Consequences of smoking for body weight, body fat distribution, and insulin resistance[1,2]

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ABSTRACT

Our aim was to critically evaluate the relations among smoking, body weight, body fat distribution, and insulin resistance as reported in the literature. In the short term, nicotine increases energy expenditure and could reduce appetite, which may explain why smokers tend to have lower body weight than do nonsmokers and why smoking cessation is frequently followed by weight gain. In contrast, heavy smokers tend to have greater body weight than do light smokers or nonsmokers, which likely reflects a clustering of risky behaviors (eg, low degree of physical activity, poor diet, and smoking) that is conducive to weight gain. Other factors, such as weight cycling, could also be involved. In addition, smoking increases insulin resistance and is associated with central fat accumulation. As a result, smoking increases the risk of metabolic syndrome and diabetes, and these factors increase risk of cardiovascular disease. In the context of the worldwide obesity epidemic and a high prevalence of smoking, the greater risk of (central) obesity and insulin resistance among smokers is a matter of major concern.   *Am J Clin Nutr* 2008;87:801–9.

INTRODUCTION

Smoking and obesity are leading causes of morbidity and mortality worldwide (1, 2). The co-occurrence of overweight and smoking has substantial consequences for health. According to the Framingham study, the life expectancy of obese smokers was 13 y less than that of normal-weight nonsmokers (3). In the same cohort, one-third to one-half of obese smokers died between the ages of 40 and 70 y, whereas only ≈10% of normal-weight nonsmokers did so (**Figure 1**).

The relation between smoking and obesity is incompletely understood. On the one hand, nicotine acutely increases energy expenditure (EE) (4) and could reduce appetite, which likely explains why smokers tend to have lower body weight than do nonsmokers and why smoking cessation is frequently followed by weight gain (5, 6). Moreover, a belief popular among both smokers and nonsmokers is that smoking is an efficient way to control body weight (7). On the other hand, studies indicate that heavy smokers (ie, those smoking a greater number of cigarettes/d) have greater body weight than do light smokers (8–10) and that there is a clustering of smoking, obesity, and lower socioeconomic status, at least in developed countries (11). Finally, there is increasing evidence that smoking affects body fat distribution and that it is associated with central obesity and insulin resistance (12, 13).

In a context of the worldwide obesity epidemic and a high prevalence of smoking (which is increasing in many parts of the world), the relation among smoking, obesity, and associated conditions has major public health relevance. Therefore, our aims were to critically review how smoking affects body weight, body fat distribution, and insulin resistance and to propose a comprehensive view of that issue.

SMOKING AND BODY WEIGHT

Do smokers have lower body weight than nonsmokers?

Numerous cross-sectional studies indicate that body weight, or body mass index (BMI; in kg/m^2), is lower in cigarette smokers than in nonsmokers (5, 14–16). In the World Health Organization Monitoring Cardiac Disease (ie, WHO MONICA) surveys, BMI was lower in smokers than in nonsmokers in 20 (men) and 30 (women) of the 42 populations, and there was no population in which smokers had a higher BMI than did nonsmokers (17). In the second National Health and Nutrition Examination Survey (ie, NHANES II) study (1976–1980), smokers weighed less than nonsmokers, and body leanness increased with the duration (but not with the intensity) of smoking (18).

Smoking's effect on body weight could lead to weight loss by increasing the metabolic rate, decreasing metabolic efficiency, or decreasing caloric absorption (reduction in appetite), all of which are associated with tobacco use. The metabolic effect of smoking could explain the lower body weight found in smokers. Smoking a single cigarette has been shown to induce a 3% rise in EE within 30 min (19). Smoking 4 cigarettes each of which contained 0.8 mg nicotine increased resting EE by 3.3% for 3 h (20). In regular smokers whose metabolism was assessed in a metabolic ward, smoking 24 cigarettes in 1 d increased the total EE from 2230 to 2445 kcal/d, and stimulation of the sympathetic nervous system activity could be involved (4). The effect of smoking on EE was weaker among obese subjects (21), and it also depended on the degree of physical activity and fitness (22, 23). Few studies have evaluated the chronic metabolic effects of smoking, and the results have conflicted (6). After 30 d of smoking cessation, the resting metabolic rate in female quitters was shown to be 16% lower than it had been when they were smoking,
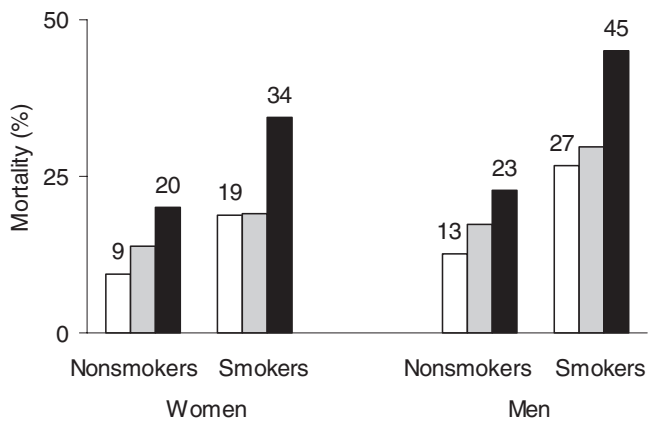
FIGURE 1. Percentages of the participants in the initial Framingham cohort study who died between age 40 and 70 y according to smoking and body-weight category. □, normal-weight; ▨, overweight; ■, obese. Adapted from reference 3.

and an increase in body weight was attributable to a decrease in resting metabolic rate and an increase in caloric intake (24). Other researchers did not find any change in resting EE after smoking cessation (25, 26). Smokers may be at higher risk of hyperthyroidism than are nonsmokers (27), which also could increase metabolic rate.

Besides its metabolic properties, nicotine could induce an acute anorexic effect: during a 2-h period, hunger and food consumption were negatively associated and satiety and fullness were positively associated with increasing doses of nicotine (28). In both smokers and nonsmokers, nicotine did not change hunger sensations but resulted in smaller caloric intake during a meal (29). However, caloric intake was higher during a meal after nicotine administration than after placebo (30). Finally, physical activity increases metabolic rate and may help to control body weight, but smokers tend to be less physically active than nonsmokers (31). Overall, whereas an acute metabolic effect of

smoking that favors weight control appears probable, the effect on caloric intake remains disputable.

Effect of smoking initiation on body weight

Cross-sectional studies indicate that mean BMI tended to be lower among smokers than among nonsmokers in many populations. One would expect that, because of the metabolic and possibly anorexic effects of smoking, those who initiate smoking during the study (called "smoking initiators") would gain less body weight over time than would nonsmokers. However, few studies have prospectively assessed changes in body weight after smoking initiation (14, 32–36; **Table 1**). Whereas some studies reported that initiators and smokers had a lower weight gain over time than did nonsmokers (14, 33, 36), other studies did not so report (32–35). Some of these studies had a large sample size; however, most included a modest number of smoking initiators. The Nurses' Health Study had a long follow-up and was sufficiently large to allow comparison of various categories of smokers and nonsmokers (32; **Figure 2**). Age- and baseline body weight–adjusted estimates were reported; both factors were major confounders of the relation between smoking and change in body weight. An 8-y follow-up of 55 000 women showed that nonsmokers had a lower weight gain than did smoking initiators or continuous smokers (32). Heavy smokers gained more weight than did light smokers in that cohort. In the study by Klesges et al (33), 5115 adults aged 18–30 y were followed for 7 y, and estimates were adjusted for age and baseline body weight, as well as for education, physical fitness, and alcohol and fat intake. Among whites, weight gain was similar in smoking initiators and nonsmokers, which indicated that smoking had no weight gain–attenuating effect. In contrast, among African Americans, weight gain was lower in smoking initiators than in nonsmokers.

These data suggest that smoking may not help to control weight. If anything, smoking (in particular, heavy smoking) seems related to weight gain. To better understand how smoking and body weight relate, it is crucial to take account of body

TABLE 1
Prospective studies on the association between smoking initiation and change in body weight[1]

Study	Participants	Follow-up	Results
Shimokata et al, 1989 (14)	1122 men	3 y	Initiators: $\bar{x} \pm$ SE body-weight gain of 0.93 $\pm$ 0.48 kg Smokers: no body weight gain
Nurses' Health Study: Colditz et al, 1992 (32)	55 000 women	8 y	Higher (age- and baseline body weight–adjusted) weight gain in initiators and smokers than in nonsmokers (*see* Figure 2)
Klesges et al, 1998 (33)	5115 young adults (18–30 old)	7 y	Among African Americans, initiators had a lower (adjusted for age, baseline body weight, and other potential confounders) weight gain (4.8 kg) than did nonsmokers (8.4 kg) or smokers (5.9 kg); among whites, weight gain was similar in initiators (6.3 kg), nonsmokers (6.1 kg), and smokers (5.5 kg)
Cooper et al, 2003 (34)	1697 adolescents	3 y	First 2 y: initiators had higher BMI increases than did nonsmokers; year 3: no difference was seen between smokers and nonsmokers
Kvaavik et al, 2003 (35)	485 adolescents and young adults	From 15 to 33 y old	Initiators during adolescence, smokers, and nonsmokers had similar risks of overweight
Stice et al, 2004 (36)	495 adolescent girls	3 y	Smokers had lower weight gain, height, and BMI gain than did nonsmokers

[1] Initiators are persons who began smoking during the course of the study in which they were participating; smokers are those who smoked regularly during the course of the study, unless specified otherwise.
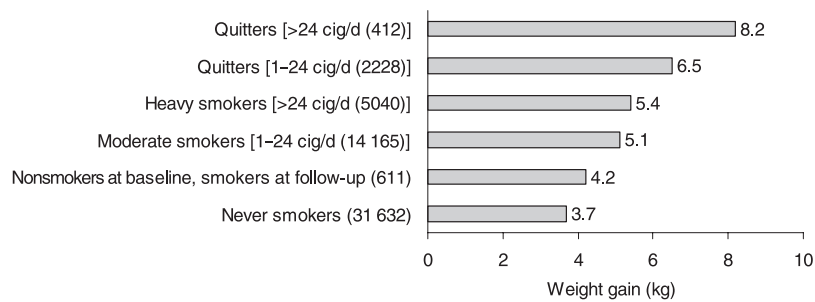
FIGURE 2. Weight gain adjusted for age and body weight at baseline in participants of the Nurses' Health Study after 8 y of follow-up, according to smoking status. *n* in parentheses. cig, cigarettes. Adapted from reference 32.

weight and weight concern at the time of smoking initiation—eg, in adolescence—and at the time of smoking cessation.

Smoking initiation and weight concerns

Adolescence is a sensitive period for smoking initiation and for excessive body weight gain. In female adolescents, smoking initiation is associated with body weight, weight concerns, and dieting behaviors (6). In a representative panel of US adolescents, smoking initiation was more frequent in females who were overweight, who reported trying to lose weight, or who described themselves as overweight than in females without those characteristics (37). Female students who previously tried to lose weight or who reported constantly thinking about weight were prospectively more than twice as likely to initiate smoking than were those who had not tried to lose weight or who did not constantly think about weight (38). In addition, the expectation of weight control may be a reason that adolescent males initiate smoking (7).

These findings suggest that, in both sexes, smoking initiation may be triggered by weight concern and previous attempts to lose weight. One implication is that the change in body weight with smoking may be determined by factors that preceded the initiation of smoking.

Do heavy smokers weigh more than light smokers?

Given the metabolic effect of smoking, it is expected that the greater the number of cigarettes smoked, the lower the smoker's body weight. However, cross-sectional studies indicate that heavy smoking could be associated with a greater risk of obesity (9, 10, 14, 39, 40). In the Cancer Prevention Study I (40), whereas smokers had lower body weight than did never or former smokers, heavy smokers ($\geq$2 packs cigarettes/d) were more likely to be overweight than were other smokers. In a sample of US men, age-adjusted BMI was 25.3 in nonsmokers and 24.7, 24.7, and 26.2 in light ($<$20 cigarettes/d), moderate (20–40 cigarettes/d), and heavy ($>$40 cigarettes/d) smokers, respectively (14). In a general adult population sample in Germany, male heavy smokers were more likely to be obese than were male light smokers (9). However, in a sample of US male twins, light (0–19 cigarettes/d), moderate (20–29 cigarettes/d), and heavy ($\geq$30 cigarettes/d) smokers were a mean of 3.2, 2.4, and 4.0 kg lighter than were nonsmokers (41).

We (10) recently showed in a large survey of a general adult population in Switzerland that the odds of being obese increased progressively with smoking. After adjustment for age, educational level, and lifestyle, the odds ratios (and 95% CIs) for obesity in men were 1.4 (0.7, 2.8) for moderate smokers (10–19 cig/d) and 2.8 (1.6, 5.1) for heavy smokers ($\geq$20 cigarettes/d) as

compared with light smokers (1–9 cigarettes/d); in women, the odds ratios were 1.1 (0.7, 1.8) for moderate smokers and 1.7 (1.1, 2.6) for heavy smokers.

Overall, these findings indicate that smoking is most often positively related to body weight and that heavy smokers are more likely to be overweight or obese than are light smokers. These observations are surprisingly rarely acknowledged, and they suggest that factors associated with smoking counter and even overtake the metabolic effect of smoking.

The question of why heavy smokers tend to have greater body weight than light smokers or nonsmokers remains unanswered. One explanation could be that heavy smokers are more likely to adopt behaviors favoring weight gain (eg, low physical activity, unhealthy diet, and high alcohol intake) than are light smokers or nonsmokers. Smokers eat less fruit and vegetables (42), adopt unhealthy patterns of nutrient intake (43), drink more alcohol (44), and engage in less physical activity than do nonsmokers (45). We have identified a strong clustering of risk behaviors (ie, low physical activity, low intakes of fruit and vegetables, and high alcohol intake) that correlated with the level of cigarette consumption (46).

Further factors also may be involved. First, because smoking initiation was shown particularly in women to be associated with weight concern or dieting and overweight (7, 37), the association of smoking with obesity could show reverse causation, with overweight as the trigger for smoking. Second, the paucity of longitudinal observation of metabolic and behavioral changes in smokers, which would take into account the number of cigarettes smoked daily, precludes conclusions about metabolic and behavioral long-term consequences of smoking. Third, because heavy smokers who tried to quit relapsed more frequently than did light smokers—among other reasons because the weight gain was important (47)—the former group is at risk of repeated cycles of weight loss and regain, so-called "weight cycling" (48, 49), which could be associated with a greater risk of overweight or obesity (49, 50). Further studies of factors associated with smoking and the dynamics of body-weight change are needed.

Change in body weight after smoking cessation

Numerous studies have shown that persons who quit smoking are likely to gain weight, as reviewed by Ward et al (6) and Filozof et al (47). The prospect of gaining weight can discourage smokers from quitting. In addition, weight gain increases the risk of relapse, particularly among normal-weight or underweight women who report chronic dieting (51), but also among men (52).

The amount of body weight gained after smoking cessation is highly variable (5, 15, 53). When current (measured) body weight was compared with body weight 10 y in the past (self-reported), smokers who quit had gained 4.4 (males) and 5.0 (females) kg more than did continuous smokers (15). In a US cohort of adults followed up over 10 y, the mean weight gain attributable to smoking cessation was 2.8 kg in men and 3.8 kg in women (4). In this cohort, a postcessation weight gain of >13 kg occurred in 9.8% of men and 13.4% of women (**Figure 3**). However, the weight gain was <3 kg in most of the quitters. Being <55 y old, being African American, or smoking ≥15 cigarettes/d increased the risk of major weight gain. Weight gain after smoking cessation was greater in heavy smokers than in light smokers (53), was less pronounced at a greater number of years since smoking cessation (54), and was inversely associated with socioeconomic status (55). Methodologic issues may have led to an underestimation of postcessation weight gain (6). Moreover, in the context of the obesity epidemic, postcessation weight gain may be greater in current than in previous cohorts of smokers.

In the United States, between one-sixth and one-quarter of the increase in the prevalence of overweight during the 1980s has been attributed to smoking cessation (15). However, an Australian study found no relation between the increased prevalence of obesity and the concomitant decrease in smoking prevalence (56), which raises doubts about the implications of a decreasing smoking prevalence on the obesity epidemic. Recently, it was shown in the United States that the decrease in smoking prevalence had a negligible effect on the continuous increase in obesity prevalence (57).

Mechanisms conducive to postcessation weight gain remain poorly understood (6). Postcessation weight gain may result from an increase in energy intake and a decrease in EE (4). Studies indicate that smoking cessation is associated with increased energy intake of up to 250–300 kcal/d shortly after smoking cessation (6) and may remain so associated for a longer period (25, 58). However, other reports indicate no change in caloric intake shortly after cessation (59). Few data are available on the long-term changes subsequent to smoking cessation. In women, the initial increase in energy intake after smoking cessation had disappeared after 6 mo (58), which is consistent with the fact that weight gain occurs early after smoking cessation (6). A decrease in physical activity was also reported after smoking cessation (60, 61). However, other studies showed that physical activity does not decrease after smoking cessation (6, 46, 62). Changes in fat oxidation (63) and in adipose tissue metabolism (eg, lipoprotein activity) (61, 62) may also be involved in postcessation weight gain. Moreover, neuropeptides involved in the regulation of food intake and EE (ie, leptin, neuropeptide Y, and orexins) and monoamines (ie, noradrenaline and dopamine) may be implicated (47).

The "set-point" hypothesis may help us to understand why quitters gain weight. This hypothesis states that alterations in body weight below or above a set-point (which is particular to each person) are countered by changes in eating behavior or EE (64). Nicotine (and possibly other smoking products) could lower the set-point. Thus, after quitting, former smokers would return to their usual set-point and, consequently, would gain weight. This hypothesis is consistent with observations in a US cohort: smokers weighed less at baseline than did nonsmokers, whereas, at follow-up, quitters had gained weight and weighed the same as nonsmokers, and continuous smokers kept a lower weight than did nonsmokers (5). Postcessation weight gain could be prevented with dietary intervention and programs aimed at increasing physical activity in combination with nicotine replacement therapy (65).

Smoking cessation appears to be associated with the person's body weight while smoking. In a cohort of 4270 participants, overweight male smokers were more likely to quit smoking than were normal-weight male smokers, whereas female smokers with a low BMI were less likely to quit than were normal-weight female smokers (66). The latter finding could relate to a greater fear of weight gain after smoking cessation among lean women. Similarly, another cohort study found in both sexes a positive association between BMI and smoking cessation (67). A large proportion of military veterans who smoked had cessation-related weight concerns; however, such concerns were not associated with the rate of cessation (68). Weight concerns on the part of older, ill smokers also may deter them from quitting smoking (69). However, a recent population-based survey suggests that weight concern may not be predictive of the rate of smoking cessation (70). Whereas cessation-related weight concerns are not consistently associated with cessation success, general weight concerns are. These results suggest that those who succeed in quitting smoking may be heavier and less worried about postcessation weight gain, which may explain part of the greater weight gain among quitters than among continuous smokers.

FIGURE 3. Category of weight gain (in kg) in men and women according to smoking status: results from a cohort of subjects aged 25–74 y in 1971–1975 after a mean follow-up of 10 y. Weight gain: □, <3.0 kg; ▨, 3.0–8.0 kg; ▧, >8.0–13.0 kg; ■, >13.0 kg. Adapted from reference 5.

SMOKING, BODY FAT DISTRIBUTION, INSULIN RESISTANCE, METABOLIC SYNDROME, AND DIABETES

Whereas there are important unresolved issues in relation to the effect of smoking on body weight, there is increasing evidence that smoking is conducive to greater accumulation of visceral fat and greater insulin resistance and that smoking increases the risk of metabolic syndrome and type 2 diabetes.
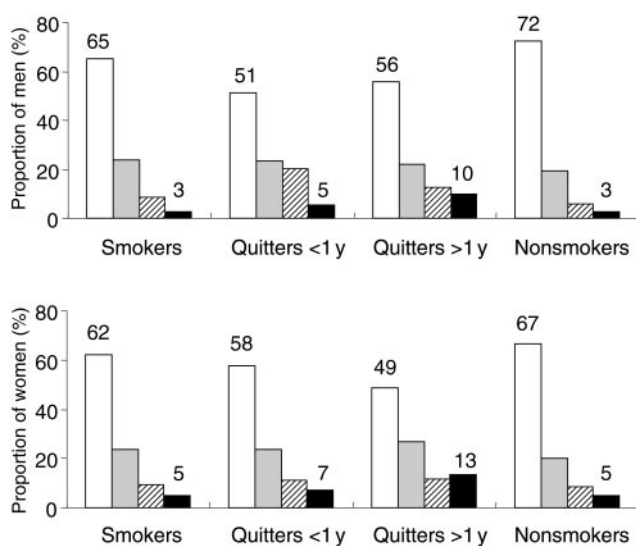
Does smoking increase waist circumference?

Waist circumference or waist-to-hip ratio (WHR) is an indicator of the amount of visceral adipose tissue (VAT). A greater amount of VAT is related to the metabolic syndrome, diabetes, and cardiovascular diseases (71). Cross-sectional studies indicate that WHR is higher in smokers than in nonsmokers (8, 14, 72–76). WHR is positively associated with the number of pack-years of smoking (74), and there is a dose-response relation between WHR and the number of cigarettes smoked (14, 73). In former smokers, WHR is negatively associated with the time since smoking cessation (74). In particular, smokers tend to have both a larger waist circumference and a smaller hip circumference than do nonsmokers (74, 75); these findings reflect not only greater abdominal fat deposition but also less muscle mass at hip level. The combination of a high WHR with a low BMI, which some authors consider a "paradox" (76), is more frequent in smokers than in nonsmokers.

Possible mechanisms of greater waist circumference among smokers

Waist circumference is strongly associated with VAT mass (71), and VAT is influenced by the cortisol concentration (77). Smokers were shown to have higher fasting plasma cortisol concentrations than did nonsmokers (78, 79). Higher cortisol concentrations could be a consequence of the stimulation of sympathetic nervous system activity that is induced by smoking (5, 80).

In addition, sex hormones could be involved (81). Women's VAT mass increased when their estrogen concentrations decreased and testosterone concentrations increased, typically after menopause (81). In other situations, a lack of estrogens and an excess of androgens was associated with VAT accumulation in women (82, 83), and testosterone administration in women was followed by an increase in VAT mass (84). Female smokers showed no change in absolute estrogen concentrations but had higher androgen concentrations (79, 85) and a lower bioavailability of estrogens (86) than did female nonsmokers. Testosterone concentrations may also be affected by smoking, although the data are inconsistent (87, 88). In men, VAT increased when testosterone concentrations decreased (89), and testosterone administration in middle-aged men reduced VAT by increasing lipolysis (90). Smoking may reduce testosterone concentrations in men (91). In male dogs, smoking induced a large reduction in serum testosterone concentrations (92). Overall, these results suggest that, in addition to excess cortisol, an imbalance between male and female sex hormones in females and a decrease in testosterone in males could play a role in the effect of smoking on VAT.

Smoking and insulin resistance

Insulin resistance, metabolic syndrome, and glucose intolerance are regarded as disturbances with a common background and strong interrelations (93). Smoking may directly increase insulin resistance (**Figure 4**). Insulin response to an oral glucose load was more pronounced in smokers than in nonsmokers (94). Insulin resistance was dose-dependently related to smoking (95). In healthy men, chronic smoking was associated with high plasma insulin concentrations, independent of other factors known to influence insulin sensitivity (96). In addition, the long-term use of nicotine gum was associated with hyperinsulinemia and insulin resistance (97). In nonobese men, insulin sensitivity
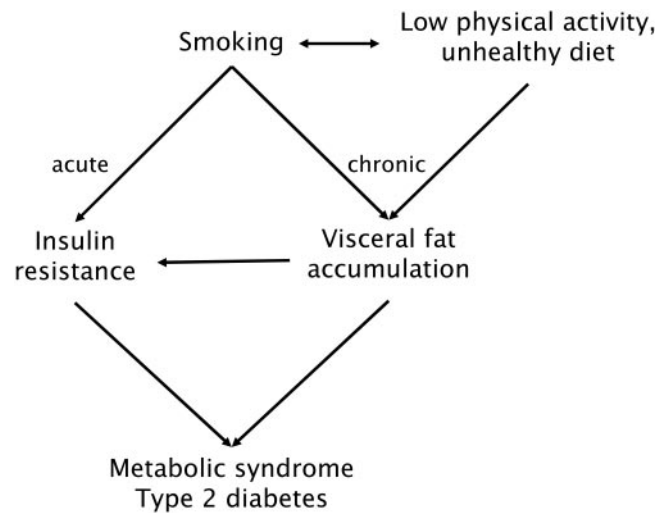

FIGURE 4. Links among smoking, insulin resistance, visceral fat accumulation, and metabolic syndrome and type 2 diabetes. The association between smoking and visceral fat accumulation may be partly explained by a confounding with the low degree of physical activity and unhealthy diet frequently encountered among smokers.

improved 8 wk after smoking cessation, despite an increase in body weight (98). Furthermore, smokers had features of insulin resistance syndrome, including low HDL cholesterol (94, 95, 99), high serum triacylglycerol (95, 99, 100), high VLDL (94), high fasting glucose (100), increased plasminogen activator inhibitor (87), and microalbuminuria (99).

Metabolic syndrome was shown to be associated with smoking. In a cross-sectional study, male smokers had higher rates of metabolic syndrome than did nonsmokers (99). Among US adolescents 12–19 y old, the prevalence of metabolic syndrome increased with tobacco exposure: it was 1.2% in adolescents not exposed to environmental tobacco smoke (ETS), 5.4% in those exposed to ETS, and 8.7% in those who smoked (101). In the Coronary Artery Risk Development in Young Adults (ie, CARDIA) prospective study (13), the 15-y incidence of glucose intolerance was 11.5% in nonsmokers not exposed to ETS, 14.4% in former smokers, 17.2% in nonsmokers exposed to ETS, and 21.8% among smokers. Adjustment for WHR did not change the association, which suggested that the greater risk of glucose intolerance in smokers was not moderated by the effect of smoking on visceral fat deposition.

Not all studies reported positive associations between smoking and glucose metabolic disturbances. In a large cross-sectional study, smoking was not associated with insulin resistance as assessed by a modified glucose tolerance test (102). In addition, a prospective study of young adults followed for 4–6 y showed that an increasing tobacco consumption was associated with a reduction in blood pressure, HDL cholesterol, body weight, and WHR and an increase in the ratio of total to HDL cholesterol—and, thus, a lower risk of metabolic syndrome. Opposite trends were found with a reduction in tobacco consumption (103).

Smoking and type 2 diabetes

The risk of type 2 diabetes is also greater in smokers than in nonsmokers (12, 104). The Health Professionals' follow-up

study showed that the relative risk of diabetes (adjusted for alcohol consumption, BMI, physical exercise, and family history of diabetes) in men who smoked 1–14, 15–24, and ≥25 cigarettes/d was 1.37 (95% CI: 0.77, 2.43), 2.38 (1.57, 3.59), and 1.94 (1.25, 3.03), respectively, compared with nonsmokers (105). In the Physicians' Health Study, a 70% greater risk of diabetes was reported for men who smoked >20 cigarettes/d than for nonsmokers (106). Similar observations were made in women (107–109).

The risk of diabetes in former smokers decreases progressively as the length of time since smoking cessation increases (105, 106, 109) and returns to normal after a few years (109). Smoking appears to aggravate insulin resistance in persons with type 2 diabetes (110) and to impair glycemic control (12). Overall, despite some conflicting observations, smoking is probably conducive to visceral fat accumulation and insulin resistance, and it increases the risk of metabolic syndrome and type 2 diabetes.

CONCLUSIONS

The pathophysiological factors involved in the association among smoking, body weight, and body fat distribution are little explored, and they remain to be elucidated. The main possible mechanisms involved, according to the information presented in this review, are outlined in **Figure 5**. On the one hand, weight gain may be limited by smoking because of increased EE and reduced food intake (Figure 5). In addition, because smoking is a strong risk factor for emaciating diseases such as cancer, lower weight among smokers may result from weight loss due to a concomitant preclinical disease (111, 112). On the other hand, especially in persons of lower socioeconomic status (11, 113), tobacco consumption is clustered with other risk behaviors known to favor weight gain (eg, poor diet and low physical activity) (Figure 5). These factors could counterbalance and even overtake the slimming effect of smoking. Weight cycling also may be involved in the association between smoking and obesity (48), which could explain why heavy smokers are more likely to be overweight or obese than are light smokers. The complexity of the associations between smoking and other behaviors conducive to weight gain strongly limits the possibility of disentangling the effect of smoking on body weight and associated conditions.

A further consequence of smoking is a hormonal imbalance that is conducive, first, to an accumulation of central fat and, then, to insulin resistance. The latter condition may represent a major link between cigarette smoking and the risk of cardiovascular disease (114). Further research is needed in that area. A testable model that integrates factors associated with smoking, body weight, and body fat and that can be used as a framework for future research is shown in Figure 5. Specifically, in view of the potential for uncontrolled confounding, serial measurements of anthropometric data (ie, weight, height, and waist circumference), fat distribution, EE, glucose metabolism, weight concern (and dieting behaviors), and health behaviors (ie, diet and physical activity) at regular intervals and the assessment of updated information on smoking habits may help elucidate the complex relation among these factors. It would be highly relevant to address the ways in which all these factors affect cardiovascular disease risk. Comparison of smoking initiators with nonsmokers may mitigate some of the major confounding issues seen with subjects who smoked throughout the study. Analyses of existing large cohort studies such as the Nurses' Health Study, the Physicians' Health Study, and the European Prospective Investigation into Cancer and Nutrition (ie, EPIC) could offer some answers.

Overall, these findings indicate that more emphasis should be placed on the risk of (central) obesity, insulin resistance, and associated conditions among smokers. In particular, whereas concerns about postcessation weight gain may deter numerous persons from quitting smoking, such persons should be made aware that smoking is not an efficient way to control body weight, does not help prevent obesity, and could favor visceral fat accumulation and increase the risk of metabolic syndrome and diabetes. Medical management and prevention programs for obesity and smoking should take into account the complex relation among these conditions.

In a broader perspective, considering that obesity is epidemic and that smoking prevalence is high and increasing in many parts of the world, especially in developing countries (115), it is clear that the co-occurrence of the 2 conditions will increase, with devastating effects on the health of the world's populations. The
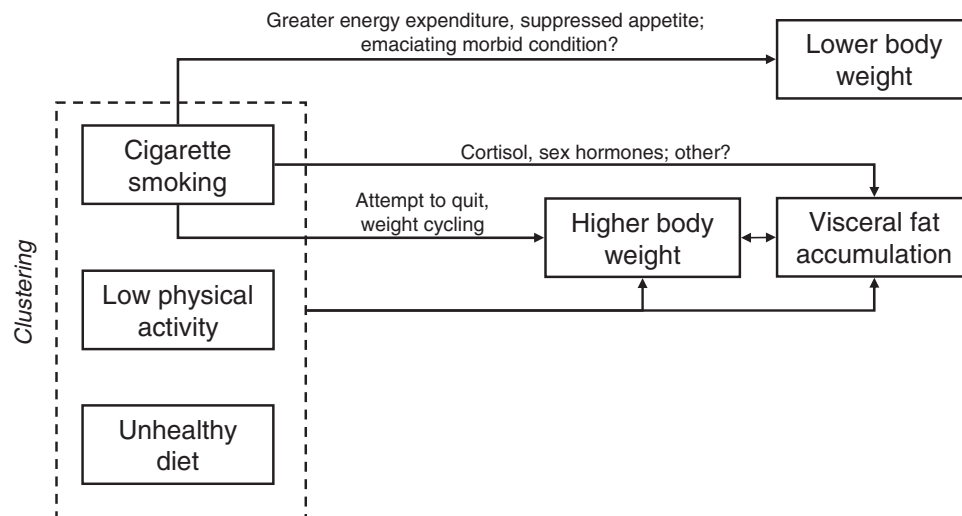

FIGURE 5. Hypothetical factors linking smoking and body weight.

prevalences of metabolic syndrome and of diabetes have paralleled the obesity epidemic and are expected to increase further (2, 116). The effect of smoking on insulin resistance and the risk of diabetes may increase these deleterious trends.

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