



HHS Public Access

Author manuscript

Obesity (Silver Spring). Author manuscript; available in PMC 2017 September 01.

Published in final edited form as:

Obesity (Silver Spring). 2016 September ; 24(9): 1834–1841. doi:10.1002/oby.21582.

The effect of tobacco cessation on weight gain, obesity and diabetes risk

Terry Bush¹, Jennifer C. Lovejoy², Mona Deprey¹, and Kelly M. Carpenter¹

¹Alere Wellbeing, Inc

²Arivale, Inc

Abstract

Objective—Most smokers gain weight after quitting and some develop new onset obesity and type 2 diabetes. The purpose of this paper is to synthesize the current science investigating the consequences of tobacco cessation on body weight and diabetes and intervention strategies that minimize or prevent weight gain while still allowing for successful tobacco cessation.

Methods—We selected systematic reviews and relevant studies that were published since prior reviews.

Results—Smoking cessation can cause excessive weight gain in some individuals and can be associated with clinically significant outcomes such as diabetes or obesity onset. Interventions that combine smoking cessation and weight control can be effective for improving cessation and minimizing weight gain, but need to be tested in specific populations.

Conclusions—In spite of the health benefits of quitting tobacco, post-cessation weight gain and new onset obesity and diabetes are a significant concern. Promising interventions may need to be more widely applied to reduce the consequences of both obesity and tobacco use.

Keywords

smoking; obesity; weight concerns; diabetes; reward system; public health

Introduction

Tobacco use continues to be a major public health problem and the leading preventable cause of death. Unfortunately, most smokers will gain weight after quitting and a significant minority of smokers will gain an excess amount which may increase their risk for diabetes onset. This paper presents a narrative review of the prevalence and impact of cessation related weight gain on obesity and diabetes and a summary of cessation interventions aimed at addressing post cessation weight gain. We primarily used PubMed to search for English

Correspondence: Terry Bush, PhD., Scientific Investigator, Alere Wellbeing, Inc., 999 Third Avenue, Suite 2000, Seattle, WA 98104, T +1 206-876-2201, terry.bush@optum.com.

Disclosures

The authors have no conflicts of interest to disclose.

Authors' contributions

All authors contributed to conceptualizing the review paper, the literature reviews and writing and editing the paper.

language articles describing the effects of tobacco cessation on weight, diabetes, and glucose control as well as studies examining mechanisms for those changes. We also searched for systematic reviews and meta-analyses of interventions for improving smoking cessation and mitigating weight gain in those quitting tobacco as well as recent articles or those not included in reviews or meta-analyses. The purpose of this review was to summarize the literature and provide recommendations for clinicians treating overweight or obese smokers.

1. Prevalence and impact of obesity and tobacco use

Smoking and obesity are the two leading causes of death in the US. (1–5) Two thirds of adults in the US are overweight or obese and approximately nine million adults with obesity are smokers. (6–8) Among adults screened for weight loss surgery, two thirds reported a history of smoking and 27% were smoking at the time of a pre-surgical evaluation. (9) Similarly, among treatment seeking smokers, two thirds were overweight or obese. (10–13) Both obesity and smoking increase the risk for type 2 diabetes, hypertension, and cardiopulmonary disease. Like smoking, obesity increases diabetes risk by increasing insulin resistance and decreasing glucose control. (14) Most importantly, co-occurrence of obesity and smoking increases the mortality risk above and beyond either risk factor alone. (15, 16) Furthermore, it has been estimated that people with obesity cost an average of \$1,360 in additional health-care expenses each year compared with the non-obese and that smokers require an average of \$1,046 in additional health-care expenses compared with nonsmokers. These estimates do not include the added costs to society due to absenteeism and loss of productivity. (16, 17)

2. Prevalence and impact of weight gain in smokers

Research has shown that while the majority of people who quit smoking gain weight, there is considerable variability in the amount of weight gain. The differences in weight gain between those who quit and those who continue to smoke ranges from 2.6 to 5.3 kg. (3, 10, 18–24) Using data from 35 population-based prospective cohort studies world-wide and comparing 63,403 smokers who had quit smoking with 388,432 who continued to smoke, Tian and colleagues found that people who quit smoking gained an average of 4.1 kg over five years, compared with 1.5 kg for continuing smokers; a difference of 2.6 kg. (19) The authors note that studies with longer follow-up time and that were conducted in North America found higher levels of weight gain. An earlier meta-analysis by Aubin and colleagues focused on weight gain in those who quit smoking as part of randomized clinical trials of cessation treatment, including pharmacotherapy, exercise and weight gain prevention studies. They reported that the average weight gain among successful quitters was 1.1 kg at one month, 2.3 kg at two months, 2.9 kg at three months, 4.2 kg at six months, and 4.7 kg at 12 months. They noted substantial variation among smokers with 16% – 21% losing weight and 13% – 14% gaining more than 10 kg at 12 months. (23) Scherr also reported large variability in weight change at 12 and 24 months among smokers who had successfully quit and that 10% gained more than 10 kg. (25) In another study, the change in weight among quitters was higher than in previous studies. Over 8 years, successful quitters gained an average of 8.79 kg (sd=6.36) while continuing smokers gained 2.24 kg (sd=6.65), a difference of 6.55 kg. (22) Importantly, for a small number of people, the amount of weight gain after tobacco cessation is significant enough to move them into an overweight or

obese categorization (Body Mass Index [BMI] $>25 \text{ mg/m}^2$ or $>30 \text{ mg/m}^2$) which could have a significant impact on health. One study, reported an increased prevalence of overweight of 15% and an increased prevalence of obesity of 18% in recent quitters, whereas in continued smokers prevalence rates increased by 2% and 5% respectively. (22) According to a meta-analysis of cohort studies, a 2.5 kg/m^2 increase in BMI for those with a starting BMI of 22 or higher increases mortality by 14%, but continued smoking far exceeds this mortality rate. (26) In addition to increased weight, cessation can also result in an increase in waist circumference or central fat, which could attenuate some of the beneficial effects of smoking cessation, especially among quitters who reduced their physical activity and those who had been heavy smokers. (27)

It's unclear which smokers are most at risk for the larger weight gain after quitting. While one study among smokers seeking cessation treatment reported no correlation between baseline BMI and smoking cessation or cessation related weight gain (24), the bulk of studies report higher weight gain in those with higher BMI prior to quitting. (18, 19, 22, 25, 28, 29) For example, for a starting BMI of 18, 23, 29, or 36 kg/m^2 , Lycett and colleagues found that post cessation weight gain was 9.8, 7.8, 10.2 and 19.4 kg, respectively, after 8 years. (22) Others at the greatest risk of gaining higher amounts of weight or triggering a chronic condition after quitting include women, especially African American women (30, 31), those with lower socio-economic status (29), poor diet and limited physical activity and greater amount of tobacco used. (31–36) A recent study looking at 10 year outcomes and comparing those who quit tobacco with those who continued to smoke found that degree of tobacco addiction (i.e., number of cigarettes per day) was the primary predictor of excessive weight gain. (18) Overall, about 10% of men and 13% of women gain 10 kg or greater after quitting. (19, 29, 31, 32, 35, 37–39) Other groups that are at increased risk for weight gain after cessation includes those with disordered eating patterns. For example, among overweight former smokers, those who reported regular binge eating were more likely to gain weight in the year following smoking cessation than overweight former smokers who were not binge eaters. (40)

3. Why people gain weight when quitting

Weight gain associated with quitting tobacco is largely due to increased energy intake and reduced energy expenditure. Smokers gain weight after they quit smoking primarily because of the removal of nicotine's effects on the central nervous system. (35, 36, 41, 42) Some smokers also attempt to cope with nicotine withdrawal by substituting eating for the 'hand to mouth' behavior of smoking which can lead to an increase in caloric intake. (35, 43, 44) However, there are differences in opinion with regard to the relative impact of nicotine-related metabolism changes and increased caloric intake. Kleppinger found in a study of women, that neither calorie intake nor physical activity level changes differed significantly between those who quit and those who continued smoking. (45) However, percentage of calories as sugar was increased which, over time, might lead to increased caloric intake and weight gain. Low satiety, emotional eating, calorie misperception and short sleep might also contribute to post cessation weight gain. (46) Regardless of weight change, those who stop smoking report an increased preference for sweet tasting foods. (44) According to a recent study, women who smoke had lower ability to perceive fat and sweetness in foods and derive

less pleasure from foods, which could lead to over-consumption. (47) It has also been suggested that the sudden drop in blood sugar in many people during the first three days of quitting could lead to common withdrawal symptoms such as headaches, dizziness and craving for sweets which in turn could lead to overeating in an attempt to cope with these symptoms. (35, 41, 43) Research on the neurobiology of nicotine addiction and withdrawal sheds some light on the problem of post-cessation weight gain. Specifically, the relationship between nicotine addiction and the neural reward mechanisms involved could mirror similar neural networks involved in some eating behaviors. In fact, food addiction appears to activate similar reward pathways in the brain as does smoking. (48) Elevated response to reward has been linked to weight gain perhaps due to an increase in caloric intake or altered food composition (e.g. more sugar which can then increase the glycemic load of the diet). (49) In one study, Stice and colleagues compared reward surfeit versus reward deficit treatment models and suggested that gradual, healthy changes to dietary intake instead of dramatic weight loss diets may be better at minimizing the sense of deprivation or loss. (50) This notion of deprivation (biological and psychological) could explain why strict dieting during an attempt to quit smoking can have a negative impact on cessation. (51) Food deprivation can reduce extracellular dopamine levels, reduce positive mood and increase drive to use nicotine. (51)

4. Consequences of smoking and smoking cessation on diabetes

Systematic reviews and the recent Surgeon General's Report have confirmed that active smoking is associated with an increased risk of type 2 diabetes. (52–55) Smokers are 30–44% more likely to develop type 2 diabetes than nonsmokers (52) and the more cigarettes consumed, the higher the risk. (52, 53, 55, 56) Multiple biological mechanisms for the causal connection between smoking and development of type 2 diabetes have been postulated, including the effects of smoking on cortisol concentrations, central obesity, inflammatory markers, oxidative stress, insulin resistance and an increase in fasting blood glucose. (55, 57–59) Smoking is particularly problematic in people who already have diabetes. People with diabetes who smoke have higher glycated hemoglobin (HbA1c) levels than non-smokers who have diabetes (60) and they are more likely to experience severe hypoglycemia, and to have trouble with insulin dosing and diabetes control. (5, 61) Some of these consequences of smoking improve after cessation, including improved insulin sensitivity and glycemic control. (53, 57–59, 61–63) Paradoxically, however, in some cases, quitting tobacco seems to worsen glycemic control and increase the risk for new onset type 2 diabetes. (64–67) A recent review reported that the relative risk of developing type 2 diabetes compared with never smokers was 1.54 (95% CI 1.36–1.74) for those who quit in the past 5 years; 1.18 (95% CI 1.07 – 1.29) for those abstaining for 5–9 years, and 1.11 (95% CI 1.02–1.20) for long-term quitters (> 10 years).(67) The mechanism by which tobacco cessation leads to diabetes onset or poorer diabetes control is not clear. The increased risk may be due to increases in visceral fat accumulation or waist circumference, chronic inflammation or excessive weight gain after quitting. (56, 68, 69) An early study with Japanese men with diabetes reported that quitting smoking for at least 6 months was associated with weight gain along with significant worsening of blood pressure, total cholesterol, triglycerides and fasting blood glucose. (70) In contrast, according to a study by Lycett, glycemic control in patients with diabetes deteriorated for about 3 years after quitting

smoking after which HbA1c levels were similar to smokers and this association was independent of post cessation weight gain. (65) It has been suggested that the reason for the adverse effect of quitting tobacco on glycemic control may be due to greater consumption of sugary foods and carbohydrates. (44, 71, 72) However, Komiya reported no significant change in HbA1c after successful cessation from baseline to 12 weeks in a sample of 132 men and 54 women, despite significant increases in BMI, LDL-C and HDL-C, and triglyceride (173 ± 105 mg/dl before versus 199 ± 129) after cessation. (35)

In summary, it is apparent that tobacco cessation, while certainly an important health behavior change, can also lead to negative metabolic consequences for some smokers. Regardless of the reported negative effects of cessation on glycemic control and diabetes risk, quitting smoking has been proven to reduce the risk of cardiovascular disease and mortality even in people with diabetes. (57, 73, 74) It is increasingly important to develop and test tobacco cessation interventions for those at risk of negative health consequences of cessation and to determine who might benefit from these interventions.

5. Tobacco cessation interventions to prevent post cessation weight gain: *Systematic Reviews and Meta-analyses*

There are two problems with the weight gain that occurs with cessation. First, concerns about weight gain can be a barrier to cessation attempts. Second, for a significant minority of people the weight gain can be enough to trigger a chronic illness like obesity or diabetes. Interventions have been developed that address both the cognitive concern about weight gain prior to a quit attempt and to minimize actual weight gain during and after cessation. It should be emphasized that these two approaches are fundamentally very different: a “weight concerns” approach is addressing beliefs about weight gain that could interfere with quitting smoking and may even encourage tolerance of some weight gain, whereas a weight loss/weight management intervention is actually trying to prevent the weight gain that occurs with cessation. An early Cochrane review of interventions to reduce weight gain among those quitting tobacco was published in 2009. (75) Recommendations from this review indicated promise for individualized weight management, NRT, and physical activity interventions when combined with cessation interventions. The same year Spring conducted a meta-analysis of 10 RCTs that tested combined weight control and cessation interventions and found evidence of short term increased abstinence for smokers and decreased post-cessation weight gain, but not in the long term (52 weeks). The review concluded that there was no evidence of harm from addressing weight along with tobacco. (76) In 2012, Farley updated the prior Cochrane review and added 5 studies for total of 16 studies reviewed. (77) The results were similar to the prior 2009 reviews. However, when adding a second paper looking at addressing weight concerns (78), the review concluded there was no long term weight suppressive effect of the weight concerns intervention and there was a possibility for weight gain. The review also concluded that interventions of weight education were not effective at any time point and reduced tobacco abstinence at 12 months. (77) However, personalized weight management was associated with reduced weight gain and had no negative effects on cessation at 12 months. (79, 80) Weight management with very low calorie meal replacement was effective at the end of treatment, but not at 12 months, but it increased tobacco abstinence at 12 months. (80, 81) Physical activity interventions designed

to increase cessation rates were also effective at reducing post-cessation weight gain at 12 months (5) and use of cessation medications such as nicotine replacement therapy (NRT) and varenicline reduced post cessation weight gain (PCWG) in the short term, but had no effects at 12 months. These results highlight the difference between “weight concerns” interventions, which strive to increase smoking cessation and not surprisingly are not associated with weight suppression after quitting, and “weight loss/weight management” interventions involving diet or targeted behavioral weight loss approaches, which do reduce weight gain.

The most current systematic reviews (published in 2012) suggest that some interventions added to tobacco cessation treatment may be safe and effective such as very low calorie diets, physical activity and NRT. (77), (82) Below we describe some of the key intervention strategies targeting tobacco cessation and weight by categories; cognitive, behavioral (diet and exercise) and pharmacologic and we added relevant studies published since the 2012 reviews.

6. Tobacco cessation and weight management combined interventions – Cognitive and Behavioral approaches

Cognitive approaches targeting body image and weight concerns—Several studies have tested interventions that elicited smokers’ beliefs about their weight and self-image and intervened on correcting unproductive thoughts about weight gain (i.e. “weight concern”). The theory behind this line of research was that excessive worry about weight gain interferes with ones’ effort and commitment to quit smoking. A number of studies have found that addressing weight concerns significantly improves smoking cessation compared to standard cessation treatments alone. (79, 80, 83, 84) Many of these weight concerns studies also showed a short term weight suppressive effect of the intervention as described in three systematic reviews. (75–77) Since the weight concerns intervention encouraged smokers not to worry about gaining weight but to focus on the benefits of quitting, it is not surprising that one of the trials showed a negative effect on post cessation weight gain. The study recruited women smokers concerned about gaining weight for a 2×2 randomized trial offering standard cessation alone vs. the weight concerns intervention crossed with placebo or bupropion. Results showed that among women offered bupropion to help with cessation, those randomized to the weight concerns intervention had significantly greater levels of abstinence at 6 months than did standard smoking cessation counseling combined with bupropion or placebo and a non-significant increase in weight gain at 6 months with no effect on weight at 12 months. (78) This study appeared in the recent Cochrane review (77) which concluded that this second weight concerns study showed increased cessation at 6 but not 12 months and that the intervention significantly increased post-cessation weight gain. (77) A more recent trial of the weight concerns intervention tested the effectiveness of this weight acceptance approach in a population-based setting of a national tobacco quitline among 2,000 male and female smokers seeking help to quit smoking. (85) Results were published after the three systematic reviews (75–77) and showed that at 6 months the intervention had a weight suppressive effect without impacting cessation rates. Among those who quit smoking, 50.8% of standard vs. 30.0% of those in the combined intervention gained weight (p=.0004) and the intervention group gained significantly less weight (p=.01);

the intervention group lost a little weight overall and the standard group gained weight. Interestingly, planned subgroup analyses revealed a significant interaction between treatment group and having diabetes ($p=.03$) indicating that the weight concerns intervention was particularly successful for those with diabetes (versus smokers without diabetes). Among those with diabetes, 19.1% in standard vs. 31.5% in the intervention quit smoking ($p=.03$) and the average change in weight among quitters was +6.8 lbs. (+3.84 kg) for standard vs. -5.2 lbs. (-2.4 kg) for intervention ($p=.009$). Among those without diabetes, 22.6% in standard vs. 21.7% in the intervention quit smoking. The intervention also produced a significant drop in weight concerns and this differential effect was a significant factor in producing the outcomes. A weakness of this study is that tobacco cessation and weight relied on self-report; a common approach in phone based interventions. In another study, Copeland found that individually tailored smoking cessation treatment for weight-concerned women was superior to group counseling sessions for smoking abstinence, but not for change in weight. (37) The authors concluded that cognitive restructuring of attitudes about smoking, appetite control and weight management should be incorporated into cessation counseling in addition to skills acquisition. In summary, results from multiple trials suggest that addressing smokers concerns about their weight or body image during tobacco cessation counseling is feasible, acceptable and important to smokers and for some, can reduce post cessation weight gain without harm to cessation efforts. However, in light of the 2012 Cochrane review, weight gain during and after cessation needs to be monitored and addressed. Moreover, the weight concerns quitline study needs to be replicated and further tested in smokers at risk for diabetes or obesity.

Educational approaches—Systematic reviews have found that education alone had no significant effects on post cessation weight gain, but may reduce tobacco abstinence at 12 months. (75–77) However, one study not included in prior reviews, found that nutritional advice added to a smoking cessation program increased tobacco abstinence at 12 months but had no significant advantage over cessation treatment alone for preventing post cessation weight gain. (86) The authors postulated that reducing anxiety about weight gain and encouraging cessation despite weight gain was a potential mechanism for why the offer of nutritional advice as part of a smoking cessation program was successful in facilitating some sustained improvements in dietary habits and improved quit rates at 12 months. Limitations of this study include the small sample sizes and the study design. Overall, similar to weight loss treatments in general, education or nutritional advice alone is not recommended to prevent those quitting smoking from gaining weight. (77)

Calorie restriction approaches—Several studies have tested a combination of smoking cessation and traditional calorie-restriction interventions using meal replacement or low calorie diets and had mixed results on cessation and weight gain. In an early study, Hall compared two different weight gain prevention treatments with 158 smokers who completed a two week tobacco treatment program and found no effect on weight outcomes. The two weight-based treatments, however, increased tobacco relapse rates. The authors concluded that the treatment arms may have been too complex and time consuming which may have diverted focus and attention away from maintaining tobacco abstinence. (51) Subsequent studies and meta-analyses of behavioral weight control and tobacco cessation found that this

was the only negative trial. (75–77) For example, one study involved a very-low calorie diet (VLCD) added to standard tobacco cessation treatment. The trial recruited only women with weight concerns and involved 11 behavioral weight control sessions over 16 weeks plus nicotine gum and an intermittent very low calorie diet routine. (81) Results showed that the VLCD arm had a significant effect on reducing weight gain at end of treatment but not at 12 months and had a significant effect on increasing abstinence at 12 months. Other trials have also shown that behavioral weight management programs delivered sequentially to tobacco cessation treatment provide an effective method for improving cessation and minimizing weight gain in quitters. (80, 87)

Physical activity approaches—Several studies have demonstrated the benefit of increased physical activity and reduced sedentary activity on both smoking cessation and weight management and were included in at least one of the prior reviews. In one study, Marcus found that the exercise group had significantly higher rates of continuous abstinence relative to the control group at the end of treatment (19.4% vs. 10.2%), at 3-months (16.4% vs. 8.2%), and 12-months. (11.9% vs. 5.4%).(88) Exercise is helpful for weight management and increases psychological well-being. (88–92) Meta-analytic results of smoking cessation studies reveal that exercise, irrespective of changes in fitness or body composition, can improve body image, improve cessation rates, and significantly reduce post cessation weight gain at 12 months. (76, 77, 82)

7. Tobacco cessation and weight management combined interventions – Pharmacologic approaches

Current medications for tobacco cessation include nicotine replacement therapy (NRT) in the form of patches, gum, lozenges and spray and prescription medications such as varenicline, bupropion and cytosine. Combination NRT treatments such as adding nicotine gum to the patch have been shown to be a more effective cessation strategy than using only one medication. (77) Systematic reviews concluded that some pharmacological interventions limited post cessation weight gain in the short term, but this was not sustained by 6 and 12 months. (36, 75, 77) More recently, Taniguchi found that varenicline significantly reduced weight gain at 12 months as compared to NRT (1.67 kg vs 2.55 kg gain in weight)(93). Others have shown that Bupropion SR and NRT, in particular 4-mg nicotine gum and 4-mg nicotine lozenge, delay, but do not prevent weight gain, but duration of medication use had a significant effect on weight. Compared to smokers who received 8 weeks of nicotine patch therapy, those who received 24 weeks of patches reported significantly less weight gain from pre-treatment to week 24 ($p=.002$) and also from week 8 to week 24 ($p=.03$). (78, 94) Notably, Schnoll found that NRT was less effective for women with obesity compared to men with obesity or women and men who were not obese and that a fast acting NRT such as the nasal spray was more effective as a cessation aid than patch for smokers with obesity. (95) In summary, smoking cessation medications have been shown to delay, but not prevent weight gain associated with smoking cessation. However, there are a limited number of studies of extended treatment duration or with long term follow-up and newer cessation medications have not been sufficiently studied with regard to weight change. Studies with new drugs available for the treatment of obesity such as sibutramine and orlistat may be

needed to determine the effects of these medications on smoking cessation and cessation-related weight gain. (36)

8. Tobacco cessation and weight management combined interventions – for people with diabetes

Research indicates that smokers who have diabetes may have worse success quitting tobacco in some, but not all studies. In a cross-sectional study of smokers who enrolled in a state quitline, Schauer found that having diabetes had no impact on the effectiveness of smoking cessation treatment on cessation; 24.3% of those with diabetes vs 22.5% of those without diabetes quit smoking at 6 months and no significant differences existed between groups for weight gain, regardless of quit status. However, participants with diabetes reported more weight gain in previous quit attempts (34.2% of those with diabetes vs 22.4% of those without diabetes gained >20 lbs. (8.84 kg, $p=.03$).(96) By contrast, an earlier study evaluated 6 month cessation outcomes of state quitlines by chronic disease and reported that those with diabetes had lower quit rates than those who did not have diabetes. (97) In the previous weight concerns study in quitlines cited above, addressing weight concerns, challenging maladaptive beliefs, and encouraging acceptance of a modest weight gain in smokers with diabetes had a significant effect on both increasing abstinence and minimizing weight gain associated with cessation. (85) This study appears to be the only randomized trial of combined tobacco and weight interventions that specifically evaluated cessation and weight outcomes among smokers with diabetes. A recent review of randomized trials reporting the effects of tobacco treatments in smokers with diabetes found no evidence of the efficacy for more intensive vs less intensive tobacco cessation treatments. In all of the 8 trials, the tobacco treatment was delivered by health care providers and usually in clinics. Moreover, considerable heterogeneity existed between the trials which included counseling, referral, advice and/or some diabetes-specific education. The review excluded a small number of trials of complex interventions targeting those with and without diabetes. While the authors suggested that more research and development is needed to determine if cessation treatments tailored to patients with diabetes are needed (98), it is clear that the positive outcomes of the weight concerns intervention among people with diabetes needs to be replicated.

9. Role of physicians in helping smokers manage their weight during tobacco cessation

Health care providers have expressed concerns about asking their patients to tackle two difficult behaviors simultaneously, such as quitting smoking and losing weight. (99) Providers also lack knowledge of a systematic integration of multiple behavioral treatments for people with co-morbid conditions. Training opportunities for delivering such interventions or referring patients to effective treatments for smoking and integrated weight control are either rare or poorly utilized. Provider attitudes may also be inadvertently affecting their treatment of smokers with obesity. One study found that among smokers who were overweight, obese, and severely obese, 3.7%, 3.4%, and 2.5%, respectively were prescribed a smoking cessation medication as compared to 5.11% of normal weight smokers. (100) These findings of lower rates of prescribing smoking cessation medications could explain why smokers with obesity may have worse cessation outcomes. Despite three comprehensive reviews (75–77) indicating the safety and short-term efficacy of combining

cessation and weight based treatments, knowledge and availability of such programs have not been widely disseminated.

The USPHS 2008 tobacco guideline which advises clinicians to help patients quit smoking first and then address weight gain either personally or by referral may need to be altered in light of new evidence of the safety and efficacy of combined tobacco cessation and weight control treatments. (94) However, the following guideline recommendations are in line with current evidence.

- Start or increase physical activity.
- Reassure smokers that some weight gain after quitting is common and usually is self-limiting with lifestyle changes.
- Suggest low-calorie substitutes to smoking such as sugarless chewing gum, vegetables, or mints.
- Maintain patients on medication known to delay weight gain (e.g., bupropion SR, NRTs—particularly 4-mg nicotine gum and lozenge).
- Refer smokers to a qualified weight loss professional or evidence-based commercial weight loss program for personalized dietary and exercise programs.

Discussion

While this is not a systematic review, important studies have been highlighted and recommendations for improvements are identified. This narrative review on the broad topic of smoking cessation, weight gain and diabetes highlights some of the seminal studies and knowledge gaps in line with the theme of the paper. This appraisal of the research shows that there is evidence that combining personalized behavioral weight management interventions with tobacco cessation treatments (either simultaneously or sequentially) can provide a safe and successful approach for reducing weight gain and improving cessation outcomes for some individuals. (75–77, 79, 82, 85) Overall, results of these trials suggest that reducing a smoker’s excessive fear of gaining weight and providing personalized dietary and physical activity interventions may limit weight gain without reducing abstinence in the short term. While the most recent Cochrane review (77) states there are not enough studies to make strong recommendations for effective interventions to prevent weight gain, separating studies that focus on “weight concerns” (not targeting weight gain prevention) from those that employ evidence-based behavioral weight loss techniques provides reasons to believe that weight management during cessation can be effective. Smoking cessation medications can also improve cessation rates, but the long term effectiveness on reducing weight gain is unknown. More research is needed with longer follow-up periods and that include high-risk populations such as smokers who are obese and those with diabetes.

In conclusion, while 80–90% of smokers will gain weight after quitting without a weight management intervention, there is some evidence to suggest that combining weight management with cessation could improve these numbers. Of particular concern are the 10 to 20% of smokers who gain in excess of 10 kg. Unfortunately, current evidence does not

provide clear ways to identify this population in advance, although individuals with more severe obesity or those with diabetes may be at greater risk and therefore should receive more aggressive weight management intervention during cessation. While it may be tempting to ask whether quitting is best for every smoker, it is important to note that the health benefits of abstaining from tobacco outweigh the health risks associated with quitting, including those of weight gain. Risk factors can be minimized by close monitoring and a sensible approach to dietary and lifestyles changes.

Recommendations and directions for future

Although research has shown the short term effectiveness of smoking cessation treatments that also address weight gain, the sustainability of these outcomes on weight and tobacco cessation in the long term warrants further research. Similarly, combination weight and tobacco based treatments need to be tested with smokers who are at high risk for, or currently have, diabetes and those who are obese. Future research and development work should include economic evaluations of current and new combined treatments, long term follow up and developing integrated interventions involving tobacco cessation, weight management and diabetes risk reduction.

For now, many of the key intervention components of combined tobacco and weight treatment could be integrated into current clinical and behavioral treatment and include encouraging smokers to add more physical activity, healthy foods, regular meals, and self-monitoring to their focus on quitting smoking. Multifaceted interventions informed by clinical, behavioral, pharmacological and genetic research are needed and these interventions should integrate new learnings from tobacco control and obesity research. Findings reviewed here are relevant to policy makers, health care professionals, research teams, and governments interested in continuing to find ways to reduce the burden of tobacco addiction and excess body weight.

Acknowledgments

Funding

Investigators' time was supported by Grant RO1DA031147 from the National Institute on Drug Abuse; Grant R21AT007845 from the National Center for Complementary and Integrative Health as well as Alere Wellbeing and Arivale, Inc. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

We thank Erica Salmon and Brooke Magnusson for manuscript preparation and support.

Reference List

1. Mokdad AH, Marks JS, Stroup DF, Gerberding JL. Actual causes of death in the United States, 2000. *JAMA*. 2004; 291(10):1238–45. Epub 2004/03/11. DOI: 10.1001/jama.291.10.1238 [PubMed: 15010446]
2. Wadden TA, Brownell KD, Foster GD. Obesity: responding to the global epidemic. *J Consult Clin Psychol*. 2002; 70(3):510–25. Epub 2002/07/02. [PubMed: 12090366]
3. Chiolero A, Faeh D, Paccaud F, Cornuz J. Consequences of smoking for body weight, body fat distribution, and insulin resistance. *Am J Clin Nutr*. 2008; 87(4):801–9. Epub 2008/04/11. [PubMed: 18400700]

4. Chiolero A, Peytremann-Bridevaux I, Paccaud F. Associations between obesity and health conditions may be overestimated if self-reported body mass index is used. *Obes Rev.* 2007; 8(4): 373–4. Epub 2007/06/21. DOI: 10.1111/j.1467-789X.2007.00375.x [PubMed: 17578386]
5. Chiolero A, Wietlisbach V, Ruffieux C, Paccaud F, Cornuz J. Clustering of risk behaviors with cigarette consumption: A population-based survey. *Prev Med.* 2006; 42(5):348–53. Epub 2006/03/01. DOI: 10.1016/j.ypmed.2006.01.011 [PubMed: 16504277]
6. Heaton CG, Vallone D, McCausland KL, Xiao H, Green MP. Smoking, obesity, and their co-occurrence in the United States: cross sectional analysis. *Bmj.* 2006; 333(7557):25–6. Epub 2006/05/16. DOI: 10.1136/bmj.38840.608704.80 [PubMed: 16698804]
7. Sturm R. The effects of obesity, smoking, and drinking on medical problems and costs. *Health Aff (Millwood).* 2002; 21(2):245–53. Epub 2002/03/20. [PubMed: 11900166]
8. Freedman DM, Sigurdson AJ, Rajaraman P, Doody MM, Linet MS, Ron E. The mortality risk of smoking and obesity combined. *Am J Prev Med.* 2006; 31(5):355–62. Epub 2006/10/19. DOI: 10.1016/j.amepre.2006.07.022 [PubMed: 17046405]
9. Levine MD, Kalarchian MA, Courcoulas AP, Wisinski MS, Marcus MD. History of smoking and postcessation weight gain among weight loss surgery candidates. *Addict Behav.* 2007; 32(10):2365–71. Epub 2007/04/06. DOI: 10.1016/j.addbeh.2007.02.002 [PubMed: 17408868]
10. Bush T, Levine MD, Deprey M, et al. Prevalence of Weight Concerns and Obesity Among Smokers Calling a Quitline. *J Smok Cessat.* 2008; 4(5):74–8. Epub 2008/12/01. DOI: 10.1375/jsc.4.2.74 [PubMed: 20548969]
11. Kendzor DE, Businelle MS, Cofta-Woerpel LM, et al. Mechanisms linking socioeconomic disadvantage and BMI in smokers. *Am J Health Behav.* 2013; 37(5):587–98. Epub 2013/08/30. DOI: 10.5993/ajhb.37.5.2 [PubMed: 23985281]
12. Kendzor DE, Costello TJ, Li Y, et al. Race/ethnicity and multiple cancer risk factors among individuals seeking smoking cessation treatment. *Cancer Epidemiol Biomarkers Prev.* 2008; 17(11):2937–45. Epub 2008/11/08. DOI: 10.1158/1055-9965.epi-07-2795 [PubMed: 18990734]
13. LaRowe TL, Piper ME, Schlam TR, Fiore MC, Baker TB. Obesity and smoking: comparing cessation treatment seekers with the general smoking population. *Obesity (Silver Spring).* 2009; 17(6):1301–5. Epub 2009/02/28. DOI: 10.1038/oby.2009.36 [PubMed: 19247276]
14. Kahn SE, Hull RL, Utzschneider KM. Mechanisms linking obesity to insulin resistance and type 2 diabetes. *Nature.* 2006; 444(7121):840–6. Epub 2006/12/15. DOI: 10.1038/nature05482 [PubMed: 17167471]
15. Koster A, Leitzmann MF, Schatzkin A, et al. The combined relations of adiposity and smoking on mortality. *Am J Clin Nutr.* 2008; 88(5):1206–12. Epub 2008/11/11. [PubMed: 18996854]
16. An R, Shi Y. Body weight status and onset of functional limitations in U.S. middle-aged and older adults. *Disabil Health J.* 2015; 8(3):336–44. Epub 2015/04/13. DOI: 10.1016/j.dhjo.2015.02.003 [PubMed: 25863703]
17. Moriarty JP, Branda ME, Olsen KD, et al. The effects of incremental costs of smoking and obesity on health care costs among adults: a 7-year longitudinal study. *J Occup Environ Med.* 2012; 54(3): 286–91. Epub 2012/03/01. DOI: 10.1097/JOM.0b013e318246f1f4 [PubMed: 22361992]
18. Veldheer S, Yingst J, Zhu J, Foulds J. Ten-year weight gain in smokers who quit, smokers who continued smoking and never smokers in the United States, NHANES 2003–2012. *Int J Obes (Lond).* 2015; 39(12):1727–32. Epub 2015/07/15. DOI: 10.1038/ijo.2015.127 [PubMed: 26155918]
19. Tian J, Venn A, Otahal P, Gall S. The association between quitting smoking and weight gain: a systemic review and meta-analysis of prospective cohort studies. *Obes Rev.* 2015; 16(10):883–901. Epub 2015/06/27. DOI: 10.1111/obr.12304 [PubMed: 26114839]
20. Klesges RC, Winders SE, Meyers AW, et al. How much weight gain occurs following smoking cessation? A comparison of weight gain using both continuous and point prevalence abstinence. *J Consult Clin Psychol.* 1997; 65(2):286–91. Epub 1997/04/01. [PubMed: 9086692]
21. Pistelli F, Aquilini F, Carrozzi L. Weight gain after smoking cessation. *Monaldi Arch Chest Dis.* 2009; 71(2):81–7. Epub 2009/09/02. [PubMed: 19719041]
22. Lycett D, Munafò M, Johnstone E, Murphy M, Aveyard P. Associations between weight change over 8 years and baseline body mass index in a cohort of continuing and quitting smokers.

- Addiction. 2011; 106(1):188–96. Epub 2010/10/12. DOI: 10.1111/j.1360-0443.2010.03136.x [PubMed: 20925685]
23. Aubin HJ, Farley A, Lycett D, Lahmek P, Aveyard P. Weight gain in smokers after quitting cigarettes: meta-analysis. *Bmj*. 2012; 345:e4439. Epub 2012/07/12. doi: 10.1136/bmj.e4439 [PubMed: 22782848]
 24. Bush TM, Levine MD, Magnusson B, et al. Impact of baseline weight on smoking cessation and weight gain in quitlines. *Ann Behav Med*. 2014; 47(2):208–17. Epub 2013/09/21. DOI: 10.1007/s12160-013-9537-z [PubMed: 24048952]
 25. Scherr A, Seifert B, Kuster M, et al. Predictors of marked weight gain in a population of health care and industrial workers following smoking cessation. *BMC Public Health*. 2015; 15:520. Epub 2015/05/31. doi: 10.1186/s12889-015-1854-7 [PubMed: 26025035]
 26. Whitlock G, Lewington S, Sherliker P, et al. Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. *Lancet*. 2009; 373(9669):1083–96. Epub 2009/03/21. DOI: 10.1016/s0140-6736(09)60318-4 [PubMed: 19299006]
 27. Pisinger C, Jorgensen T. Waist circumference and weight following smoking cessation in a general population: the Inter99 study. *Prev Med*. 2007; 44(4):290–5. Epub 2007/01/16. DOI: 10.1016/j.ypmed.2006.11.015 [PubMed: 17222450]
 28. Froom P, Kristal-Boneh E, Melamed S, Gofer D, Benbassat J, Ribak J. Smoking cessation and body mass index of occupationally active men: the Israeli CORDIS Study. *Am J Public Health*. 1999; 89(5):718–22. Epub 1999/05/04. [PubMed: 10224984]
 29. Swan GE, Carmelli D. Characteristics associated with excessive weight gain after smoking cessation in men. *Am J Public Health*. 1995; 85(1):73–7. Epub 1995/01/01. [PubMed: 7832265]
 30. Sanchez-Johnsen LA. Smoking cessation, obesity and weight concerns in black women: a call to action for culturally competent interventions. *J Natl Med Assoc*. 2005; 97(12):1630–8. Epub 2006/01/07. [PubMed: 16396055]
 31. Williamson DF, Madans J, Anda RF, Kleinman JC, Giovino GA, Byers T. Smoking cessation and severity of weight gain in a national cohort. *N Engl J Med*. 1991; 324(11):739–45. Epub 1991/03/14. DOI: 10.1056/nejm199103143241106 [PubMed: 1997840]
 32. Prod'hom S, Locatelli I, Giraudon K, et al. Predictors of weight change in sedentary smokers receiving a standard smoking cessation intervention. *Nicotine Tob Res*. 2013; 15(5):910–6. Epub 2012/10/11. DOI: 10.1093/ntr/nts217 [PubMed: 23048177]
 33. Klesges RC, Meyers AW, Klesges LM, La Vasque ME. Smoking, body weight, and their effects on smoking behavior: a comprehensive review of the literature. *Psychol Bull*. 1989; 106(2):204–30. Epub 1989/09/01. [PubMed: 2678202]
 34. Kokkinos P. Physical activity, health benefits, and mortality risk. *ISRN Cardiol*. 2012; 2012:718789. Epub 2012/12/01. doi: 10.5402/2012/718789 [PubMed: 23198160]
 35. Komiyama M, Wada H, Ura S, et al. Analysis of factors that determine weight gain during smoking cessation therapy. *PLoS One*. 2013; 8(8):e72010. Epub 2013/08/31. doi: 10.1371/journal.pone.0072010 [PubMed: 23991026]
 36. Filozof C, Fernandez Pinilla MC, Fernandez-Cruz A. Smoking cessation and weight gain. *Obes Rev*. 2004; 5(2):95–103. Epub 2004/04/17. DOI: 10.1111/j.1467-789X.2004.00131.x [PubMed: 15086863]
 37. Copeland AL, Martin PD, Geiselman PJ, Rash CJ, Kendzor DE. Smoking cessation for weight-concerned women: group vs. individually tailored, dietary, and weight-control follow-up sessions. *Addict Behav*. 2006; 31(1):115–27. Epub 2005/06/01. DOI: 10.1016/j.addbeh.2005.04.020 [PubMed: 15925449]
 38. Rabkin S. Relationship between weight change and the reduction or cessation of cigarette smoking. *Int J Obes*. 1984; 8(6):665–73. Epub 1984/01/01. [PubMed: 6533089]
 39. Flegal KM, Troiano RP, Pamuk ER, Kuczmarski RJ, Campbell SM. The influence of smoking cessation on the prevalence of overweight in the United States. *N Engl J Med*. 1995; 333(18):1165–70. Epub 1995/11/02. DOI: 10.1056/nejm199511023331801 [PubMed: 7565970]
 40. White MA, Peters EN, Toll BA. Effect of binge eating on treatment outcomes for smoking cessation. *Nicotine Tob Res*. 2010; 12(11):1172–5. Epub 2010/10/05. DOI: 10.1093/ntr/ntq163 [PubMed: 20889472]

41. Carney RM, Goldberg AP. Weight gain after cessation of cigarette smoking. A possible role for adipose-tissue lipoprotein lipase. *N Engl J Med.* 1984; 310(10):614–6. Epub 1984/03/08. DOI: 10.1056/nejm198403083101002 [PubMed: 6694672]
42. Audrain-McGovern J, Benowitz NL. Cigarette smoking, nicotine, and body weight. *Clin Pharmacol Ther.* 2011; 90(1):164–8. Epub 2011/06/03. DOI: 10.1038/clpt.2011.105 [PubMed: 21633341]
43. Jo YH, Talmage DA, Role LW. Nicotinic receptor-mediated effects on appetite and food intake. *J Neurobiol.* 2002; 53(4):618–32. Epub 2002/11/19. DOI: 10.1002/neu.10147 [PubMed: 12436425]
44. Rodin J. Weight change following smoking cessation: the role of food intake and exercise. *Addict Behav.* 1987; 12(4):303–17. Epub 1987/01/01. [PubMed: 3687515]
45. Kleppinger A, Litt MD, Kenny AM, Oncken CA. Effects of smoking cessation on body composition in postmenopausal women. *J Womens Health (Larchmt).* 2010; 19(9):1651–7. Epub 2010/08/20. DOI: 10.1089/jwh.2009.1853 [PubMed: 20718625]
46. Biedermann L, Zeitz J, Mwinyi J, et al. Smoking cessation induces profound changes in the composition of the intestinal microbiota in humans. *PLoS One.* 2013; 8(3):e59260. Epub 2013/03/22. doi: 10.1371/journal.pone.0059260 [PubMed: 23516617]
47. Pepino MY, Mennella JA. Cigarette smoking and obesity are associated with decreased fat perception in women. *Obesity (Silver Spring).* 2014; 22(4):1050–5. Epub 2014/01/15. DOI: 10.1002/oby.20697 [PubMed: 24415517]
48. Blum K, Liu Y, Shriner R, Gold MS. Reward circuitry dopaminergic activation regulates food and drug craving behavior. *Curr Pharm Des.* 2011; 17(12):1158–67. Epub 2011/04/16. [PubMed: 21492092]
49. Stice E, Burger KS, Yokum S. Reward Region Responsivity Predicts Future Weight Gain and Moderating Effects of the Taq1A Allele. *J Neurosci.* 2015; 35(28):10316–24. Epub 2015/07/17. DOI: 10.1523/jneurosci.3607-14.2015 [PubMed: 26180206]
50. Stice E, Rohde P, Gau J, Shaw H. Effect of a dissonance-based prevention program on risk for eating disorder onset in the context of eating disorder risk factors. *Prev Sci.* 2012; 13(2):129–39. Epub 2011/10/07. DOI: 10.1007/s11121-011-0251-4 [PubMed: 21975593]
51. Hall SM, Tunstall CD, Vila KL, Duffy J. Weight gain prevention and smoking cessation: cautionary findings. *Am J Public Health.* 1992; 82(6):799–803. Epub 1992/06/01. [PubMed: 1585959]
52. Willi C, Bodenmann P, Ghali WA, Faris PD, Cornuz J. Active smoking and the risk of type 2 diabetes: a systematic review and meta-analysis. *JAMA.* 2007; 298(22):2654–64. Epub 2007/12/13. DOI: 10.1001/jama.298.22.2654 [PubMed: 18073361]
53. National Center for Chronic Disease P, Health Promotion Office on S, Health. The Health Consequences of Smoking-50 Years of Progress: A Report of the Surgeon General. Atlanta (GA): Centers for Disease Control and Prevention (US); 2014. Reports of the Surgeon General.
54. Tonstad S. Cigarette smoking, smoking cessation, and diabetes. *Diabetes Res Clin Pract.* 2009; 85(1):4–13. Epub 2009/05/12. DOI: 10.1016/j.diabres.2009.04.013 [PubMed: 19427049]
55. Nakanishi N, Nakamura K, Matsuo Y, Suzuki K, Tatara K. Cigarette smoking and risk for impaired fasting glucose and type 2 diabetes in middle-aged Japanese men. *Ann Intern Med.* 2000; 133(3):183–91. Epub 2000/07/25. [PubMed: 10906832]
56. Yeh HC, Duncan BB, Schmidt MI, Wang NY, Brancati FL. Smoking, smoking cessation, and risk for type 2 diabetes mellitus: a cohort study. *Ann Intern Med.* 2010; 152(1):10–7. Epub 2010/01/06. DOI: 10.7326/0003-4819-152-1-201001050-00005 [PubMed: 20048267]
57. Clair C, Rigotti NA, Meigs JB. Smoking cessation, weight change, and risk of cardiovascular disease--reply. *JAMA.* 2013; 310(3):323. Epub 2013/07/19. doi: 10.1001/jama.2013.7945 [PubMed: 23860997]
58. Benowitz NL. Cigarette smoking and cardiovascular disease: pathophysiology and implications for treatment. *Prog Cardiovasc Dis.* 2003; 46(1):91–111. Epub 2003/08/16. [PubMed: 12920702]
59. Eliasson B, Attvall S, Taskinen MR, Smith U. Smoking cessation improves insulin sensitivity in healthy middle-aged men. *Eur J Clin Invest.* 1997; 27(5):450–6. Epub 1997/05/01. [PubMed: 9179554]

60. Nilsson PM, Gudbjornsdottir S, Eliasson B, Cederholm J. Smoking is associated with increased HbA1c values and microalbuminuria in patients with diabetes--data from the National Diabetes Register in Sweden. *Diabetes Metab.* 2004; 30(3):261–8. Epub 2004/06/30. [PubMed: 15223978]
61. Eliasson B, Mero N, Taskinen MR, Smith U. The insulin resistance syndrome and postprandial lipid intolerance in smokers. *Atherosclerosis.* 1997; 129(1):79–88. Epub 1997/02/28. [PubMed: 9069521]
62. Qin R, Chen T, Lou Q, Yu D. Excess risk of mortality and cardiovascular events associated with smoking among patients with diabetes: meta-analysis of observational prospective studies. *Int J Cardiol.* 2013; 167(2):342–50. Epub 2012/01/19. DOI: 10.1016/j.ijcard.2011.12.100 [PubMed: 22251416]
63. Celermajer DS, Sorensen KE, Georgakopoulos D, et al. Cigarette smoking is associated with dose-related and potentially reversible impairment of endothelium-dependent dilation in healthy young adults. *Circulation.* 1993; 88(5 Pt 1):2149–55. Epub 1993/11/01. [PubMed: 8222109]
64. Balkau B, Vierron E, Vernay M, et al. The impact of 3-year changes in lifestyle habits on metabolic syndrome parameters: the D.E.S.I.R study. *Eur J Cardiovasc Prev Rehabil.* 2006; 13(3):334–40. Epub 2006/08/24. [PubMed: 16926661]
65. Lycett D, Nichols L, Ryan R, et al. The association between smoking cessation and glycaemic control in patients with type 2 diabetes: a THIN database cohort study. *Lancet Diabetes Endocrinol.* 2015; 3(6):423–30. Epub 2015/05/04. DOI: 10.1016/s2213-8587(15)00082-0 [PubMed: 25935880]
66. Stein JH, Asthana A, Smith SS, et al. Smoking cessation and the risk of diabetes mellitus and impaired fasting glucose: three-year outcomes after a quit attempt. *PLoS One.* 2014; 9(6):e98278. Epub 2014/06/04. doi: 10.1371/journal.pone.0098278 [PubMed: 24893290]
67. Pan A, Wang Y, Talaei M, Hu FB, Wu T. Relation of active, passive, and quitting smoking with incident type 2 diabetes: a systematic review and meta-analysis. *Lancet Diabetes Endocrinol.* 2015; 3(12):958–67. Epub 2015/09/22. DOI: 10.1016/s2213-8587(15)00316-2 [PubMed: 26388413]
68. Oba S, Noda M, Waki K, et al. Smoking cessation increases short-term risk of type 2 diabetes irrespective of weight gain: the Japan Public Health Center-Based Prospective Study. *PLoS One.* 2012; 7(2):e17061. Epub 2012/08/11. doi: 10.1371/journal.pone.0017061 [PubMed: 22879858]
69. Morimoto A, Ohno Y, Tatsumi Y, et al. Impact of smoking cessation on incidence of diabetes mellitus among overweight or normal-weight Japanese men. *Diabetes Res Clin Pract.* 2012; 96(3):407–13. Epub 2012/04/13. DOI: 10.1016/j.diabres.2012.03.007 [PubMed: 22494491]
70. Tamura U, Tanaka T, Okamura T, et al. Changes in Weight, cardiovascular risk factors and estimated risk of coronary heart disease following smoking cessation in Japanese male workers: HIPOP-OHP study. *J Atheroscler Thromb.* 2010; 17(1):12–20. Epub 2010/01/19. [PubMed: 20081325]
71. Hall SM, McGee R, Tunstall C, Duffy J, Benowitz N. Changes in food intake and activity after quitting smoking. *J Consult Clin Psychol.* 1989; 57(1):81–6. Epub 1989/02/01. [PubMed: 2925977]
72. Perkins KA, Epstein LH, Pastor S. Changes in energy balance following smoking cessation and resumption of smoking in women. *J Consult Clin Psychol.* 1990; 58(1):121–5. Epub 1990/02/01. [PubMed: 2319045]
73. Luo J, Rossouw J, Margolis KL. Smoking cessation, weight change, and coronary heart disease among postmenopausal women with and without diabetes. *JAMA.* 2013; 310(1):94–6. Epub 2013/07/04. DOI: 10.1001/jama.2013.6871 [PubMed: 23821094]
74. Pirie K, Peto R, Reeves GK, Green J, Beral V. The 21st century hazards of smoking and benefits of stopping: a prospective study of one million women in the UK. *Lancet.* 2013; 381(9861):133–41. Epub 2012/10/31. DOI: 10.1016/s0140-6736(12)61720-6 [PubMed: 23107252]
75. Parsons AC, Shraim M, Inglis J, Aveyard P, Hajek P. Interventions for preventing weight gain after smoking cessation. *Cochrane Database Syst Rev.* 2009; (1):Cd006219. Epub 2009/01/23. doi: 10.1002/14651858.CD006219.pub2 [PubMed: 19160269]

76. Spring B, Howe D, Berendsen M, et al. Behavioral intervention to promote smoking cessation and prevent weight gain: a systematic review and meta-analysis. *Addiction*. 2009; 104(9):1472–86. Epub 2009/06/25. DOI: 10.1111/j.1360-0443.2009.02610.x [PubMed: 19549058]
77. Farley AC, Hajek P, Lycett D, Aveyard P. Interventions for preventing weight gain after smoking cessation. *Cochrane Database Syst Rev*. 2012; 1:Cd006219. Epub 2012/01/20. doi: 10.1002/14651858.CD006219.pub3 [PubMed: 22258966]
78. Levine MD, Perkins KA, Kalarchian MA, et al. Bupropion and cognitive behavioral therapy for weight-concerned women smokers. *Arch Intern Med*. 2010; 170(6):543–50. Epub 2010/03/24. DOI: 10.1001/archinternmed.2010.33 [PubMed: 20308641]
79. Perkins KA, Marcus MD, Levine MD, et al. Cognitive-behavioral therapy to reduce weight concerns improves smoking cessation outcome in weight-concerned women. *J Consult Clin Psychol*. 2001; 69(4):604–13. Epub 2001/09/12. [PubMed: 11550727]
80. Spring B, Pagoto S, Pingitore R, Doran N, Schneider K, Hedeker D. Randomized controlled trial for behavioral smoking and weight control treatment: effect of concurrent versus sequential intervention. *J Consult Clin Psychol*. 2004; 72(5):785–96. Epub 2004/10/16. DOI: 10.1037/0022-006x.72.5.785 [PubMed: 15482037]
81. Danielsson T, Rossner S, Westin A. Open randomised trial of intermittent very low energy diet together with nicotine gum for stopping smoking in women who gained weight in previous attempts to quit. *Bmj*. 1999; 319(7208):490–3. discussion 4. Epub 1999/08/24. [PubMed: 10454403]
82. Aveyard P, Lycett D, Farley A. Managing smoking cessation related weight gain. *Pol Arch Med Wewn*. 2012; 122(10):494–8. Epub 2012/11/06. [PubMed: 23123526]
83. Napolitano MA, Lloyd-Richardson EE, Fava JL, Marcus BH. Targeting body image schema for smoking cessation among college females: rationale, program description, and pilot study results. *Behav Modif*. 2011; 35(4):323–46. Epub 2011/04/20. DOI: 10.1177/0145445511404840 [PubMed: 21502132]
84. Clark MM, Hays JT, Vickers KS, et al. Body image treatment for weight concerned smokers: a pilot study. *Addict Behav*. 2005; 30(6):1236–40. Epub 2005/06/01. DOI: 10.1016/j.addbeh.2004.10.009 [PubMed: 15925132]
85. Bush T, Levine MD, Beebe LA, et al. Addressing weight gain in smoking cessation treatment: a randomized controlled trial. *Am J Health Promot*. 2012; 27(2):94–102. Epub 2012/11/02. DOI: 10.4278/ajhp.110603-QUAN-238 [PubMed: 23113779]
86. Leslie WS, Koshy PR, Mackenzie M, et al. Changes in body weight and food choice in those attempting smoking cessation: a cluster randomised controlled trial. *BMC Public Health*. 2012; 12:389. Epub 2012/05/31. doi: 10.1186/1471-2458-12-389 [PubMed: 22642755]
87. Filia SL, Baker AL, Kulkarni J, Williams JM. Sequential behavioral treatment of smoking and weight control in bipolar disorder. *Transl Behav Med*. 2012; 2(3):290–5. Epub 2013/09/28. DOI: 10.1007/s13142-012-0111-1 [PubMed: 24073127]
88. Marcus BH, Albrecht AE, King TK, et al. The efficacy of exercise as an aid for smoking cessation in women: a randomized controlled trial. *Arch Intern Med*. 1999; 159(11):1229–34. Epub 1999/06/17. [PubMed: 10371231]
89. Donnelly JE, Blair SN, Jakicic JM, Manore MM, Rankin JW, Smith BK. American College of Sports Medicine Position Stand. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. *Med Sci Sports Exerc*. 2009; 41(2):459–71. Epub 2009/01/08. DOI: 10.1249/MSS.0b013e3181949333 [PubMed: 19127177]
90. Hoffman MD, Hoffman DR. Exercisers achieve greater acute exercise-induced mood enhancement than nonexercisers. *Arch Phys Med Rehabil*. 2008; 89(2):358–63. Epub 2008/01/30. DOI: 10.1016/j.apmr.2007.09.026 [PubMed: 18226663]
91. Jakicic JM, Marcus BH, Lang W, Janney C. Effect of exercise on 24-month weight loss maintenance in overweight women. *Arch Intern Med*. 2008; 168(14):1550–9. discussion 9–60. Epub 2008/07/30. DOI: 10.1001/archinte.168.14.1550 [PubMed: 18663167]
92. Ussher M, Nunziata P, Copley M, West R. Effect of a short bout of exercise on tobacco withdrawal symptoms and desire to smoke. *Psychopharmacology (Berl)*. 2001; 158(1):66–72. Epub 2001/10/31. DOI: 10.1007/s002130100846 [PubMed: 11685385]

93. Taniguchi C, Tanaka H, Oze I, et al. Factors associated with weight gain after smoking cessation therapy in Japan. *Nurs Res.* 2013; 62(6):414–21. Epub 2013/10/30. DOI: 10.1097/nnr.0000000000000000 [PubMed: 24165217]
94. Fiore MCJC, Baker TB, et al. Treating Tobacco Use and Dependence: 2008 Update. *Clinical Practice Guideline.* 2008
95. Schnoll RA, Patterson F, Wileyto EP, Tyndale RF, Benowitz N, Lerman C. Nicotine metabolic rate predicts successful smoking cessation with transdermal nicotine: a validation study. *Pharmacol Biochem Behav.* 2009; 92(1):6–11. Epub 2008/11/13. DOI: 10.1016/j.pbb.2008.10.016 [PubMed: 19000709]
96. Schauer GL, Bush T, Cerutti B, Mahoney L, Thompson JR, Zbikowski SM. Use and effectiveness of quitlines for smokers with diabetes: cessation and weight outcomes, Washington State Tobacco Quit Line, 2008. *Prev Chronic Dis.* 2013; 10:E105. Epub 2013/06/29. doi: 10.5888/pcd10.120324 [PubMed: 23806800]
97. Bush T, Zbikowski SM, Mahoney L, Deprey M, Mowery P, Cerutti B. State quitlines and cessation patterns among adults with selected chronic diseases in 15 states, 2005–2008. *Prev Chronic Dis.* 2012; 9:E163. Epub 2012/11/10. doi: 10.5888/pcd9.120105 [PubMed: 23137862]
98. Nagrebetsky A, Brettell R, Roberts N, Farmer A. Smoking cessation in adults with diabetes: a systematic review and meta-analysis of data from randomised controlled trials. *BMJ Open.* 2014; 4(3):e004107. Epub 2014/03/08. doi: 10.1136/bmjopen-2013-004107
99. Siddiqi KDO, Siddiqi N. Smoking Cessation in Long-Term Conditions: Is There “An Opportunity in Every Difficulty”? *Int J Popul Res.* 2013; 2013:10. doi: 10.1155/2013/251048
100. Yu Y, Rajan SS, Essien EJ, Yang M, Abughosh S. The relationship between obesity and prescription of smoking cessation medications. *Popul Health Manag.* 2014; 17(3):172–9. Epub 2014/05/03. DOI: 10.1089/pop.2013.0059 [PubMed: 24784163]

Study Importance

- Tobacco cessation is an important public health priority, yet many smokers gain weight after quitting, in some cases offsetting some of the health benefits of quitting.
- Smoking is a risk factor for diabetes, but cessation could interfere with glucose control for some.
- Some interventions that combine tobacco cessation and weight control have proven effective in helping smokers quit without excess weight gain.
- Previous reviews of this area have not focused on the integration of neurobiological, behavioral and health services research and none have included intervention effects on diabetes.
- Integration of tobacco cessation, weight management and diabetes prevention and management may be a new direction for health care.