

## Research Article

# Unraveling the Relationship between Smoking and Weight: The Role of Sedentary Behavior

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Research has shown that current smokers have a lower mean body mass index (BMI) than never and former smokers, with former smokers having the highest mean BMI. A number of physiological mechanisms have been hypothesized to explain this pattern, but few studies have explored the possible role of behavioral factors. Using data from the cross-sectional National Health and Nutrition Examination Survey 1999–2006, this descriptive study explored the associations among smoking status, sedentary behavior, and two anthropometric measures (BMI and waist circumference (WC)). Sedentary behavior was significantly higher among current smokers compared to never and former smokers; former smokers had higher levels of sedentary behavior compared to never smokers. The association between smoking status and anthropometric outcomes was moderated by sedentary behavior, with current smokers evidencing higher BMI and WC at higher levels of sedentary behavior compared to lower levels of sedentary behavior. Results are discussed in terms of their implications for interventions, particularly with respect to postcessation weight gain.

## 1. Background

Obesity and tobacco use are the two leading causes of preventable death and disease in the United States [1]. Despite declines in smoking prevalence from a peak in the 1960s, tobacco use remains the leading cause of preventable death and disease in the USA [2]. It is estimated that 440,000 Americans die prematurely each year as a result of tobacco use and exposure [3]. Approximately 20.6% of USA adults are current smokers, defined as smoking at least 100 cigarettes during their lifetime and every day or some days currently [4]. As smoking rates have declined, obesity rates (having a body mass index (BMI) of 30 or higher) have doubled in the USA since 1980 with recent data indicating that more than 33% of USA adults are obese [5]. The rate of mortality due to overweight/obesity is estimated to account for approximately 365,000 deaths yearly [6].

Research indicates that smoking and body weight are interrelated, but the relationship is complex and not well understood. In general, cigarette smoking has an inverse association with body weight or BMI [7–9], and smoking cessation has been linked to weight gain [8, 10, 11]. Few studies have examined the relationship between smoking and body shape, specifically central adiposity. Some studies suggest that smokers have greater abdominal obesity compared to nonsmokers [12–14]. Independent of overall adiposity, having a larger waist circumference (WC), or android body shape, is associated with mortality in adults age 50 and older and metabolic disease risk [15–17]. Body shape, rather than BMI, may better explain why smokers have a higher risk of metabolic syndrome, in particular type 2 diabetes [18]. A number of biological mechanisms have been proposed to explain this relationship between

smoking and body weight including nicotine's effect on metabolism and its role as an appetite suppressor [19, 20]. Additional hypothesized mechanisms include nicotine's impact on glucose tolerance and insulin sensitivity and its role in increased lipoprotein lipase activity [21]. However, despite the clear pharmacological effects of nicotine, it may be that behavioral factors also play an important role in the relationship between smoking status and weight, particularly in the context of smoking cessation. People who smoke may be more likely to be physically inactive or engage in other poor health habits. Furthermore, the physiological effects of nicotine may mask the deleterious effects of poor diet and physical inactivity for weight.

Smoking has often been described as a "gateway behavior" as people who start smoking are likely to engage in other health risk behaviors (e.g., use of other drugs, excessive use of alcohol), and a growing body of research suggests that people who engage in one health risk behavior (e.g., smoking) are likely to engage in others (e.g., poor diet) [22–24]. However, as noted above, the links between smoking and weight are somewhat complicated and less well understood—varying as a function of smoking status (e.g., current versus former smokers) and the metabolic benefits that nicotine conveys. A better understanding of the interplay between smoking and weight may be derived from focusing on the associations between smoking status and the behaviors linked to BMI including diet, physical activity, and sedentary behaviors. To these authors' knowledge, little previous epidemiological and descriptive work has examined the associations between smoking status and weight-related behaviors. It is possible that negative weight-related health behaviors established while a person is a current smoker are masked by some of the physiological metabolic benefits of smoking. These metabolic benefits may be less pronounced at extreme levels of some weight-related health behaviors (e.g., having 4 or more hours of sedentary leisure time per day).

Understanding how these weight-related health behaviors are associated with smoking status is important for understanding the cumulative health risk that current smokers may have as a function of the multitude of risk behaviors in which they engage [25]. Further, understanding patterns of weight-related behaviors that are characteristic of current smokers may serve to inform interventions that target postcessation weight gain. To date, interventions that include weight management in the context of smoking cessation treatment have targeted increasing physical activity, decreasing calorie intake, or both [26–30]. However, a meta-analysis examining weight-related behavioral interventions to reduce postcessation weight gain concluded that combined smoking cessation and weight control treatments result in significantly higher short-term smoking abstinence rates compared to smoking treatments alone, with no statistically significant weight maintenance benefit long term (>6 months) [31]. As described, these interventions focused primarily on reducing caloric intake or increasing physical activity. None have focused on the role of sedentary behavior, which has been shown to be an independent risk factor for obesity and related health outcomes [32, 33]. Thus, more

research is needed to better understand the emergence of weight-related health behaviors in the context of current smoking. Addressing sedentary behavior may be particularly important in this population in terms of its contribution to risk for disease in current smokers and to inform future interventions targeting weight management among those who are trying to stop smoking.

Sedentary behavior is defined as any activity that does not increase energy expenditure substantially above a resting level including behaviors such as sleeping, sitting, and lying down [34]. Sedentary behavior is often assessed as leisure "screen time" such as watching TV, watching videos, or using a computer. While this is a new area for empirical research, existing studies have used self-reported sitting time as a marker of sedentary behavior [35–37]. Research has shown that the test-retest reliability for TV viewing and computer use is excellent among older adults, suggesting that in the absence of objective sedentary measurement, self-reported measures may be used as an alternative [36].

It is important to note that sedentary behavior is not synonymous with physical inactivity [37, 38]. An individual can meet guidelines for high physical activity and also have long periods of sedentary behavior during the day. Research to date has suggested that sedentary behavior (independent of time spent sleeping) is a risk factor for overweight/obesity and other health outcomes, distinct from the health benefits of physical activity [33, 39–41]. Of substantial concern, sedentary behavior appears to be widespread within the USA population. Accelerometer data from USA individuals age six and older revealed that individuals spend almost 55% of their monitored time (10-hour day) in sedentary behaviors [42]. A 2007 study offered further support for high levels of sedentary behavior within the USA adult population such that adults spent more than half (9.3 hours/day) of their waking hours in sedentary activities and the remainder in light intensity physical activity (6.4 hours/day) with less than one hour a day in moderate to vigorous physical activity [43]. Although research has indicated that current smokers are less likely to be physically active than their nonsmoking counterparts, little is understood about the interplay between smoking status and sedentary behavior [44, 45].

The primary objective of this descriptive study is to better understand the relationships among sedentary behavior, smoking status, and body weight/shape in the USA population. This study used cross-sectional population level data to describe sedentary behavior patterns including characteristics associated with sedentary behavior. We have chosen to focus our analysis on sedentary behavior, and not physical activity, given the significant findings in the literature of sedentary behavior as an independent risk factor for chronic disease and a shift in public health to target interventions on decreasing sedentary behavior [32–34, 37, 46]. We tested the relationship between smoking status and sedentary behavior and the unique contributions of each of these factors to two anthropometric outcomes, BMI and WC. The final objective of this study was to test whether the relationship between sedentary behavior and anthropometric measures (BMI and WC) varied as a function of smoking status.

## 2. Materials and Methods

**2.1. Data Collection.** The current study utilized the National Health and Nutrition Examination Survey (NHANES) continuous data from 1999 to 2006 to test the associations among Smoking status and sedentary behavior were assessed via anthropometrics (i.e., BMI and WC). The NHANES uses a complex, multistage, probability-sampling design to obtain a nationally representative sample of the USA population. Beginning in 1999, continuous NHANES datasets have been released every two years. Data for the current study came from two primary sources: a direct interview and physical examination. Smoking status and sedentary behavior were assessed via self-report within the interview portion of the survey. Body measurements were taken by trained health technicians in NHANES mobile examination centers (MECs) using standardized examination methods and calibrated equipment.

### 2.2. Measures

**Body Mass Index (BMI).** BMI was computed from weight and standing height from the physical examination. The following formula was used:  $BMI = \text{Weight (kg)}/\text{Height (m}^2\text{)}$ . Participants were categorized using the CDC cutoff points for adult obesity ( $BMI \geq 30.0$ ) versus not obese ( $BMI < 30$ ).

**Waist Circumference (WC).** WC was measured in centimeters in the physical examination and used as a continuous variable within these analyses as no clear clinical guidelines for cut points exist. Examiners located the right ilium of the pelvis, drew a horizontal line just above the uppermost lateral border, and used a tape measure, keeping it horizontal, around this point.

**Sedentary Behavior.** A survey item asked participants about their typical daily hours of sedentary behavior outside of work over the past 30 days. This measure assessed hours spent sitting and watching TV or videos; the item used in the 1999–2002 survey years also included computer use. Low sedentary behavior was defined as reporting one hour or less per day, moderate sedentary behavior was defined as two to three hours, and high sedentary behavior was defined as four or more hours of reported sedentary behavior. Prior studies have used this measure of sedentary behavior and similar categories [32, 35–37, 47].

**Smoking Status.** All participants were asked “Have you ever smoked 100 cigarettes in your entire life?” Never smokers were those who answered “no” to this question. Individuals who answered yes to this question were further asked, “Do you now smoke cigarettes?” Those who answered “yes” were classified as current smokers. Former smokers were those who answered “no” to this question.

**Covariates.** Sociodemographic characteristics including sex, age, ethnicity, and education were collected. Participants

reported on average how many times per week they eat meals that were prepared in a restaurant or not at home (never or less than weekly, one time per week, or multiple times per week). Prior studies have used out of home eating and have shown that it is positively associated with greater weight [48–50]. Survey year was also included as a categorical variable clustered by two-year increments. This was included as overweight and obesity rates have increased significantly over the survey period.

**2.3. Data Analyses.** SAS callable Sudaan was used to estimate standard errors of point estimates for the complex survey data. All data were weighted to provide representative estimates of the USA adult population. Pregnant women and those under 20 years of age were excluded from analyses. Chi-square analyses and *t*-tests were used to examine the bivariate associations between sedentary behavior, smoking, weight variables, and covariates. Logistic regression was used to examine the influence of sedentary behavior and smoking on obesity ( $BMI \geq 30$ , versus not obese) controlling for sex, age, education, race, survey year, and dining out. Linear regression analysis was used to examine the effect of sedentary behavior and smoking status on WC controlling for sex, age, education, race, survey year, and dining out. Moderation was examined by including interaction terms for sedentary behavior by smoking status in these models to determine if sedentary behavior’s effect on weight outcomes differed by smoking status.

## 3. Results

Descriptive statistics for sedentary behavior are reported in Table 1. Over 20% of the population reported four or more hours of leisure time sedentary behavior per day over the last 30 days. BMI and sedentary behavior were significantly related such that those with less sedentary behavior had a significantly lower BMI ( $F(2) = 100.44, P < .0001$ ). WC and sedentary behavior were significantly related such that those with less sedentary behavior had a significantly smaller WC ( $F = 173.30, P < .0001$ ). Almost 30% of current smokers reported high sedentary behavior compared to only about 20% of never smokers. Sedentary behavior was lower in never smokers compared to former smokers ( $t = -8.88, P < .0001$ ); and lower in former smokers compared to current smokers ( $t = -3.89, P = .0003$ ). Thus, current smokers evidenced the highest levels of sedentary behavior.

Mean BMI for all smoking status categories fell within the overweight category ( $25.0 \geq BMI \leq 30.0$ ). BMI was greater in former smokers ( $M = 28.81, SE = .15$ ) compared to never smokers ( $M = 28.40, SE = .33; t = -2.85, P = .0060$ ) and greater in never smokers compared to current smokers ( $M = 27.18, SE = .12; t = 7.82, P < .0001$ ). Similarly, WC was greater in former smokers ( $M = 99.95, SE = .37$ ) compared to never smokers ( $M = 95.92, SE = .33; t = -10.83, P < .0001$ ) and greater in never smokers compared to current smokers ( $M = 94.86, SE = .32; t = 2.59, P = .0121$ ). Thus, current smokers had the lowest BMI and WC, whereas former smokers had the highest.

TABLE 1: Descriptive statistics for sedentary behavior.

Weighted % (unweighted N )	Sedentary behavior			Total (row)
	Low ( $\leq 1$ hour)	Moderate (2-3 hours)	High ( $\geq 4$ hours)	
Total	31.42 (5172)	45.39 (7873)	23.19 (4594)	100 (17639)
Smoking status				
Never	35.79 (2962)	44.85 (3984)	19.35 (1958)	49.94 (8904)
Former	28.65 (1214)	46.64 (2190)	24.71 (1320)	25.27 (4724)
Current	25.44 (988)	45.29 (1691)	29.27 (1308)	24.78 (3987)
		Chi2 = 48.42, <i>df</i> = 4, <i>P</i> < .0001		
BMI				
Not obese	34.03 (3790)	45.20 (5404)	20.77 (2858)	69.07 (12065)
Obese	25.58 (1382)	45.82 (2469)	28.60 (1736)	30.93 (5592)
		Chi2 = 73.47, <i>df</i> = 2, <i>P</i> < .0001		
Waist circumference				
Smaller	35.56 (2919)	45.15 (3970)	19.28 (2007)	52.04 (8905)
Larger	26.92 (2253)	45.65 (3903)	27.43 (2587)	47.96 (8752)
		Chi2 = 85.16, <i>df</i> = 2, <i>P</i> < .0001		
Sex				
Male	29.53 (2520)	47.46 (4148)	23.01 (2346)	49.52 (9019)
Female	33.27 (2652)	43.35 (3725)	23.37 (2248)	50.48 (8638)
		Chi2 = 13.08, <i>df</i> = 2, <i>P</i> < .0001		
Race				
White	31.58 (2550)	46.28 (4074)	22.14 (2244)	71.95 (8879)
Black	24.26 (839)	39.60 (1433)	36.14 (1349)	10.87 (3624)
Mexican American	36.29 (1338)	47.21 (1773)	16.50 (692)	7.28 (3805)
Other	34.50 (445)	43.96 (593)	21.54 (309)	9.89 (1349)
		Chi2 = 33.06, <i>df</i> = 6, <i>P</i> < .0001		
Age (years)				
20–40	34.99 (2027)	44.43 (2637)	20.59 (1314)	39.80 (5979)
41–60	34.50 (1849)	45.65 (2487)	19.85 (1228)	38.16 (5566)
61+	19.62 (1296)	46.67 (2749)	33.70 (2052)	22.05 (6112)
		Chi2 = 49.14, <i>df</i> = 4, <i>P</i> < .0001		
Education				
< HS	26.80 (1601)	42.50 (2358)	30.69 (1651)	20.00 (5619)
HS	26.19 (1053)	45.62 (1871)	28.19 (1290)	25.96 (4216)
Associates or some college	31.63 (1310)	46.01 (2132)	22.35 (1132)	29.86 (4578)
$\geq$ College	40.57 (1196)	46.83 (1498)	12.59 (511)	24.18 (3206)
		Chi2 = 43.96, <i>df</i> = 6, <i>P</i> < .0001		
Survey year				
1999-2000	27.73 (1179)	47.91 (1893)	24.36 (1045)	22.65 (4121)
2001-2002	30.38 (1291)	44.02 (2060)	25.60 (1301)	26.05 (4661)
2003-2004	33.59 (1340)	44.35 (1968)	22.07 (1167)	25.39 (4475)
2005-2006	33.57 (1362)	45.58 (1952)	20.86 (1081)	25.90 (4400)
		Chi2 = 5.65, <i>df</i> = 6, <i>P</i> = .0001		
Dining out (per week)				
<1 time or never	30.05 (1443)	40.17 (2018)	29.78 (1561)	21.84 (5031)
1 time	33.22 (1151)	44.91 (1730)	21.87 (907)	20.53 (3790)
$\geq 2$ times	31.30 (2578)	47.53 (4125)	21.17 (2126)	57.63 (8835)
		Chi2 = 25.51, <i>df</i> = 4, <i>P</i> < .0001		

TABLE 2: Logistic regression analyses predicting obesity (BMI).

	Odds ratio (confidence interval)	Beta (confidence interval)	P value
Sedentary behavior			
Low ( $\leq 1$ hour)	1.00	0	—
Moderate (2-3 hours)	1.34 (1.22–1.48)	0.30 (.20–.39)	<.0001
High ( $\geq 4$ hours)	1.78 (1.59–2.01)	0.58 (.46–.70)	<.0001
Smoking status			
Never	1.00	0	—
Former	1.06 (0.96–1.18)	0.06 (–.05–.16)	.2659
Current	0.69 (0.61–0.77)	–.38 (–.49– .26)	<.0001
Dining out (per week)			
<1 time or never	1.00	0	—
1 time	1.11 (0.97–1.27)	0.10 (–.03–.24)	.1284
$\geq 2$ times	1.32 (1.19–1.47)	0.28 (.18–.38)	<.0001
Sex			
Male	1.00	0	—
Female	1.23 (1.14–1.34)	0.21 (.13–.29)	<.0001
Race			
Non-Hispanic white	1.00	0	—
Non-Hispanic black	1.52 (1.40–1.65)	0.42 (.34–.50)	<.0001
Mexican American	1.10 (0.96–1.27)	0.10 (–.04–.24)	.1752
Other	0.80 (0.68–0.94)	–0.22 (–.38– .06)	.0071
Age	—	0	.3139
Education			
< HS	1.44 (1.23–1.69)	0.37 (.20–.53)	<.0001
HS	1.54 (1.34–1.77)	0.43 (.30–.57)	<.0001
Associates/some college	1.43 (1.26–1.63)	0.36 (.23–.49)	<.0001
$\geq$ College	1.00	0	—
Survey year			
1999-2000	1.00	0	—
2001-2002	0.95 (0.80–1.13)	–0.05 (–.23–.12)	.5389
2003-2004	1.11 (0.94–1.31)	0.10 (–.06–.27)	.2022
2005-2006	1.20 (1.00–1.45)	0.19 (–.00–.37)	.0512

Results from a logistic regression analysis predicting obesity are presented in Table 2. Compared to individuals with low levels of sedentary behavior ( $\leq 1$  hour/day), those reporting moderate sedentary behavior were 1.34 times more likely to be obese, and those with high sedentary behavior levels were 1.78 times more likely to be obese. The probability of current smokers being obese was 0.69 times that of never smokers. Individuals who reported dining out two or more times per week were 1.32 times more likely to be obese compared to those who dined out less than one time a week. Participants who were male, in the “other” race category, and had greater education had a lower likelihood of being obese. There was no statistically significant influence of survey year; however, a trend for greater obesity in more recent years was noted.

Results from a linear regression analysis predicting WC are presented in Table 3. Compared to individuals with low levels of sedentary behavior ( $\leq 1$  hour/day), those with moderate sedentary behavior had a WC 2.24 cm larger ( $P < .0001$ ), and those with high sedentary behavior had a WC

5.52 cm larger ( $P < .0001$ ) controlling for all other variables in the model. Current smokers had a 2.42 cm smaller WC compared to never smokers ( $P < .0001$ ), whereas former smokers had a 1.06 cm larger WC ( $P = .0042$ ). Similar to BMI, in the multivariate model, those in the “other” race category and having higher education had lower odds of a larger WC. However, females were less likely to have a larger WC than males. Greater age was associated with a larger WC. The two most recent survey years showed a statistically significantly higher WC compared to the first survey year.

To test the moderating role of smoking status in the association between sedentary behavior and weight outcomes, an interaction term was included in each of the two models reported above (see Table 4). The results from the logistic regression analysis predicting obesity showed that smoking status moderated the relationship between sedentary behavior and BMI ( $F(4) = 4.13, P = .0051$ ). In the adjusted model, low sedentary former and moderate and high sedentary never and former had significant increased odds of obesity compared to low sedentary never smokers. Highly sedentary

TABLE 3: Linear regression analyses predicting waist circumference.

	Beta coefficient (confidence interval)	P value
<b>Sedentary behavior</b>		
Low ( $\leq 1$ hour)	0	—
Moderate (2-3 hours)	2.24 (1.60–2.88)	<.0001
High ( $\geq 4$ hours)	5.52 (4.66–6.39)	<.0001
<b>Smoking status</b>		
Never	0	—
Former	1.06 (.35–1.78)	.0042
Current	-2.42 (-3.19– -1.64)	<.0001
<b>Dining out (per week)</b>		
<1 time or never	0	—
1 time	0.94 (.06–1.82)	.0365
$\geq 2$ times	2.05 (1.40–2.69)	<.0001
<b>Sex</b>		
Male	0	—
Female	-6.80 (-7.41– -6.18)	<.0001
<b>Race</b>		
Non-Hispanic white	0	—
Non-Hispanic black	0.83 (.10–1.56)	.0257
Mexican American	-0.11 (-1.14–.92)	.8355
Other	-2.46 (-3.72– -1.21)	.0002
Age	0.17 (.16–.19)	<.0001
<b>Education</b>		
< HS	2.95 (1.99–3.92)	<.0001
HS	3.25 (2.42–4.08)	<.0001
Associates/some college	2.80 (2.03–3.57)	<.0001
$\geq$ College	0	—
<b>Survey year</b>		
1999-2000	0	—
2001-2002	0.55 (-.69–1.80)	.3771
2003-2004	1.94 (.68–3.21)	.0031
2005-2006	2.08 (.54–3.62)	.0090

current smokers were at marginally increased odds of obesity compared to low sedentary never smokers ( $P = .0876$ ). Figure 1 shows mean BMI as a function of smoking status at varying levels of sedentary behavior. As shown, there were no statistically significant differences in mean BMI between never and former smokers as a function of sedentary behavior. However, there were statistically significant differences in mean BMI between never and current smokers as a function of sedentary behaviors. As shown in Figure 1, at moderate and high levels of sedentary behavior, mean BMI differed between never and current smokers such that current smokers had lower BMI ( $t = 1.97, P < .0001$ ;  $t = 8.16, P < .0001$ , resp.; Cohen's  $d = 11.97, r = .99$ ). Those with the highest levels of sedentary behavior in all smoking status categories had the highest mean BMI. Further, it is worth noting that, as shown in Figure 1, although BMI was relatively similar for current smokers at low and moderate

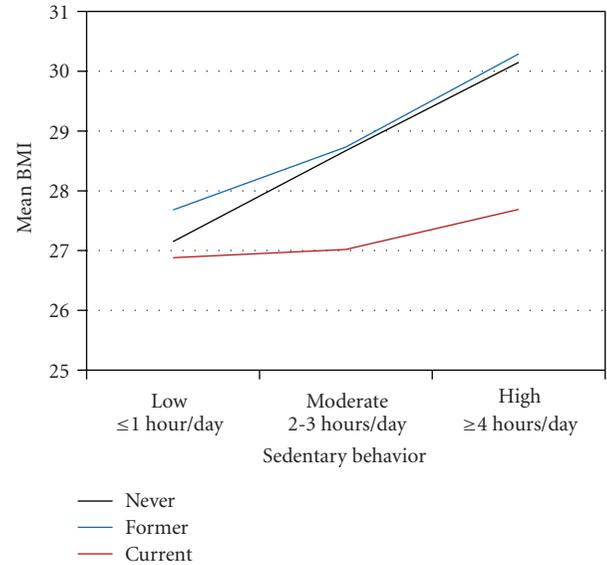


FIGURE 1: The interactive effect of SB and smoking status on obesity.

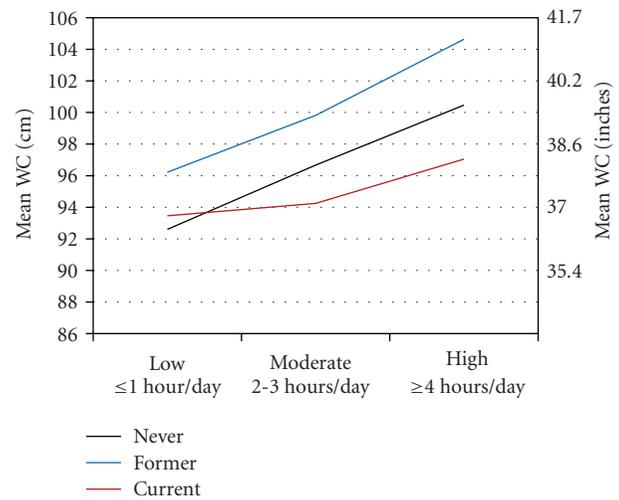


FIGURE 2: The interactive effect of SB and smoking status on WC.

levels of sedentary behavior, BMI was notably higher for smokers at high levels of sedentary behavior.

The results from the linear regression (see Table 5) analysis predicting WC demonstrated that smoking status also moderated the association between sedentary behavior and WC ( $F(4) = 4.73, P = .0022$ ). In the adjusted model, low sedentary former smokers, moderately sedentary never and former smokers, and highly sedentary never, former, and current smokers had significantly larger WC compared to low sedentary never smokers. Figure 2 shows the WC means as a function of smoking status at varying levels of sedentary behavior. As shown, at low levels of sedentary behavior, current smokers had a slightly larger WC than never smokers although this difference was not statistically significant ( $t = -1.48, P = .1455$ ). Former smokers had a significantly larger WC compared to current smokers ( $t = -3.89, P = .0003$ ) at low levels of sedentary behavior. As was the case with BMI,

TABLE 4: Analyses predicting body mass index (BMI) including interaction terms.

	Odds ratio (confidence interval)	Beta coefficient (confidence interval)	P value
Low sedentary never smoker	1.00	—	—
Low sedentary former smoker	1.19 (1.00–1.41)	0.17 (.00–.34)	.0490
Low sedentary current smoker	.93 (0.77–1.13)	–0.07 (–.26–.12)	.4642
Moderate sedentary never smoker	1.52 (1.34–1.74)	0.42 (.29–.55)	<.0001
Moderate sedentary former smoker	1.46 (1.26–1.70)	0.38 (.23–.53)	<.0001
Moderate sedentary current smoker	.98 (0.85–1.14)	–.02 (–.17–.13)	.8312
High sedentary never smoker	2.01 (1.72–2.36)	0.70 (.54–.86)	<.0001
High sedentary former smoker	2.23 (1.86–2.67)	0.80 (.62–.98)	<.0001
High sedentary current smoker	1.18 (0.98–1.42)	0.16 (–.02–.35)	.0876
Dining out (per week)			
<1 time or Never	1.00	0	—
1 time	1.11 (0.97–1.27)	0.10 (–.03–.24)	.1368
≥2 times	1.32 (1.19–1.46)	0.28 (.17–.38)	<.0001
Sex			
Male	1.00	0	—
Female	1.24 (1.14–1.34)	0.21 (.13–.29)	<.0001
Race			
Non-Hispanic white	1.00	0	—
Non-Hispanic black	1.53 (1.40–1.66)	0.42 (.34–.51)	<.0001
Mexican American	1.10 (0.96–1.27)	0.10 (–.05–.24)	.1782
Other	0.80 (0.68–0.94)	–0.22 (–.38– –.06)	.0073
Age			
	1.00	0	.3633
Education			
< HS	1.43 (1.22–1.69)	0.36 (.20–.52)	<.0001
HS	1.53 (1.34–1.76)	0.43 (.29–.57)	<.0001
Associates or some college	1.42 (1.24–1.62)	0.35 (.22–.48)	<.0001
≥ College	1.00	0	—
Survey year			
1999-2000	1.00	0	—
2001-2002	0.95 (0.80–1.13)	–0.05 (–.23–.12)	.5442
2003-2004	1.11 (0.95–1.31)	0.11 (–.06–.27)	.1977
2005-2006	1.21 (1.00–1.46)	0.19 (.00–.38)	.0485

the most notable difference in WC among current smokers was at higher levels of sedentary behavior.

#### 4. Discussion

These analyses from a nationally representative, cross-sectional dataset revealed several interesting findings regarding the interplay between smoking status, sedentary behavior, and indicators of weight status (i.e., BMI, WC). Smoking status and sedentary behavior were associated such that current smokers reported the highest levels of sedentary behavior, followed by former smokers and never smokers. Furthermore, this study revealed that smoking status moderated the relationship between sedentary behavior and weight-related outcomes in the USA population. In other words, at varying levels of smoking status, sedentary behavior had a different effect on BMI and WC. To the best of our knowledge, this is the first study to show the

interactive effect of these modifiable risk behaviors that influence weight-related outcomes. In addition to using a measure of BMI, WC was also examined as an outcome variable. Importantly, although both BMI and WC were lower among current smokers compared to former and never smokers at almost all levels of sedentary behavior, the pattern of findings suggested that both BMI and WC were higher among current smokers at high levels of sedentary behavior. In addition, other factors associated with sedentary behavior including demographic characteristics and dining out were examined, highlighting important characteristics at the population level that will be critical to pursue in future research.

At low levels of sedentary behavior, current smokers and never smokers did not have significantly different BMI. However, at moderate and high levels of sedentary behavior, it appeared that current smokers had a significantly lower BMI compared to never smokers in those sedentary behavior categories. This is consistent with previous research.

TABLE 5: Analyses predicting waist circumference including interaction terms.

	Beta coefficient (confidence interval)	P value
Low sedentary never smoker	—	—
Low sedentary former smoker	1.30 (0.04–2.56)	.0432
Low sedentary current smoker	−0.47 (−1.52–0.59)	.3811
Moderate sedentary never smoker	2.88 (2.02–3.75)	<.0001
Moderate sedentary former smoker	3.58 (2.50–4.65)	<.0001
Moderate sedentary current smoker	0.07 (−.95–1.09)	.8910
High sedentary never smoker	6.35 (5.14–7.56)	<.0001
High sedentary former smoker	7.66 (6.27–9.05)	<.0001
High sedentary current smoker	2.55 (1.33–3.76)	<.0001
Dining out (per week)		
<1 time or never	0	—
1 time	.92 (.04–1.80)	.0403
≥2 times	2.01 (1.36–2.65)	<.0001
Sex		
Male	0	—
Female	−6.79 (−7.40–6.18)	<.0001
Race		
Non-Hispanic white	0	—
Non-Hispanic black	.82 (.11–1.54)	.0252
Mexican American	−.12 (−1.15–.91)	.8147
Other	−2.45 (−3.70–1.19)	.0002
Age	.17 (.15–.19)	<.0001
Education		
< HS	2.92 (1.96–3.88)	<.0001
HS	3.19 (2.37–4.01)	<.0001
Associates or some college	2.74 (1.97–3.50)	<.0001
≥ College	0	—
Survey year		
1999–2000	0	—
2001–2002	.57 (−.68–1.81)	.3656
2003–2004	1.94 (.69–3.20)	.0030
2005–2006	2.08 (.54–3.63)	.0091

Similarly, at low levels of sedentary behavior, smokers and never smokers did not have significantly different WC, yet again at moderate and high levels of sedentary behavior current smokers had a lower WC than never smokers. Prior research has demonstrated that nicotine has a number of physiological effects including increasing metabolism [19–21]. While the current study did not directly assess the

impact of nicotine, it may be that there was a metabolic benefit of nicotine among current smokers at low and moderate levels of sedentary behavior as demonstrated on both the BMI and WC outcomes. That is, at low and moderate levels of sedentary behavior, nicotine may have buffered weight gain which would have occurred in current smokers and is demonstrated in former smokers.

Although current smokers were most sedentary, we also found that former smokers were more sedentary than never smokers. This suggests that a pattern of sedentary behavior may become established while people are current smokers. This pattern may continue after cessation for many former smokers. This has several important implications for both current and former smokers. First, it is possible that the physiological effects of nicotine mask the negative effects of sedentary behavior on weight status. However, when nicotine is removed during cessation, the impact of sedentary behavior on weight emerges in former smokers. Sedentary behavior may thus function as a potential mechanism of postcessation weight gain which could be directly targeted within an intervention.

Former smokers were also more likely to be obese and had a larger WC compared to never smokers in the bivariate analyses. When examining these weight differences in the context of sedentary behavior, never and former smokers had a similar BMI at varying levels of sedentary behavior. Conversely, never and former smokers had significantly different WC at all levels of sedentary behavior. These differences in body shape suggest that while former smokers may not be at risk for greater adiposity, they appear to be at risk for increased central adiposity compared to never smokers. Former smokers' higher risk for central adiposity may explain why this group is particularly at risk for weight-related health challenges (e.g., Type 2 diabetes). Both smoking cessation and sedentary behavior are associated with weight gain and metabolic syndrome [10, 51, 52]. Epidemiologic research has shown an association between sedentary behavior and chronic disease risk factors including central adiposity and elevated blood glucose and insulin [32, 53–56]. The results of the current study may help to explain recent findings that smokers who recently quit smoking were at increased risk of type 2 diabetes [52]. While we saw no difference between never and former smokers in terms of BMI in the model with the interaction term, we did see significant differences at varying levels of sedentary behavior between these two groups with regards to WC.

This research has important implications for smoking cessation interventions. The Clinical Practice Guideline for smoking cessation includes potential ways of addressing weight gain concerns when smokers make a quit attempt [57]. These include (1) explaining that the health risks of weight gain are small when compared to the risks of continued smoking, (2) recommending physical activities and healthy diet to control weight, and (3) suggesting that patients concentrate primarily on smoking cessation, not weight control, until ex-smokers are confident that they will not start smoking again [57]. The findings from the current study suggest that reducing time spent in sedentary behavior may be a potential intervention strategy and warrants further

research. This may be a valuable and important public health message for the population as a whole, but in particular for smokers who are attempting to quit smoking.

The importance of these findings must be recognized in light of several limitations. The measurements of smoking status and sedentary behavior were self-reported. A study comparing self-reported smoking data to measurements of serum cotinine (a metabolite of nicotine) suggested that self-reported smoking was generally quite consistent with measured nicotine exposures [58]. It is likely that sedentary behavior was underreported and with a more refined self-report measure or objective sedentary behavior assessment, we may show stronger associations with smoking and weight-related outcomes. We attempted to include a measure of work-related sedentary behavior in follow-up analyses. However, limitations in the way this item was worded in the continuous NHANES survey (e.g., with a strong emphasis on lifting rather than general movement during work) led us to focus on leisure time sedentary behavior for this study. Importantly, we were able to see associations of this self-reported sedentary behavior with smoking and weight-related outcomes. Furthermore, leisure time sedentary behavior (rather than work place sedentary behavior) may be a more probable intervention point for public health practitioners. While we have proposed pathways for how these relationships may unfold, this data is cross-sectional in nature, and directionality must be tested in longitudinal studies. Future studies should also look specifically at how these risk factors and behaviors predict disease outcomes.

This study is the first nationally representative study to examine the relationships between sedentary behavior, smoking status, and weight-related outcomes. Our outcome measures, BMI and WC, were objectively assessed. Furthermore, the current study specifically examined the role of sedentary behavior, going beyond previous research that has focused on the links between smoking and physical activity [44, 45].

Future studies should examine more refined measures of smoking status, as prior studies suggest that there may be variation in weight outcomes depending on number of years smoking and amount smoked [59, 60]. Exploring sedentary behavior in the context of other factors that influence postcessation weight gain will be important for the development of weight management interventions in the context of smoking cessation. It will also be important to explore other co-occurring health behaviors including diet, physical activity, and alcohol consumption.

## 5. Conclusions

Both smoking and weight status have been identified as important public health concerns, contributing to a substantial percentage of preventable mortality in the USA. Over the past 20 years, a good deal of public policy has been devoted to reducing smoking in the general population. Obesity rates have soared over this same time period, and emerging evidence suggests that postcessation weight gain

may be greater than previously thought, contributing to important health risks for former smokers such as diabetes, cardiovascular disease, and metabolic syndrome. Although it is likely that there are important physiological mechanisms involved in postcessation weight gain, behavioral factors may also be important contributors. The findings presented here speak to the role of sedentary behavior in the association between smoking status and weight status. Patterns of sedentary behavior may be established while people are current smokers. This has important implications for smoking cessation interventions which need to take into account both the potential health risks of postcessation weight gain and the psychological barrier that weight gain may pose to cessation efforts. Targeting sedentary behavior may be one mechanism through which these risks to cessation may be addressed.

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