, 15 min 5 days/ week at their home or work site, a minimum of 2 hours resting between the exercise sessions	TG_1: 60-75 % _O_{2max} TG_2: 50-65 % HRR	18 months	self-selected, 3-day food records	WHR ─ $\dot{V}O_{2max}$ ↑ body weight ↓ until 9 months, afterwards body weigh ↑ body fat ↓
Donnelly *et al.* (2003) [33]	TG: 20-40 min 5 days/ week CG: no intervention	TG: 60-75 % HRR	16 months	diet, partly self-selected and instructed, recorded by phone calls	TG (m): BMI ↓, Body fat ↓ TG (f): BMI ─, Body fat ─, no weight gain CG: no changes
Gillett *et al.* (1996) [32]	TG_1: health fitness education TG_2: health fitness education and aerobic training in groups, 60 min 3 days/ week CG: no exercise	TG_1: 60-75 % HRR TG_2: 60-75 % HRR	16 weeks	self-selected	TG_1:$\dot{V}O_{2max}$ ─, Body fat % ─, flexibility ↑ TG_2: $\dot{V}O_{2max}$ ↑, Body fat % ↓, hand grip strength ↑, flexibility ↑ 18 drop out
Jakicic *et al.* (1999) [37]	TG_1: 5 days/ week; 20 min (week 1-4), 30 min (week 5-8), 40 min (week > 9) TG_2: 5 days/ week; 20-40 min TG_3: like TG_2 self selected home based exercise with treadmill	self-selected	18 months	reduction of energy intake, education in groups	$\dot{V}O_{2max}$ ↑ Body weight ↓ Body fat ↓ Body fat % ↓ no differences between the groups
Kraemer *et al.* (1999) [30]	TG_1: only diet TG_2: diet and endurance training, 3 days/ week TG_3: diet, endurance and heavy resistance training, 3 days/ week CG: no intervention	TG_2: 70-80 % HR_{max} TG_3: 70-80 % HR_{max}	12 weeks	caloric restriction, weekly nutrition education in groups	TG_{1-3}: BMI ↓, Body fat % ↓, $\dot{V}O_{2max}$ ↓ TG_1: fat free mass ↓ TG_2 /TG_3: $\dot{V}O_{2max}$ ↑, TG_3: maximum strength ↑ CG: no changes

(Table 3) contd…..

Study	Groups/Exercise	Intensity	Period of Time	Diet	Selected Results
Leutholtz *et al*. (1995) [34]	TG_1: exercise, 3 days/ week TG_2: exercise, 3 days/ week	TG_1: 60 % HRR TG_2: 40 % HRR	12 weeks	caloric restriction - Opifast (420 kcal/ day, 5 days/ week)	BMI ↓ Body weight ↓ Body fat ↓ $\dot{V}O_{2max}$ ↑ no differences between the groups
Miller *et al*. (2002) [31]	TG: regular aerobic exercise 30-45 min, 3 days/ week (treadmill and bicycle ergometer training, walking in stadium) CG: no intervention	50-75 % HR_{max}	9 weeks	TG: DASH Diet	TG: body weight ↓, BMI ↓, HR ↓ CG: no changes
Niemann *et al*. (2000) [29]	TG_1: exercise, 5 days/ week, 20-45 min walking TG_2: diet TG_3: exercise and diet - (like TG_1 and TG_2) CG: 4 days/ week, 45 min Stretching	60-75 % HR_{max}	12 weeks	TG_2: 1200-1300 kcal/ day TG_3: 1200-1300 kcal/ day weekly nutrition education in groups	TG_1 /TG_3: $\dot{V}O_{2max}$ ↑ TG_2 /TG_3: BMI ↓, Body fat % ↓
Pritchard *et al*. (1997) [28]	TG_1: diet TG_2: exercise, 3 days/ week, 30 min; own aerobic exercise CG: monthly weight-monitoring	65-75 % HR_{max}	12 months	caloric restriction, information transfers to The Weight Loss Guide of the Australian Heart Foundation	TG_1: Body weight ↓ after 3, 6, 9 and 12 month TG_2: Body weight ↓ after 12 month CG: no changes

BIA - bioelectrical impedance plethysmography; BMI - Body Mass Index; HR - heart rate; HR_{max} - maximum heart rate; HRR - heart rate reserve; kcal - kilocalorie; CG - control group; f - female; m - male; max – maximum; min - minutes; N - group (total); n - subgroup; TG - treatment group; $\dot{V}O_{2max}$ - maximum oxygen uptake.

Table 4. Summary of Results Regarding "Diet Only" [19, 28-30, 36, 38]

Only Diet	N	k	r_g	95 % CI	S^2_r	S^2_{rho}	%SE	SD_{res}	Chi^2	BESD	g
Body weight (kg)	107	6	0.401	0.388-0.413	0.04	0.04	99.9	-0.0004	p=0.306	0.30/0.70	0.7
Body fat (kg)	81	5	0.393	0.393-0,393	0.003	0.044	100	-0.041	p=0.986	0.30/0.70	0.856
Body fat (%)	77	4	0.544	0.148-0.939	0.066	0.026	38.80	0.041	p=0.016	0.23/0.77	1.295
Maximal oxygen uptake ($\dot{V}O_{2max}$) (ml/min/kg)	24	2	0.182	-0.672-1.036	0.268	0.078	29.09	0.19	p=0.009	0.41/0.59	0.371

BESD - Binomial Effect Size Display; g - standardized mean differences; k - number of groups; 95% CI - 95% confidence interval of population effect sizes; N - subjects (total); Chi^2 - significance of χ^2 (test of homogeneity); r_g - population effect size (weighted mean); SD_{res} - residual standard deviation; %SE - random samples within monitored variance; s^2_r - variance of effect size r_g; s^2_{rho} - residual variance; $\dot{V}O_{2max}$ - maximum oxygen uptake.

Table 5. Summary of Results Regarding "Physical Exercise and Diet" [19, 29-31, 34, 36, 38]

Combination of Physical Exercise and Diet	N	k	r_g	95 % CI	S^2_r	S^2_{rho}	%SE	SD_{res}	Chi^2	BESD	g
Body weight (kg)	184	9	0.472	0.162-0.781	0.055	0.03	54.23	0.025	p=0.035	0.26/0.74	1.07
Body fat (kg)	140	7	0.52	0.52-0.52	0.017	0.027	100	-0.01	p=0.627	0.24/0.76	1.217
Body fat (%)	129	6	0.564	0.277-0.851	0.043	0.022	50.18	0.021	p=0.035	0.22/0.78	1.366
Maximal oxygen uptake ($\dot{V}O_{2max}$) (ml/min/kg)	61	4	-0.660	-0.66- -0.66	0.013	0.021	100.00	-0.008	p=0.468	0.83/0.17	-1.760

BESD - Binomial Effect Size Display; g - standardized mean differences; k - number of groups; 95% CI - 95% confidence interval of population effect sizes; N - subjects (total); Chi^2 - significance of χ^2 (test of homogeneity); r_g - population effect size (weighted mean); SD_{res} - residual standard deviation; %SE - random samples within monitored variance; s^2_r - variance of effect size r_g; s^2_{rho} - residual variance; $\dot{V}O_{2max}$ - maximum oxygen uptake.

conducted with different kinds of subjects to create parallelism structure of different programs; exercise duration ranged from ten minutes daily [2, 14] up to 280 and more minutes per week [9]. The studies reviewed were narrowly

Table 6. Summary of Results Regarding "Physical Exercise Only" [27-29, 32, 33, 35, 37]

Exercise Only	N	k	r_g	95 % CI	S^2_r	S^2_{rho}	%SE	SD_{res}	Chi²	BESD	g
Body weight (kg)	238	8	0.079	0.074-0.074	0.005	0.033	100	-0.028	p=0.990	0.46/0.54	0.148
Body fat (kg)	232	8	0.207	0.207-0.207	0.009	0.032	100	-0.023	p=0.944	0.40/0.60	0.424
Body fat (%)	380	12	0.205	0.205-0.205	0.008	0.029	100	-0.021	p=0.986	0.40/0.60	0.418
Maximal oxygen uptake ($\dot{V}O_{2max}$) (ml/min/kg)	189	6	-0.420	-0.751- 0.084	0.051	0.022	42.77	0.029	p=0.015	0.71/0.29	-0.92

BESD - Binomial Effect Size Display; g - standardized mean differences; k - number of groups; 95% CI - 95% confidence interval of population effect sizes; N - subjects (total); Chi^2 - significance of χ^2 (test of homogeneity); r_g - population effect size (weighted mean); SD_{res} - residual standard deviation; %SE - random samples within monitored variance; s^2_r - variance of effect size r_g; s^2_{rho} - residual variance; $\dot{V}O_{2max}$ - maximum oxygen uptake.

Table 7. Summary of Results Regarding "No Intervention" [28-31, 33]

No Intervention	N	k	r_g	95 % CI	S^2_r	S^2_{rho}	%SE	SD_{res}	Chi²	BESD	g
Body weight (kg)	134	7	0.024	0.244-0.244	0.010	0.052	100	-0.043	p=0.970	0.49/0.51	0.050
Body fat (kg)	58	4	-0.032	-0.032- -0.032	0.011	0.069	100	-0.058	p=0.635	0.52/0.48	-0.063
Body fat (%)	92	5	0.136	0.136-0.136	0.041	0.052	100	-0.012	p=0.422	0.43/0.57	0.274
Maximal oxygen uptake ($\dot{V}O_{2max}$) (ml/min/kg)	64	3	-0.218	-0.220- -0.220	0.002	0.043	100	-0.040	p=0.931	0.61/0.39	-0.450

BESD - Binomial Effect Size Display; g - standardized mean differences; k - number of groups; 95% CI - 95% confidence interval of population effect sizes; N - subjects (total); Chi^2 - significance of χ^2 (test of homogeneity); r_g - population effect size (weighted mean); SD_{res} - residual standard deviation; %SE - random samples within monitored variance; s^2_r - variance of effect size r_g; s^2_{rho} - residual variance; $\dot{V}O_{2max}$ - maximum oxygen uptake.

focused, with relatively few variables (Table **2**). The subjects ranged from 21 to 54 years of age, with a mean age of 40. Most of the studies were performed with subjects that were moderately obese; however, the definition of obesity varied in the studies. Body Mass Index (BMI) was the primary criterion, but all authors included overweight (BMI > 25) and obese (BMI > 30) subjects in a single study group. Thus, the results could present a distorted picture, as it is conceivable that physical exercise is a more effective intervention strategy for older or more severely obese individuals [11].

In this meta-analysis, we aimed to avoid the pitfalls commonly involved in compiling this kind of systematic review. The electronic literature located depends on the number of databases searched and the search strategy and key words used. In this study, all relevant medical research databases were taken into account; the search strategy covered all medical subject terms ("mesh search") in each database. Selecting the relevant studies from the wealth of titles and abstracts could have presented a problem; this was addressed by utilizing a list of inclusion criteria and having two reviewers independently assess which studies merited inclusion in the meta-analysis. In the end, although the entire references from each paper selected were checked for other possible eligible studies, only thirteen met the criteria, as the meta-analysis was restricted to studies based on randomized controlled trials. Thus, the greatest weakness of this review is the small number of studies involved.

The main result of this meta-analysis is that changes in diet alone or in combination with physical exercise are the most effective courses of treatment when it comes to weight loss and changing body composition, i.e. increasing lean body mass and decreasing body fat (Table **3**). With regard to the parameters examined, the interventions "d" and "dpe" resulted in greater weight loss than "pe" alone. These results partly confirm the outcomes of earlier reviews.

For example, while the results of the meta-analysis by Garrow & Summerbell (1995), which included 28 studies published between 1966 and 1993 [19], demonstrated that exercise only could reduce weight by three kilograms in 30 weeks [20], they indicated that a combination of diet and exercise had the greatest effect and that "strength training" had no discernable influence on weight loss.

Miller *et al*. (1997) performed a meta-analysis of 493 primary studies published from 1969 to 1994 [20]. The objective of the review was to determine the effect of exercise and changes in diet, both alone and in combination, on weight loss; the subjects were middle-aged and moderately overweight rather than obese and the duration of treatment was fairly long, i.e. 15 weeks. The authors found that both changes in diet alone and changes in diet in combination with exercise were more effective in inducing weight loss in short-term interventions than exercise alone. In his review, Wing (1999) confirmed that a combination of exercise and changes in diet produced the best outcome in short-term interventions, while emphasizing the importance of exercise in maintaining and stabilizing weight over the long term [19]. Gleim (1993) asserted that exercise had a beneficial effect in reducing lifestyle diseases in overweight individuals, even when little or no weight loss resulted [13, 18, 22]. Blundell and King found that exercise did not lead to an increase in average daily caloric intake [10]. These results show that dieting is more effective in reducing weight, but that exercise is more effective in reducing fat during the early phase of a weight-reducing program in healthy overweight or obese persons [40-42]. Furthermore,

adherence is such an important factor that Biddle & Fox (1998) recommended the utilization of special health consultants to support individuals in weight loss programs [22, 38] however the performance of training of the included studies was not described. Also dropouts exert a high influence on the results of the single studies [van Baak]. However, the included studies did not refer to dropout-rates. As to the best kind of exercise, Rippe & Hess (1998) found that walking had the highest influence to combat obesity, followed by swimming, biking, and low-intensity aerobics [13, 18, 40].

4. CONCLUSION

In conclusion, the data obtained in long-term clinical trials evaluating various methods of weight maintenance are supported by this review of the literature [11]. Though exercise intensity and duration varied, as did the organization of the programs, all studies reviewed found that physical exercise had beneficial effects in overweight and obese subjects. However, when it comes to inducing weight loss, the results indicate that physical exercise combined with changes in diet is the most effective form of treatment. Unfortunately, the information supplied about diet regimens was usually not very detailed. More research to evaluate different strategies for short- and long-term weight loss and weight maintenance programs would be extremely useful.

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