

Weighing Solutions to Obesity

An Overview of
Studies on Prevention
and Intervention

March 2016

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MILKEN INSTITUTE
PUBLIC HEALTH SUMMIT

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Executive Summary

The physical and economic toll of obesity is immense and indisputable. More than two-thirds of adults in the United States are either overweight or obese, and more than one-third of all adults are obese.¹ A risk factor for numerous chronic diseases, obesity accounts for \$147 billion annually in health-care costs.²

Linked to diabetes, hypertension, and heart disease, obesity results in reduced quality of life, increased morbidity, and higher mortality rates for millions of people. It also levies a significant economic burden on the United States.³ In addition to health-care costs, obesity-related absenteeism and presenteeism in the workplace diminish productive output of the labor market by billions of dollars.^{4,5}

Groups with a stake in health care—from government to business leaders to care providers—all have identified the need for solutions to this problem. Many obesity interventions have been designed, tested, and published in the literature. Researchers have aggregated the results of similar studies into systematic reviews, descriptive analyses of multiple studies, and meta-analyses, which quantitatively aggregate study results.

Because obesity is such a widely studied topic, numerous reviews and meta-analyses exist examining various facets of interventions. In fact, after sorting through thousands of potentially relevant papers, we found 29 meta-analyses on effectiveness and many more systematic reviews. For busy professionals in the field, sorting through this expanse of literature to find the right evidence to build their intervention may not be feasible. Ideally, all of that information would be in one place.

This paper intends to serve as a starting point for such an endeavor. It reviews existing systematic reviews, rather than individual studies, to provide an introduction to obesity reduction and prevention interventions; the components that lead to their success; their effectiveness in the real world; and their associated costs. By presenting summaries of evidence, reviews of reviews can guide interested parties to sources of further information.⁶

We found a total of 35 studies satisfying the search criteria—29 were meta-analyses examining obesity lifestyle interventions, and 10 were systematic reviews examining cost-effectiveness, with four overlapping. The examined interventions were greatly varied in terms of populations, durations, structure, and content, so it was difficult to compare between meta-analyses.

Still, the broad findings were encouraging. Judging from the results of the meta-analyses, it is clear that investing in obesity prevention and reduction is a worthwhile endeavor—these programs create measurable weight loss. Few reported no significant effect in terms of weight loss, and the average weight loss from studies reporting the outcome measure in kilograms (kg) ranged from 0.6 kg to 7.4 kg (1.3 pounds to 16.3 pounds).

Information on costs was less prevalent and reporting measures differed greatly among studies that presented economic data. However, most lifestyle interventions reporting cost-effectiveness in terms of incremental costs per quality-adjusted life years (QALYs) found many of them to be cost-effective based on the commonly cited threshold of \$50,000 per QALY gained.

Below are some notable observations from our review of reviews:

- **Diet works better than exercise, but multi-component interventions are best.** One review found that a combined behavioral weight-management program improved weight loss by 1.72 kg compared with diet alone and by as much as 6.29 kg compared with just physical activity. Specifically, inclusion of a behavioral technique such as motivational interviewing along with diet and exercise may further improve results.
- **There was often no significant difference in results between interventions provided by physicians and those by lay people.** Two reviews determined that lay versus professional interventionist had no effect on outcomes, though one review found that dietitian contact improved results while psychiatrist contact did not. As personnel costs made up a large portion of overall program costs, increasing the proportion of programs delivered by less expensive interventionists may increase cost-effectiveness.
- **Technology may be a worthwhile investment.** Interventions using computers, phones, or texting as the only delivery method fared better than usual care but worse than interventions delivered in person. When technology was added on to in-person care, there were increases in weight loss of 1.0 kg to 1.48 kg.
- **Commercial programs work.** Commercial meal-replacement programs were some of the most effective, resulting in 6.8 kg to 7.4 kg in weight loss. However, they also tended to be more expensive than lifestyle interventions.

When examining studies, stakeholders must consider the difference between efficacy and effectiveness. While it is understood that in a perfect setting diet and exercise result in weight loss, it's crucial to learn how people will respond to an intervention in the real world. Consider, for example, that a large proportion of the examined study populations consisted of

middle-aged, non-Hispanic Caucasian women, but evidence shows that minority or low-income populations, who tend to be the most vulnerable to obesity, may approach behavioral-change interventions differently.^{7,8} In addition, factors such as attrition rates must be kept in mind to ensure that implemented strategies are sustainable.

Despite the vast number of studies on the topic, more research remains to be done. Money toward public health is not abundant, so efforts are best focused on devising interventions that are the most effective and provide the best value. Strong research is requisite in this process. Specifically, research that provides more detailed descriptions of interventions will make it easier to understand and replicate the interventions in the real world or in a future study.

Further, in a real-world setting, costs significantly affect the feasibility of implementing an obesity intervention, as well as its potential size and scope. However, there is very little data comparing the relative cost-effectiveness of interventions or moderator effects. For example, while the results of this review revealed that higher-intensity interventions (in terms of duration, frequency of contact, and number of components) are often more effective, it is less clear whether such interventions are more cost-effective than lower-intensity interventions. Improved reporting on cost outcomes would help determine this.

Recommendations

This paper also identifies where research is lacking and what needs to be done so that future studies and reviews can better assist decision-makers. Here are potential ways to develop research that can lead to real change:

- Study and review interventions on a diverse patient population that is representative of the population with or at risk for chronic disease.
- Report program structures, intervention costs, and relevant health-care costs in more granular detail in both studies and reviews.
- Perform moderator analyses on such details in meta-analyses to better understand the context of successful interventions.
- Standardize outcome measures and follow-up practices to enable study of comparative effectiveness.
- Finally, undertake a large meta-analysis with in-depth moderator analysis that could enable quantitative comparison of interventions and their components.

Introduction

By its nature, obesity is not a permanent affliction, and therein lies an opportunity to improve public health and economic conditions. On an individual scale, weight loss even as small reductions is associated with multiple health benefits,⁹ and on a population scale, these incremental changes could result in significant economic improvements.

Looking at prevalence figures, it is clear there is a pressing need to find effective solutions. Obesity has increasingly become a serious health and economic problem in the United States over the past 25 years, affecting the quality of life for many Americans and diminishing productivity in the workplace. In 1990, less than 15 percent of Americans were obese in each state. Today, that figure has about doubled. Two out of three adults nationwide are overweight (defined as a body mass index of 25 or greater) and one out of three is obese (BMI or 30 or greater).¹⁰

Not only does obesity lead to physical harm—it is a risk factor for chronic diseases such as diabetes, hypertension, and heart disease, resulting in reduced quality of life, increased morbidity, and increased mortality for millions—but it also levies a significant economic burden on the United States.¹¹ Obesity causes \$147 billion annually in health-care costs (in 2008 dollars),¹² and obesity-related absenteeism and presenteeism in the workplace diminish productive output of the labor market by billions of dollars as well.^{13,14}

The simple and obvious prescription for obesity is weight loss, which is associated with improvements in health outcomes, prevention of disease onset, and mitigation of side effects of disease. There is no established minimum for weight loss to be beneficial.¹⁵ Small reductions may be associated with loss of visceral fat, which may have multiple health benefits.¹⁶

Groups with a stake in health care have identified the need for solutions that prevent and reduce obesity. Many interventions exist, and with the increasing prevalence and capabilities of technology, more are being designed. Researchers have reviewed numerous interventions to establish efficacy and statistical relationships. But they have yet to create an ideal method to sort through this abundance of options and identify a tailored, evidence-based optimal solution.

When health professionals are planning interventions and writing grants for funding, they often have to show that a proposed intervention is evidence-based before being allowed to implement it. This is a practice to ensure the program is effective and worth the allocation of resources. However, many trials do not examine effectiveness of interventions (the results of such programs in real-world situations). Rather, research often examines the efficacy of interventions, or the program's results under ideal conditions. This process eliminates potential confounding factors, ensuring that the intervention itself is capable of yielding the desired outcome.

However, interventions shown to be efficacious in research do not always translate to the desired outcomes in the real world. In a trial setting, many barriers to quality care are eliminated. Access to the health setting is generally easy for study participants, the intervention likely poses no cost to them, and practitioners are often highly trained and focused on intervention outcomes. In the real world, one or all of these factors may cease to be true, and studies examining real-world interventions often show no positive outcomes even when the efficacy trial had a significant result.¹⁷ Decision-makers should keep in mind the potential that evidence of efficacy—rather than effectiveness—may provide false information. For similar reasons, this review examines studies that report effectiveness versus efficacy.

The goal of this study is to assist the increasing number of decision-makers in search of the ideal way to create and implement an effective obesity intervention. We carried out a review of systematic reviews of obesity prevention and reduction interventions. This review examined components of studies targeting weight loss to identify which components are most strongly associated with positive results. Understanding the effects of intervention components as well as the intervention as a whole allows program planners to best tailor their review to their environment and target population.

As health-care costs rise, the number of people with a stake in population health is becoming more apparent. It is a problem not just for health professionals. Employers have incentives to reduce chronic disease to minimize health insurance costs. Community-based organizations can implement public health interventions to improve the quality of life of their target population. Local governments can implement programs so that their constituents become a healthier and more productive workforce, effectively boosting their economy. This review examines the effectiveness of interventions that can be implemented in a variety of settings, not only in a clinical environment by a physician.

On an individual level, obesity can be affected primarily through diet and exercise. Additional pharmacological and surgical interventions exist, but they have more specific indications and require more direct expertise to provide, so they are not the subject of this review. Instead, this review examines primary and secondary prevention together. In primary prevention, the goal is to offset incidence of disease; in secondary prevention, it is to mitigate disease symptoms and side effects. In the case of obesity and chronic disease, weight reduction can contribute to both primary and secondary prevention. Oftentimes the interventions are similar and in many real-world settings the patient populations will overlap. While people with disease may qualify for additional medical interventions such as pharmacotherapy or bariatric surgery, diet and exercise continue to be effective in reducing weight or BMI for this population.

Costs play a large role in this process, because funding of health programs is so fragmented and large-scale behavioral interventions are often too expensive to be feasible.¹⁸ Obesity counseling by health professionals is infrequent, because insurance rarely covers its costs, increasing out-of-pocket expenses for the patients. Additionally, reimbursement to health professionals for obesity prevention is low or nonexistent and, in an environment where practice revenue corresponds to reimbursement, there is often insufficient time for counseling.¹⁹ As such, this review also examines costs associated with obesity interventions to provide insight into maximized health gains from resources invested in obesity prevention.

In tackling the abundance of literature on obesity prevention and reduction, this review aims to create an accessible introduction that informs health professionals about the diversity of obesity interventions and how to best structure their own obesity programs. It looks at meta-analyses examining effectiveness of reduction and prevention programs, as well as systematic reviews and meta-analyses on the economics of obesity interventions.

Overview Results

Study Characteristics

We found 29 meta-analyses analyzing effectiveness of obesity interventions and 10 reviews with information on costs, with four overlapping for a total of 35 studies examined in this overview. The interventions examined were generally diet, physical activity, behavioral interventions, or a combination of the three. Reviews generally focused on the effects of one or several components of an intervention on weight-loss outcomes. These components include different approaches of behavioral interventions (e.g., comparing diet or physical activity), delivery methods (e.g., online or in person), and program intensity (e.g., multi-component or single component).

Description of intervention specifics was often lacking in reviews, and descriptive terms were vague. For example, a behavioral intervention could refer to a general lifestyle intervention or, more specifically, to an intervention espousing a psychological technique such as motivational interviewing. We identified behavioral interventions as those using a specific psychological technique such as self-care. Often, intervention program structures were not well-quantified. Controls were generally assigned to standard care or a lower-intensity intervention. Intensity can stem from frequency of intervention contact, duration of intervention, or number of intervention components.

The meta-analyses examined randomized controlled trials, nonrandomized controlled trials, quasi-randomized controlled trials, cohort studies, and controlled before-and-after studies.

Of the 29 included reviews, only three revealed no significant summary effect on weight loss measured in kilograms or reductions in BMI. Individual studies report outcomes as the average (mean) difference between intervention group and the control for all the participants in the study. Meta-analyses report the outcomes of multiple studies as one number. Generally, they weight the outcomes based on the sample size and variance of the study and aggregate the mean differences from individual studies based on the weights, yielding a weighted mean difference, also reported as a summary effect. For reviews showing significant weight loss in kilograms (kg), summary effects ranged from -0.6 kg to -7.4 kg in terms of weighted mean difference between study arm and control. (See Appendix for results tables.)

Reviews reported high levels of heterogeneity among individual studies, which makes it difficult to compare effectiveness. As such, results from the included reviews are described qualitatively. Included studies revealed relatively low levels of publication bias. Risk of bias in study characteristics was assessed using Overview Quality Assessment Questionnaire criteria for systematic reviews and meta-analyses. Included reviews were generally of high quality. (See Appendix for details on study quality and assessment.)

Intervention Characteristics

Intervention Components

While most of the interventions examined in the reviews included a dietary component, none of the reviews had a specific dietary focus. As the efficacy of diet on weight loss is well-established for reducing obesity and chronic disease, reviews examining this relationship alone without considering more granular intervention components were excluded.²⁰

Three reviews examined interventions that had to do with physical activity. Two of them compared aerobic training and resistance training: One showed no significant difference in weight loss, though it did find a significant reduction in BMI, while the other found a significant weighted mean difference of -1.15 kg in favor of aerobic over resistance training.^{21,22} Combined aerobic and resistance training revealed a significant increase in weight loss of 2.03 kg compared with resistance training alone.²³ The last study examined the effect of pedometers on physical activity interventions, finding a significant difference in weight loss of 1.27 kg associated with pedometer use and an average loss of 0.05 kg per week.²⁴

Seven reviews examined behavioral components to obesity intervention: stress management,²⁵ motivational interviewing,^{26,27} self-help,²⁸ self-regulation,²⁹ empowerment,³⁰ and multi-component behavioral techniques.³¹ Two studies, on empowerment and self-regulation, found no significant effect of this focus on weight outcomes. Effects of other behavioral interventions ranged from 1.3 to 2.8 kg in weight loss, with the largest effect associated with the multi-component intervention.³²

Delivery

Eight studies examined effects of delivery modalities on weight-loss outcomes. Six examined the effects of technology-assisted interventions,^{33,34,35,36,37,38} one examined effects of in-person intervention supervision,³⁹ and the last examined group versus individual delivery. Supervised exercise resulted in a significant mean difference of -2.4 kg compared with unsupervised physical activity interventions.⁴⁰ Group interventions were associated with significantly increased weight loss by 1.4 kg compared with individual interventions,⁴¹ although this result contradicts some findings in moderator analyses and subset analyses of other examined reviews.⁴²

Technology-based interventions used the Internet, mobile phones, computer programs, telemedicine, and/or SMS messaging in various functions and frequencies.^{43,44,45,46,47} Two studies found no significant difference between a technology-based intervention and a minimal-care control, and one found significant improvements with enhanced Web-based interventions compared with general education Web-based interventions (this was not

compared with a minimal intervention control).^{48,49} Generally, technology-based interventions showed significant weight loss compared with non-technology controls, ranging from 0.68 kg to 1.44 kg. Two reviews examined interventions delivery solely using technology compared with interventions delivered in person and found significant weight gains of 1.27 to 1.47 kg.^{50,51} Including a technology-based intervention with an in-person intervention results in larger weight reductions compared with in-person interventions alone (-1.0 kg to -1.48 kg).

Intensity

One study compared multi-component behavioral intervention with single-component diet and single-component physical activity interventions, with the multi-component intervention improving outcomes compared with both controls.⁵² The weighted mean difference was significantly larger using single-component physical activity interventions compared with diet interventions (-6.29 kg versus -1.72 kg).

Maintenance

Three reviews assessed the maintenance of health effects after the active phase of obesity interventions, assessing whether weight loss was sustainable in the long term. One examined dietary counseling interventions, revealing a maximum net treatment effect of 1.9 kg/m² (this study examined BMI) at one year, followed by regain.⁵³ Another found increased weight loss with time, revealing a weighted mean difference of -1.56 kg at 12 months and -1.96 kg at 18 months.⁵⁴ The last study examined a lifestyle intervention at three years, finding significant weight loss for both overweight and obese individuals. Results were reported by population: Compared with the control group, weight loss for the primary prevention group was 2.2 kg more and for the secondary prevention group was 3.49 kg more.⁵⁵

Population or Setting

The last eight reviews examined the effects of interventions by population or setting. Two studies examined workplace interventions,^{56,57} one review examined males only,⁵⁸ one review examined older adults,⁵⁹ and four studies examined translation of multi-component interventions into real-world settings.^{60,61,62,63} All summary effects showed significant differences in weight loss compared with control. Reviews focused on older adults and males because many trials have a very small proportion of these individuals as participants, despite a large number of both men and older adults suffering from obesity and chronic disease. These reviews have some of the largest summary estimates, -5.66 kg from the all-male study⁶⁴ and -3.0 kg for the older-adult intervention.⁶⁵ Two studies specifically examined commercial meal-replacement programs, finding the largest summary effects of any examined intervention (-6.83 kg and -7.4 kg).^{66,67}

Intervention Component Analyses

Generally speaking, a meta-analysis aims to determine quantitatively whether an intervention is actually effective. It also enables examination of how interventional characteristics influence treatment outcome, which is accomplished through moderator analyses such as subset analyses and meta-regression.⁶⁸ In this case, the outcome measure is weight loss, and the moderator analysis essentially helps identify the optimum elements for a given obesity intervention.

Intervention Components

Being specific about intervention structure seemed to improve weight loss, but the effectiveness of various programs was inconsistent across reviews. For example, one study found no significant effect comparing dietary interventions versus control, high-carb and low-fat diets compared with other diets, or in adding any type of physical activity to dietary intervention compared with diet alone.⁶⁹

The following are intervention approaches that were found to significantly improve weight loss:

- Recommending walking⁷⁰
- Counting calories⁷¹
- Recommending fewer calories per day
- Combining diet and exercise programs as opposed to single-activity interventions⁷²

Behavioral and Theoretical Components

From our overall analyses, multi-component behavioral weight-loss programs were deemed to be effective. Many behavioral or psychological techniques were found to significantly improve weight loss. Among them:

- Having weight as a primary outcome.
- Having a clearly defined goal.
- Using an attention control.
- Measuring treatment fidelity.
- Using a behavioral component as part of a multi-component trial.⁷³
- Using a trans-theoretical model (instead of social cognitive theory).⁷⁴
- Using behavior-change techniques that compare participant behaviors with those of others.⁷⁵

Self-regulation and self-empowerment had no significant effect on weight loss and labeling an intervention as “behavior modification” worsened outcomes.^{76,77}

Delivery Method

With increasing focus on health-care delivery in recent years, examining how the delivery modality of obesity interventions affects weight loss is important. Thus far, however, the effects of the delivery methods seemed to be varied, sometimes contradicting results of other meta-analyses:

- Supervised exercise and general in-person contact had no significant effect on weight loss.⁷⁸
- Contact with a dietitian showed significant improvements, while contact with a psychologist had no significant effect.⁷⁹
- Two reviews found no significant effect from Web-based or computer-based delivery while one review did, which contradicts meta-analysis results on delivery methods.^{80,81,82}
- Individualized instructions significantly improved outcomes.⁸³

Intensity

It would seem logical to conclude that a more intense program—be it longer, with more frequent contact, or having more components—would result in better outcomes. However, several reviews noted that an overly burdensome intervention might not be sustainable. That was not explored in depth. The potential for increased attrition after a certain program intensity should be further examined.

- Increased frequency of contact was associated with improved outcomes.^{84,85,86,87,88}
- Two studies have meta-analyses that support no significant effect of effectiveness on intensity.^{89,90}
- Some studies found improvements in weight loss associated with increased time,^{91,92,93,94} while others found worsening of health outcomes with increased duration of intervention.⁹⁵

Participants

It is important to target an intervention to the population being treated, so it makes sense for researchers to examine how weight loss in an intervention is affected by the population within the study.

- One study reported that absence of diabetes was a significant predictor of weight loss⁹⁶ or slower weight gain, while another study said disease status had no significant effect.⁹⁷

- Younger participants were associated with more weight loss,⁹⁸ though this may contradict the one review examining the older adult population that had a relatively large summary effect compared with the other examined reviews.⁹⁹
- One study found that primary prevention interventions were associated with significant weight loss but not significant reductions in BMI, and the opposite was true for secondary prevention interventions.¹⁰⁰

Economic Evaluation

While health outcomes of obesity prevention and reduction interventions have been widely examined, information on costs and cost-effectiveness for the same programs is sparse. This review found 10 systematic reviews reporting information on costs and cost-effectiveness. We have included data for interventions outside the inclusion criteria for our review of effectiveness, in order to provide a frame of reference for relative costs and outcomes of different types of obesity interventions. As it stands, the cost data is not comprehensive, but it serves to inform resource allocation as much as possible.

Cost of interventions generally included expenses such as administration, materials, salary, and transportation. It was variously reported as dollars, dollars per person, or dollars per outcome. Cost-effectiveness examined the costs over a time horizon per disability-adjusted life-years (DALYs) or quality-adjusted life-years (QALYs) determined through modeling. Outcomes were reported as incremental cost-effectiveness ratios (ICERs). The ICER can be compared with a commonly cited willingness-to-pay standard, which is \$50,000 per QALY gained or DALY averted.¹⁰¹ Examination of cost-effectiveness using models incorporates an intervention's effects on future costs and outcomes of a population, rather than only comparing the short-term effects of an intervention.

One review examined the long-term cost-effectiveness (time horizon of greater than 40 years), reporting incremental ICERs in terms of both incremental cost per QALY gained and incremental cost per DALY averted.¹⁰² Most behavioral interventions that focused on diet and/or exercise were cost-effective based on the \$50,000 threshold. Interventions with ICERs above the willingness-to-pay threshold often cited increased program costs associated with patient time and transport, combined with smaller improvements in health outcomes.¹⁰³ Behavioral interventions focused on increasing social support were cost-effective but had larger overall ICERs (averaging around \$30,000 per QALY). The most cost-effective program used the Internet as a delivery method, with an ICER of \$1,498 per DALY averted.

Community interventions were cost-effective other than those in schools, which suffered from expensive delivery structures, low participation, and minimal outcomes. In addition, preventive interventions that focused on children often did not show improved health outcomes until

later in life. This means that statistically, the future costs and benefits may be discounted, which could lead to lower measures of cost-effectiveness. Environmental interventions such as taxation of unhealthy foods, subsidization of healthy foods, and food labeling were cost-effective. However, these analyses should be viewed with caution, as results are sensitive to assumptions about rates of weight maintenance and target population participation. These types of interventions were not incorporated into our effectiveness review of meta-analyses.

ICERs were dependent on program components and associated costs. For example, a walking program generated an ICER under \$1,235, which was substantially less than another behavioral program ICER of \$30,491 (though this is still considered cost-effective as defined by the aforementioned threshold).¹⁰⁴

The cost-effectiveness of multi-component interventions in compared with that of the individual components has not been well-established.¹⁰⁵ Studies assessing both approaches found a tendency toward increased cost-effectiveness for multi-component interventions, citing larger health gains and the potential for savings through economies of scale (specifically, lower administrative costs).¹⁰⁶ One analysis of commercial programs found a cost (per kilogram lost) of \$155 for one lifestyle-management program, \$213 for another, and \$424 for a commercial meal-replacement program.¹⁰⁷ Overall costs of those programs averaged at \$377, \$682, and \$2,512 per person, respectively.

Diabetes self-management training is an example of a multi-component lifestyle intervention generally found to be cost-effective in a variety of formats, including group education in a health-care setting and team-based community approaches using dietitians and pharmacists.¹⁰⁸ According to one study, more intensive interventions were cost-effective in higher-risk populations.¹⁰⁹ In addition, diabetic patients are often able to obtain dietary counseling through dietitians within a health-care setting through medical nutritional therapy, which is a reimbursed service for most insurance.¹¹⁰ The evidence to support cost-effectiveness of this service is not strong, but such a service may be easier to access by patients since it can be reimbursed.¹¹¹ Further, the review examining such interventions did not report ICERs or explain the definition of “cost-effective” for the included studies, and therefore is not strong evidence. One study reported diabetes program costs, citing six session material costs at \$934 and 16 session material costs at \$1,075, with a significant increase when using clinically trained staff compared with laypersons (the type of interventionist was found to have no significant effect on outcomes).¹¹²

Four reviews presented information on workplace wellness programs. One review examined worksite interventions under the lens of profitability. Results were aggregated based on study design, with randomized controlled trials finding no return on investment in terms of absenteeism or medical costs, while nonrandomized controlled trials found returns on investment for both.¹¹³ Previous aggregations found returns in terms of averted medical costs and/or productivity loss ranging from \$1.40 to \$4.60 per dollar spent, though analyses aggregated studies with differing methodologies that were not specific to weight loss.¹¹⁴ Average annual per-capita costs of workplace obesity prevention programs ranged from \$11 to \$1,384, with a median of \$155.¹¹⁵ Another study examined overall program material costs, requiring an investment of \$762 to \$25,276.¹¹⁶ Two programs found a cost-per-pound-lost ranging from \$1.44 to \$1.66 (or \$3.17 to \$2.65 per kg lost). Another review found that wellness programs saved between \$176 and \$1,539 per participant per year.¹¹⁷

Novel technologies in the form of “adaptive e-learning devices” were examined for cost-effectiveness in obesity prevention and reduction.¹¹⁸ They were not found to be cost-effective, primarily due to high fixed costs and no statistically significant effect on weight change.¹¹⁹ However, another study examining long-term cost-effectiveness of an Internet delivery intervention found an ICER under \$2,000 per DALY averted, which is highly effective.¹²⁰ The two computer-based interventions with cost data ranged from \$115 to \$139 per patient (these are not ICERs).¹²¹ As technology becomes cheaper, and such interventions are possible using Internet and mobile technology, cost-effectiveness ratios may improve.

Discussion

Increasingly, systematic reviews are performing statistical analyses on individual intervention components for a better understanding of structural influences on health outcomes. This review combined examinations of meta-analyses on interventions and systematic reviews on economics to shed light on the available interventions as well as the literature on their effectiveness.

Unfortunately, the interventions are not well-described in the literature, so comparing summary effects is difficult when examining a review of reviews. Still, this review reveals opportunities for creation and implementation of obesity reduction strategies. For example, one pattern emerging from this analysis was that diet has a larger effect than physical activity on weight loss. If appropriate for the target population, decision-makers can focus on dietary interventions or ensure that nutrition is part of multi-component programs, thereby increasing the value of their public health spending. More specifically, program planners can be mindful that promoting calorie counting, recommending fewer calories per day, and combining diet and exercise within one intervention can improve weight loss.

The People Factor

An opportunity to save money can be found in the delivery personnel associated with an intervention. Several reviews examined differences in weight loss with lifestyle interventions delivered by health professionals and by laypersons, finding no significant difference in weight-loss outcome. As highly trained professionals are more expensive to hire, increasing use of layperson-delivered interventions may decrease costs and increase cost-effectiveness of programs. Reduced need for initial investment reduces the risk of beginning a program, which may increase the likelihood and feasibility of stakeholders' being able to plan and implement one.

Furthermore, given the disparity in socioeconomic status between health professionals such as physicians and the average American with obesity, community health workers or laypersons delivering interventions may have increased cultural competency, potentially increasing uptake and improving outcomes in socioeconomically disadvantaged populations.^{122,123}

Technology's Role

Current evidence does not strongly support the potential for technology to replace in-person lifestyle interventions. However, technology yields significant improvements in weight loss when used in addition to typical lifestyle interventions. Though magnitude of weight loss was relatively small in the studies reviewed, improvements associated with access to technology-based modalities may still be cost-effective if the patient population has easy access to or already owns the technology platform. More research must be undertaken in this area.

Increased integration of technology into society has resulted in increased social connectedness. Social support plays a large role in general health as well as the likelihood to change behavior. In fact, social support intervention is one of the four strategies recommended by the task force on community preventive services.¹²⁴ Among the studies of technology interventions examined, some included social support through access to chat rooms, forums, or buddy-system e-mails to others undergoing the intervention. Few studies in the included reviews quantitatively examined social support as a factor in obesity prevention and reduction, but this should be included in future meta-analysis and meta-regression. As technology becomes more integrated into health care, opportunities to increase social support need to be developed and tested.

Cost and Effectiveness

Data examining costs and cost-effectiveness of obesity interventions was infrequently reported. Inconsistent methods among studies and models make it difficult to aggregate and compare study findings. However, several trends surrounding costs did emerge. Most behavioral interventions tended to be cost-effective.¹²⁵ Programs that were not cost-effective were often hindered by expenses associated with program operation, such as large administrative costs and/or high levels of patient time and transportation, both of which reduce cost-effectiveness.¹²⁶

Highly intensive interventions, with greater frequency of contact, more components, or increased duration, typically cost more but also generally improved health outcomes. They tended to be more cost-effective for at-risk populations and thus may be more appropriate for secondary prevention of disease.^{127,128} Indeed, many of the examined behavioral interventions focused on obese and overweight people, while fewer studies examined primary prevention of obesity in the well population.¹²⁹ While economic reviews mentioned the possibility of improved cost-effectiveness in populations at greater risk, our analysis of intervention effectiveness showed inconsistent results on the connection between weight loss and outcomes such as diagnosis with chronic disease. Further research is needed to explore the relationships of health status, effectiveness of weight-loss interventions, and costs.

Wellness in the Workplace

The workplace is an increasingly common point of care for obesity reduction, and businesses often begin workplace wellness programs with a hope of return on investment. Data is not conclusive on this possibility, although if enough people are motivated to begin behavior change based on access to such a program, results from non-randomized controlled trials may imply that a return on investment is indeed possible.¹³⁰

Of all reviews, those examining workplace wellness were most likely to report economic data. However, reporting of costs was varied, ranging from cost per pound lost to overall program costs with no mention of size of target population. A consistent method of evaluation would allow collaborative improvement through learning from alternative interventions.

Limitations of Existing Studies

There was significant heterogeneity across included reviews and in studies pooled to create summary effects. Many reviews or individual studies did not report relevant intervention components such as intervention intensity, which was shown by other reviews to affect weight-loss outcomes. Intensity should be controlled for or examined through subset analysis to ensure it is not confounding results. Many studies did not control for other relevant confounders either.

The review revealed inconsistent results when assessing the relationship between duration of intervention and weight change. Some reviews reported a positive association between weight loss with duration, but one review found a reduction in weight loss after a certain point in the timeline of the intervention. One review saw no significant difference between outcomes based on intervention duration. However, we must consider that there is a difference between weight loss measured directly after an intervention and long-term weight-loss maintenance. Perhaps a shorter intervention may not have the same effect on weight maintenance as a longer one, though this was not routinely measured. Also, differences in intervention duration cause difficulty when comparing a single end point. For example, at 12 months after inception of the intervention, some participants may have been in the maintenance phase for eight months while others may just be finishing the active phase of their intervention. The relationship of length of active phase, length of maintenance time, and weight loss varies according to the data examined.

Many reviews were not explicit about the setting of the individual studies examined. The setting of an included intervention is important as it relates to the generalizability and effectiveness of the intervention. If individual studies and reviews do not provide information on intervention details—such as provider, setting, and attrition—it is difficult to assess how realistic an intervention program truly is, and therefore it is difficult to determine whether the study shows efficacy or effectiveness.

Obesity is not the absolute measure of health status, and so weight loss should not be the sole indicator of health improvement. Positive changes in diet and exercise, for example, can result in better health without a measurable change in body weight.¹³¹ Such healthful habits may increase muscle mass as a proportion of body weight without resulting in significant weight loss. Also considering waist circumference, hemoglobin A1C, chronic disease incidence, and other morbidities and then examining the correlations of these values with weight loss may improve the accuracy of this review.

In addition, measurements of obesity are imperfect indicators of health status across race and ethnic groups. For example, one study applied a BMI cutoff of 23 as an indicator of being overweight for the Asian patient population, despite the fact that this population has a lower average BMI than other populations and a higher prevalence of diabetes at a given BMI compared with whites.^{132,133} Cultural examination of chronic disease-related health practices should be further examined and incorporated into obesity interventions to improve patient-centeredness and cultural competency. No systematic review examining minority populations or culturally tailored interventions met the inclusion criteria for this overview.

The quality-of-review summary of the effectiveness of intervention components is limited due to the low quality of the data informing these estimates. As program components are not the primary outcome, they are often not reported. As such, it is difficult to incorporate all studies meeting the inclusion criteria into a meta-regression, which then produces less reliable information on the association between structural intervention components and weight loss in participants.

In terms of economic analysis, most studies quantify only health-care costs, despite the fact that many costs fall outside the health-care sector. Cost-effectiveness was examined because it is an accepted technique in evaluating public health interventions, though a societal approach should be taken when many costs are not directly related to the health-care system, as might be the case in a community or environmental health-care intervention. Societal perspectives generally include direct medical costs, indirect medical costs (e.g. transportation, informal care), and labor market outcomes (e.g., productivity loss).

Cost-effectiveness analysis is generally used to measure long-term outcomes. The interventions included in the effectiveness portion of this review examine outcomes on a much shorter scale (under five years compared with over 40 years).¹³⁴ However, it is difficult to assess the long-term effectiveness of any behavioral intervention, as little data exists and weight regain is common.¹³⁵ Methods to calculate future health outcomes and costs associated with an intervention are highly debated; these methods could significantly change absolute and relative cost-effectiveness.¹³⁶

Improving the Research

To maximize their impact, future studies need to report program specifics, including materials; target population characteristics; interventionist and relevant provider training; costs; and both short- and long-term outcomes. Without specific details about format and content of an examined intervention, it is difficult to assess the resources a program would actually require. Systematic reviews and meta-analyses should try to perform moderator review or meta-regression for a better understanding of which intervention components work to reduce obesity, so people in the field can apply this knowledge to achieve better outcomes. Similarly, more research into the dose-response relationship between intensity and health outcomes as well as weight loss after active phase of the intervention would enable creation of the most efficient and sustainable obesity-reduction strategies.

Interventions should be undertaken in more diverse settings. This would help improve tailoring of programs and understanding of the intersection between weight loss and culture. Researchers should strive for increased generalizability, as obesity is not a disease that primarily affects white, non-Hispanic women (the typical population in many of the reviewed trials).

Attrition rates and the causes for attrition should be further investigated, as this type of analysis may provide insight into barriers to behavioral change. Lifestyle interventions should present results using intention-to-treat analysis when appropriate, as that informs effectiveness rather than efficacy. Efficacy of diet and exercise to lose and maintain weight is well-established. Analysis of attrition may shed light on the uptake and sustainability of an intervention in the real world.

The presence or absence of adverse events such as musculoskeletal symptoms were rarely reported. This could inform future program coordinators of potential problems. If these are a significant side effect that had gone unnoticed during such interventions, developers of interventions should structure them in such a way as to emphasize safety and form while engaging in exercises (as some programs may specify a type of exercise that is novel to the participant).

Data from single trials generally does not provide strong enough evidence to inform resource allocation decision-making.¹³⁷ More robust research on cost-effectiveness of interventions in the short and long term, and for specific population groups, is needed. A systematic methodology to evaluate societal costs associated with prevention interventions should be established, and both trials and programs implemented in the field should record costs associated with providing care along with outcomes. A uniform model to evaluate cost-effectiveness would allow better comparison of interventions. Cost-effectiveness should include long-term outcomes, incorporating risks for chronic disease and associated costs. Sensitivity analysis should include examinations of variations in long-term weight maintenance, proportion of population reached, and the costs of interventions.

Conclusion

This review provides additional insight into the various components of lifestyle interventions for obesity prevention and reduction. It was crucial to identify the individual effects of the intervention components to ensure that they are necessary to the intervention as a whole.

Researchers are also beginning to examine the effectiveness of different combinations of intervention components, with mixed results. Optimizing obesity interventions will be an iterative process, and should use data from previous interventions to inform plans for future ones. As more data is generated—specifically cost-related data—program evaluation and quality improvement will become easier.

Program development and evaluation should be a dynamic process. Each intervention has a different target population, which moderates the effectiveness of any program. It is crucial that future studies examine a more diverse participant group that represent those at risk for obesity in the U.S. Otherwise, decision-makers may proceed based on false information from the reviews, providing funding for programs that are not effective because they are not tailored to the population in need.

A common theme through the analysis was the complementary effects of intervention components. In practice, different stakeholders will have power to change different aspects of the community or environment. These different groups, from government to community-based organizations to the public sector, will have to collaborate to develop and coordinate a plan to tackle the growing obesity epidemic.

Methodology

We adapted accepted methods for systematic reviews, including PRISMA guidelines (see Appendix for details), as a framework for this review of systematic reviews. These methods were altered as minimally as possible to guide the research process for locating potential studies. An individual reviewer was responsible for identification of studies through title, abstract, and full-text review as well as data extraction and analysis.

Search Strategy

Comprehensive search terms were used to find meta-analyses examining effectiveness and systematic reviews assessing cost-effectiveness of obesity prevention and reduction programs published in the last 10 years. Both MEDLINE and the Cochrane Library were searched. (See Appendix for terms used in search strategy.)

Inclusion Criteria

The reviews included examined the effectiveness of obesity-prevention interventions. Reviews had to examine the adult population, and the majority of included trials had to take place in the United States, while other trials could take place in developed countries—to ensure comparability of outcomes, delivery systems, and patient populations. The reviews included all reported mean difference in weight or BMI compared with a control group, and all trials included in summary estimates had a control arm.

Exclusion Criteria

Studies that examined effectiveness of specific macro-nutrient diets were omitted. Meta-analyses that reviewed the efficacy of a single intervention compared with a control of usual care were omitted as the relationship of diet and physical activity to obesity is already well-established. Reviews that did not expand on more specific intervention characteristics were not included. Reviews of cost-effectiveness that focused primarily on modeling methods were excluded.

Data Extraction

Upon finalization of included studies from full-text review, we extracted information on review aim, population, study types, interventions, and attrition rates. Outcome measures included weight loss compared with a control group. We also recorded information on moderator analysis, significant factors in meta-regression, and results of subset analysis. If mean difference for weight loss was not reported through meta-analysis, mean difference for BMI or standardized mean difference from weight loss or BMI would be recorded in its place. Intervention structural characteristics were categorized into activity focus, delivery modality, population, and intensity. For economic analyses, cost-effectiveness information was recorded. Publication bias was primarily examined using funnel plots or Egger's tests.

Appendix

Results Tables

Table 1 | Behavioral

STUDY	POPULATION	INTERVENTION	CONTROL	TIME RANGE	STANDARDIZED MEAN DIFFERENCE	95% CONFIDENCE INTERVAL OR SIGNIFICANCE
Angermayr 2010	Adults with or at risk for type 2 diabetes or coronary heart disease	Lifestyle, including diet, physical activity, and stress management	Less intensive or usual care	4-6 months	-0.25 kg/m ² (BMI)	(-0.49, -0.02)
				8-12 months	-0.42 kg/m ² (BMI)	(-0.76, -0.08)
Armstrong 2011	Overweight and obese adults	No motivational interviewing	No motivational interviewing	3-18 months	-1.47 kg	(-2.05, -0.88)
Conn 2014	Healthy adults	No motivational interviewing	No motivational interviewing	NR	-1.3 kg	Significant
Hartmann-Boyce 2014A	Overweight and obese adults	Behavioral weight-management program	Non-behavioral weight management	12 months	-2.8 kg	(-3.6, -2.1)
Hartmann-Boyce 2015	Overweight and obese adults	Self-help	Non-self-help intervention or minimal care	6 months	-1.85 kg	(-2.86, -0.83)
Huisman 2009	Adults with type 2 diabetes	Weight-reduction programs with self-regulation principles	Non-self-regulation	6 weeks-4 years	NSE	
Kuo 2014	Adults with chronic metabolic disease	Empowerment-based self-management	Non-empowerment-based intervention	NR	NSE	

NR: Not reported. NSE: No significant effect.
Source: Milken Institute.

Table 2 | Delivery

STUDY	POPULATION	INTERVENTION	CONTROL	TIME RANGE	STANDARDIZED MEAN DIFFERENCE	95% CONFIDENCE INTERVAL OR SIGNIFICANCE
Conn 2014	Healthy adults	Supervised exercise	No supervision	NR	-2.4 kg	Significant
Kodama 2012	Overweight and obese adults	Internet and lifestyle intervention	Non-Web controls	3 months-2.5 years	-0.68 kg	p=0.03
		Internet and obesity care	Obesity care		-1.00 kg	p<0.001
		Internet and lifestyle intervention	Face-to-face care		+1.27 kg	p=0.01
		Internet and initial weight loss	Non-Web controls		-1.01 kg	p=0.03
Liu 2015	Adults	Mobile phone and weight-loss intervention	Less intensive or usual care	1 month-12 months	-1.44 kg	(-2.12, -0.76)
Neve 2010	Overweight and obese adults	Web-based lifestyle intervention	Minimal intervention	6 weeks-2 years	NSE	
		Enhanced Web-based	General education, Web-based		-2.24 kg	(-3.21, -1.27)
Pal 2014	Adults with type 2 diabetes	Computer-based diabetes self-management	Less intensive or usual care	1-18 months	NSE	
Paul-Ebhohimhen 2009	Adults with BMI \geq 28 kg/m ²	Group setting	One-on-one delivery	12-16 months	-1.4 kg	(-2.7, -0.1)
Reed 2012	Overweight and obese adults	Computer-based and in-person lifestyle intervention	In-person intervention	2-12 months	-1.48 kg	(-2.52, -0.43)
		Computer-based only			+1.47 kg	(0.13, 2.81)
Widmer 2015	Adults seeking cardiovascular disease prevention	Digital health intervention	Usual care	4.5 months-2 years	-1.26 kg	(-2.04, -0.48)

NR: Not reported. NSE: No significant effect.

Source: Milken Institute.

Table 3 | Intensity

STUDY	POPULATION	INTERVENTION	CONTROL	TIME RANGE	STANDARDIZED MEAN DIFFERENCE	95% CONFIDENCE INTERVAL OR SIGNIFICANCE
Johns 2014	Overweight and obese adults	Combined behavioral weight-management program	Diet	12 months	-1.72 kg	(-2.80, -0.64)
			Physical activity		-6.29 kg	(-7.33, -5.25)

Source: Milken Institute.

Table 4 | Maintenance

STUDY	POPULATION	INTERVENTION	CONTROL	TIME RANGE	STANDARDIZED MEAN DIFFERENCE	95% CONFIDENCE INTERVAL OR SIGNIFICANCE
Dansinger 2007	Overweight and obese adults	Dietary counseling	Usual care	12 months	-1.9 kg/m ² (BMI)	(-2.3, -1.5)
Dombrowski 2014	Obese adults	Lifestyle intervention	Usual care	12 months	-1.56 kg	(-2.27, -0.86)
				18 months	-1.96 kg	(-2.73, -1.20)
Galani 2007	Primary prevention	Lifestyle	Standard care	3 years	-2.2 kg	Significant
	Secondary prevention				-3.49 kg	p<0.0001

Source: Milken Institute.

Table 5 | Physical Activity

STUDY	POPULATION	INTERVENTION	CONTROL	TIME RANGE	STANDARDIZED MEAN DIFFERENCE	95% CONFIDENCE INTERVAL OR SIGNIFICANCE
Richardson 2008	Sedentary overweight and obese adults	Pedometer	No pedometer	1-12 months	-1.27 kg	(-1.85, -0.70)
Schwing-shackl 2013	Overweight and obese adults	Aerobic training	Resistance training	2-6 months	-1.15 kg	p=0.04
		Combined training			-2.03 kg	p<0.0001
Yang 2014	Adults with type 2 diabetes	Aerobic training	Resistance training	2-12 months	NSE	

NSE: No significant effect.

Source: Milken Institute.

Table 6 | Population

STUDY	POPULATION	INTERVENTION	CONTROL	TIME RANGE	STANDARDIZED MEAN DIFFERENCE	95% CONFIDENCE INTERVAL OR SIGNIFICANCE
Ali 2012	Adults at high risk for diabetes	Diabetes prevention program	Less intensive or usual care	12 months	-3.99% (percent of weight lost)	(-5.16, -2.83)
Anderson 2009	Worksite employees	Worksite lifestyle intervention, randomized controlled trials	Untreated	6-12 months	-1.2 kg	(-2.1, -0.5)
		All study designs			-1.4 kg	(-6.7, 1.6)
Dunkley 2014	Adults at high risk for diabetes	Diabetes prevention program	Usual care	12 months	-2.32 kg	(-2.92, -1.72)
Finkelstein 2014	Adults with an average BMI below 40	Commercial weight-loss program I	Usual care	12 months	-2.4 kg	(-3.0, -1.8)
		Commercial weight-loss program II			-3.2 kg	(-4.9, -1.4)
		Commercial meal-replacement program			-7.4 kg	(-8.9, -5.7)
Hartmann-Boyce 2014B	Overweight and obese adults	Commercial weight-management programs	Usual care	12 months	-2.22 kg	(-2.90, -1.54)
		Commercial meal replacements		12 months	-6.83 kg	(-8.39, -5.26)
		Multi-component behavioral weight management through primary care		12 months	0.45 kg	(-1.34, 0.43)
Verweij 2011	Worksite employees	Workplace diet and exercise	Less intensive or usual care	2 months-6 years	-1.19 kg	(-1.64, -0.74)
		Workplace physical activity			-1.08 kg	(-1.79, -0.36)
Witham 2010	Obese adults, aged 60+	Lifestyle intervention	No supervision	12 months	-3.0 kg	(-5.1 kg, -0.9 kg)
Young 2012	Overweight and obese adult males	Lifestyle intervention	No intervention	3 weeks-24 months	-5.66 kg	(-6.35, -4.97)

Source: Milken Institute.

PRISMA Guidelines

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is a set of evidence-based guidelines to dictate the process and structure of systematic reviews.¹³⁸ We adopted the guidelines to suit the need of this review of reviews while trying to maintain consistency with other systematic review formats. The PRISMA checklist was followed except in situations where style, time, or resources prevented following the guidelines. For example, no protocol was registered externally, only one reviewer examined studies for inclusion and data extraction, and only two databases were examined. Other protocol items were followed, as reported in the text.

Study counts:

- Number of records identified through database search: 8,489
- Number of full-text articles assessed for eligibility: 156
- Number of articles included in effectiveness synthesis: 29
- Number of articles included in economic synthesis: 10
- Total number of articles included: 34

Methodological Quality Assessment

This study used the Overview Quality Assessment Questionnaire (OQAQ), a validated tool that measures the methodological quality of systematic reviews and meta-analyses based on the criteria below.¹³⁹ A study was considered high quality if it had an overall quality score above 5.

Assessment questions quoted directly from OQAQ:

1. Were the search methods used to find evidence reported?
2. Was the search strategy for evidence reasonably comprehensive?
3. Were the criteria used for deciding which studies to include in the overview reported?
4. Was bias in the selection of studies avoided?
5. Were criteria used for assessing validity of the included studies reported?
6. Was the validity of all studies referred to in the text assessed using appropriate criteria (either in selecting studies for inclusion or in analyzing studies that are cited)?
7. Were methods used to combine the findings of relevant studies (to reach a conclusion) reported?
8. Were findings of the relevant studies combined appropriately relative to the primary question addressed?
9. Were the conclusions made by the author(s) supported by the data and/or analysis reported in the overview?
10. How would you rate the scientific quality of the overview? (rated on a scale of 1-7)

STUDY	QUESTION NUMBER									
	1	2	3	4	5	6	7	8	9	10
Ali 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Anderson 2009	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Angermayr 2010	Y	P	Y	Y	Y	Y	Y	Y	Y	6
Armstrong 2011	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Conn 2014	Y	Y	Y	C	Y	Y	P	C	Y	6
Dansinger 2007	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Dombrowski 2014	P	C	Y	Y	Y	Y	Y	Y	Y	6
Dunkley 2014	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Finkelstein 2014	Y	Y	Y	C	Y	Y	Y	Y	Y	7
Galani 2007	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Hartmann-Boyce 2014A	Y	Y	Y	P	Y	Y	Y	Y	Y	7
Hartmann-Boyce 2014B	Y	Y	Y	P	Y	Y	Y	Y	Y	7
Hartmann-Boyce 2015	Y	Y	Y	P	Y	Y	Y	Y	Y	7
Huisman 2009	Y	Y	Y	Y	P	Y	P	Y	Y	6
Johns 2014	Y	Y	Y	P	Y	Y	Y	Y	Y	7
Kodama 2012	Y	Y	Y	C	Y	Y	Y	Y	Y	6
Kuo 2014	Y	Y	Y	C	Y	Y	Y	Y	Y	6
Liu 2015	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Neve 2010	Y	N	Y	Y	Y	Y	Y	Y	Y	6
Pal 2014	Y	Y	Y	Y	Y	Y	P	Y	Y	6
Paul-Ebhohimhen 2009	P	C	Y	Y	Y	Y	Y	Y	Y	5
Reed 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Richardson 2008	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Schwingshackl 2013	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Verweij 2011	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Widmer 2015	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Witham 2010	Y	Y	Y	Y	Y	Y	Y	Y	Y	7
Yang 2014	Y	Y	Y	P	Y	Y	Y	Y	Y	7
Young 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y	7

Responses: Y= yes, N=no, C=can't answer, P=partially
Source: Milken Institute.

Search Strategy

Below are the search terms and strategy used to find studies for inclusion in this review. The strategy is catered for MEDLINE.

1. Disease Focus

("obesity"[MeSH] OR "obese"[tiab] OR "obesity"[tiab] OR "overweight"[MeSH] OR "overweight"[tiab] OR "body mass index"[MeSH] OR "body mass index"[tiab] OR "BMI"[tiab] OR "adipose"[tiab] OR "adiposity"[tiab] OR "body weight changes"[MeSH] OR "ideal body weight"[MeSH] OR "body weight maintenance"[MeSH] OR "weight"[tiab])

2. Intervention Type

("preventive health services"[MeSH] OR "health promotion"[tiab] OR "education"[tiab] OR "prevention"[tiab] OR "preventive"[tiab] OR "life style"[MeSH] OR "lifestyle"[tiab] OR "life style"[tiab])

OR

("physical education and training"[MeSH] OR "exercise"[MeSH] OR "exercise therapy"[MeSH] OR "physical fitness"[MeSH] OR "sports"[MeSH] OR "exercise"[tiab] OR "physical"[tiab] OR "activity"[tiab] OR "activities"[tiab] OR "training"[tiab] OR "fitness"[tiab] OR "sports"[tiab] OR "endurance"[tiab])

OR

("nutritional sciences"[MeSH] OR "diet, food, and nutrition"[MeSH] OR "caloric restriction"[MeSH] OR "nutrition therapy"[MeSH] OR "diet"[tiab] OR "nutrition"[tiab] OR "food"[tiab] OR "calories"[tiab] OR "intake"[tiab] OR "energy"[tiab] OR "eat"[tiab] OR "eating"[tiab] OR "ate"[tiab] OR "consume"[tiab] OR "consuming"[tiab] OR "consumed"[tiab])

OR

("behavior therapy"[MeSH] OR "counseling"[MeSH] OR "counseling"[tiab] OR "therapy"[tiab] OR "motivate"[tiab] OR "motivational"[tiab] OR "self-care"[MeSH] OR "self-management"[tiab] OR "self-care"[tiab])

3. Study Design

(“review literature as topic”[MeSH] OR “meta-analysis as topic”[MeSH] OR “meta-analysis”[publication type] OR “review”[publication type] OR “review”[tiab] OR “meta-analysis”[tiab])

OR

(“randomized” OR “experiment” OR “experimental” OR “trial” OR “trials” OR “observational” OR “prospective” OR “cohort” OR “intervention” OR “control” OR “controlled”) OR (“costs and cost analysis”[MeSH] OR “cost-effectiveness” OR “cost-benefit” OR “cost-utility” OR “economic” OR “cost”) OR (“Cochrane” OR “Medline”)

4. Exclusion Criteria

(“surgical procedures, operative”[MeSH major topic] OR “bariatric surgery”[MeSH major topic] OR “neoplasms”[MeSH] OR “pregnancy”[MeSH major topic] OR “musculoskeletal diseases”[MeSH major topic] OR “mental disorders”[MeSH major topic] OR “pharmacologic actions”[MeSH major topic] OR “adolescent”[MeSH major topic] OR “child”[MeSH major topic] OR “infant”[MeSH])

Search Process:

(1 AND 2 AND 3) AND (NOT 4)

Endnotes

1. Flegal et al., "Prevalence of Obesity and Trends in the Distribution of Body Mass Index among US Adults, 1999–2010," *Journal of the American Medical Association* 307, no.5 (2012), pp. 491–497. Available online: <http://jama.jamanetwork.com/article.aspx?articleid=1104933>.
2. Finkelstein et al., "Annual Medical Spending Attributable to Obesity: Payer and Service-Specific Estimates," *Health Affairs* 28, no. 5 (2009), pp. 822-831.
3. Griffiths et al., "Economic Evaluations of Adult Weight Management Interventions: A Systematic Literature Review Focusing on Methods Used for Determining Health Impacts," *Applied Health Economics and Health Policy* 10, no. 3 (2012), pp. 145-162.
4. Anderson et al., "The Effectiveness of Worksite Nutrition and Physical Activity Interventions for Controlling Employee Overweight and Obesity: A Systematic Review," *American Journal of Preventive Medicine* 37, no. 4 (2009), pp. 340-357.
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10. Flegal et al., "Prevalence of Obesity and Trends in the Distribution of Body Mass Index among US Adults, 1999–2010," *Journal of the American Medical Association* 307, no. 5 (2012), pp. 491–497. Available online: <http://jama.jamanetwork.com/article.aspx?articleid=1104933>.
11. Griffiths et al., "Economic Evaluations of Adult Weight Management Interventions: A Systematic Literature Review Focusing on Methods Used for Determining Health Impacts," *Applied Health Economics and Health Policy* 10, no. 3 (2012), pp. 145-162.
12. Finkelstein et al., "Annual Medical Spending Attributable to Obesity: Payer and Service-Specific Estimates," *Health Affairs* 28, no. 5 (2009), pp. 822-831.
13. Anderson et al., "The Effectiveness of Worksite Nutrition and Physical Activity Interventions for Controlling Employee Overweight and Obesity: A Systematic Review," *American Journal of Preventive Medicine* 37, no. 4 (2009), pp. 340-357.
14. Finkelstein et al., "The Costs of Obesity in the Workplace," *Journal of Occupational and Environmental Medicine* 52, no. 10 (2010), pp. 971-976.
15. Conn et al., "Impact of Physical Activity Interventions on Anthropometric Outcomes: Systematic Review and Meta-Analysis," *Journal of Primary Prevention* 35, no. 4 (2014), pp. 203-215.
16. Ibid.
17. Hartmann-Boyce et al., "Behavioural Weight Management Programmes for Adults Assessed by Trials Conducted in Everyday Contexts: Systematic Review and Meta-Analysis," *Obesity Review* 15, no. 11 (2014), pp. 920-932.

18. Griffiths et al., "Economic Evaluations of Adult Weight Management Interventions: A Systematic Literature Review Focusing on Methods Used for Determining Health Impacts," *Applied Health Economics and Health Policy* 10, no. 3 (2012), pp. 145-162.
19. Kodama et al., "Effect of Web-Based Lifestyle Modification on Weight Control: A Meta-Analysis," *International Journal of Obesity* 36, no. 5 (2012), pp. 675-685.
20. Sweet and Fortier, "Improving Physical Activity and Dietary Behaviours with Single or Multiple Health Behaviour Interventions? A Synthesis of Meta-Analyses and Reviews," *International Journal of Environmental Research and Public Health* 7, no. 4 (2010), pp.1720-1743.
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27. Conn et al., "Impact of Physical Activity Interventions on Anthropometric Outcomes: Systematic Review and Meta-Analysis," *Journal of Primary Prevention* 35, no. 4 (2014), pp. 203-215.
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