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Examining substance use and affective processes as multivariate risk factors associated with overweight body mass among treatment-seeking smokers

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Cigarette smoking and obesity are two major public health problems. However, factors related to the underlying risk for being overweight are not well established. Certain demographic, smoking, and psychological factors have been linked to overweight/obese body mass. The current study examined a multivariate risk model, stratified by gender, in order to better explicate the nature of overweight body mass among daily smokers. In a sample of treatment-seeking smokers (n = 395), among males and females, (1) older age, (2) stronger expectancies about the weight/appetite control effects of smoking, (3) greater smoking-based inflexibility/avoidance due to smoking-related sensations, and (4) less problematic alcohol use, were associated with being overweight. Additionally, among males, having a tobacco-related medical problem and higher tolerance for physical discomfort aided in the discriminant function model for classifying smokers as overweight. Together, numerous cognitive–affective vulnerabilities and smoking processes may be targetable and potentially inform weight-related prevention programs among smokers.

Keywords: cigarette smoking; overweight; behavioral health; nicotine dependence

Background

Smoking remains one of the most pressing public health concerns in the USA (US Department of Health and Human Services, 2014) as one in five adults still smoke (18.1%; Centers for Disease Control and Prevention [CDCP], 2014). Adult obesity is also a costly public health problem (prevalence of 34.9% in adults; Ogden, Carroll, Kit, & Flegal, 2014) that is associated with increased risk for various medical problems (heart disease, stroke, type 2 diabetes, certain cancers). The *combined impact* of smoking and obesity is associated with a three- to five-fold increased risk of mortality relative to normal weight individuals who have never smoked (Freedman et al., 2006; Whitlock et al., 2009). Although it is well documented that multiple unhealthy behaviors frequently co-occur (Chiolero, Wietlisbach, Ruffieux, Paccaud, & Cornuz, 2006; Fine, Philogene, Gramling, Coups, & Sinha, 2004; Pronk et al., 2004), the nature of the associations between smoking and obesity are presently unclear (Chiolero, Faeh, Paccaud, & Cornuz, 2008).

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Despite work that has found lower body mass status and increased dieting activity among smokers relative to nonsmokers (Chiolero et al., 2006; Stice & Martinez, 2005; Strauss & Mir, 2001; Williamson et al., 1991), it is estimated that about 20% of smokers are overweight (Gregg et al., 2005). Although the metabolic advantage of smoking is only slight (Perkins, 1993), smokers (particularly women) report stronger preferences for thin body shapes and greater body dissatisfaction relative to nonsmoking women (Pomerleau & Saules, 2007), and concerns about weight gain are often cited as barriers to cessation (Perkins, Levine, Marcus, & Shiffman, 1997; Pomerleau, Zucker, & Stewart, 2001; Saules, Tate, & Pomerlaeu, 2008). Importantly, *heavier smoking* is associated with increased risk of obesity (Chiolero, Jacot-Sadowski, Faeh, Paccaud, & Cornuz, 2007), even among former (male) smokers (John, Hanke, Rumpf, & Thyrian, 2005). Smokers who are interested in treatment for smoking cessation are more apt to be overweight/obese than those not interested in quitting smoking (LaRowe, Piper, Schlam, Fiore, & Baker, 2009). Some work has found that high alcohol and coffee intake and low physical activity are associated with an increased likelihood of heavier smoking (Baumert et al., 2010). Indeed, many smokers may be at risk for obesity due to the "coupling of problem health behaviors" with smoking (e.g. physical inactivity, lower intake of fruits and vegetables; Chiolero et al., 2007).

It is also possible that the presence of anxiety and mood symptoms or disorders are related to the smoking-obesity link given higher base rates of affective psychopathology among smokers (e.g. CDCP, 2013; Lasser et al., 2000) and obese adults (e.g. Brumpton, Langhammer, Romundstad, Chen, & Mai, 2013; Gariepy, Nitka, & Schmitz, 2010). Underlying emotion-regulatory dysfunction (e.g. low discomfort tolerance, difficulties with emotion regulation) are also implicated in the development and maintenance of problematic eating behavior and obesity (Forman, Butryn, Hoffman, & Herbert, 2009; Gianini, White, & Masheb, 2013; Lillis & Hayes, 2008), physical inactivity (Isasi, Ostrovsky, & Wills, 2013), and cigarette smoking (e.g. Brandon et al., 2003; Brown, Lejuez, Kahler, & Strong, 2002; Leyro, Zvolensky, & Bernstein, 2010; Zvolensky, Feldner, Eifert, & Brown, 2001). Thus, these cognitive–affective processes may inform the linkages between smoking and obesity (Gifford & Lillis, 2009).

Given that there are likely a host of factors that contribute to body mass index (BMI) among smokers, the current study aimed to test a *multivariate* "risk profile". It was hypothesized that the following factors would be associated with an overweight BMI status: older age, higher nicotine dependence, greater motivation to quit smoking, problematic alcohol use, past-month cannabis use, current depressive/anxiety disorders, holding stronger expectancies about the weight/appetite control properties of smoking, tending to respond inflexibly to smoking-related distress, and greater discomfort intolerance and emotion dysregulation.

Method

Participants and procedures

Participants were adult daily smokers recruited for potential inclusion in a randomized controlled trial examining the efficacy of two smoking cessation interventions (clinicaltrials.gov #NCT01753141). Participants were between ages 18 and 65 who reported smoking ≥ 8 cigarettes per day, with motivation to quit rated as at least 5 or higher on a 10-point scale. Individuals responding to study advertisements were scheduled for an in-person, baseline evaluation. After providing written informed consent, participants were interviewed via diagnostic assessment and completed computerized self-report

questionnaires (detailed below). The current study is based on secondary analyses of a sub-sample of people who provided complete data during the baseline session, which took place prior to the commencement of the intervention. A total of 574 participants provided baseline data; 179 cases were not included in analyses due to low smoking rate (cigarettes per day < 8) or incomplete data, yielding a sample of 395 cases for the present analyses (46.6% female; M_{age} = 37.5, SD = 13.48; 88.1% non-Hispanic White; 72.5% completed at least some college education).

The average daily smoking rate was 18.7 cigarettes (SD = 9.40). Participants reported smoking for 19.5 years (SD = 13.31) and initiated smoking at 14.7 years of age (SD = 3.40). The average BMI for the sample was 26.7 (SD = 5.91; range 15.2–50.5). Of the sample, 53.7% of the sample was classified as overweight (n = 212; BMI ≥ 25).

Measures

A *demographics form* was used to collect gender, age, race/ethnicity, and educational background. The *Structured Clinical Interview-Non-Patient Version for DSM-IV* (SCID-I/NP; First, Spitzer, Gibbon, & Williams, 2007) was administered by trained research assistants or doctoral-level staff to assess the presence of past year anxiety/depressive disorders. A *medical history form* was used to collect height and weight, and to assess current and lifetime physical illness. BMI (kg/m^2) was calculated from self-reported weight and height, which was then dichotomized to classify normal/underweight smokers (BMI < 25) and overweight smokers (BMI ≥ 25); per the World Health Organization guidelines (WHO, 1995). To index the presence of physical illness (reported history of heart problems, hypertension, respiratory disease, and/or asthma), a dichotomous variable was coded (0 = No history, 1 = Positive history).

The *Fagerström Test for Nicotine Dependence* (FTND; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991) is a six-item self-report scale that was used to assess gradations in tobacco dependence. Scores range from 0 to 10, with higher scores reflecting high levels of physiological dependence on nicotine. The *Motivational Aspects of Smoking Cessation Questionnaire* (MASC; Rundmo, Smedslund, & Gotestam, 1997) is a 10-item questionnaire used to index aspects of motivation to quit smoking, with items rated on a five-point Likert scale (0 = *No, not at all motivated* to 4 = *Yes, very motivated*).

Alcohol use was assessed using the *Alcohol Use Disorder Identification Test* (AUDIT; Babor, de la Fuente, Saunders, & Grant, 1992), a 10-item self-report measure that indexes the presence of problematic alcohol use; higher scores reflect more problematic alcohol use. To assess cannabis use in the past 30 days, a single item from the *Marijuana Smoking History Questionnaire* (MSHQ; Bonn-Miller & Zvolensky, 2009) was used: "Please rate your marijuana use in the past 30 days" (Responses range from 0 = *No use*, 4 = *Once a week*, to 8 = *More than once a day*); dichotomously coded to reflect a cannabis use status variable (0 = No use; 1 = Past 30-day use).

The *Avoidance and Inflexibility Scale* (AIS; Gifford et al., 2004) is a 13-item self-report measure that assesses one's tendency to avoid smoking-related distress, including distressing thoughts/feeling related to smoking and internal sensations. Items are rated on a five-point Likert scale (1 = *Not at all* to 5 = *Very much*). *The Smoking Consequences Questionnaire* (SCQ; Brandon & Baker, 1991) is a 50-item self-report measure used to asses smoking expectancies on a 10-point scale of occurrence likelihood (0 = *Completely unlikely* to 9 = *Completely likely*). The SCQ yields four subscales: negative reinforcement/negative affect reduction, negative consequences, appetite-weight control, and positive reinforcement/sensory satisfaction.

The Discomfort Intolerance Scale (DIS; Schmidt, Richey, & Fitzpatrick, 2006) is a five-item self-report measure of one's intolerance of physically relevant discomfort. Items are rated on a seven-point Likert scale (range 0–6), with higher ratings/total scores indicating higher levels of discomfort intolerance. The *Difficulties with Emotion Regulation Scale* (DERS; Gratz & Roemer, 2004) is a 36-item self-report measure that assesses, on a five-point Likert-type scale (1 = *Almost never* to 5 = *Almost always*), the degree to which respondents experience dysregulated emotional states. Items can be summed to produce a total score, with higher scores reflecting greater dysregulation.

Results

Analyses were conducted stratified by gender to account for differences in BMI for males and females. Descriptive statistics were conducted to characterize smokers in terms of the tested multivariate risk factors.[1] Then, stepwise discriminant function analyses were utilized to examine the relative contribution of risk factors in terms of their association with BMI status (either overweight or normal/underweight status). A minimization of Wilks' lambda selection rule was used to only retain only significant model predictors. The leave-one-out cross-validation procedure was used to test the reliability of the discriminant function. Box's M indicated that the assumptions of equality of covariance matrices were met. Descriptive results and standardized discriminant functions are reported in Table 1.

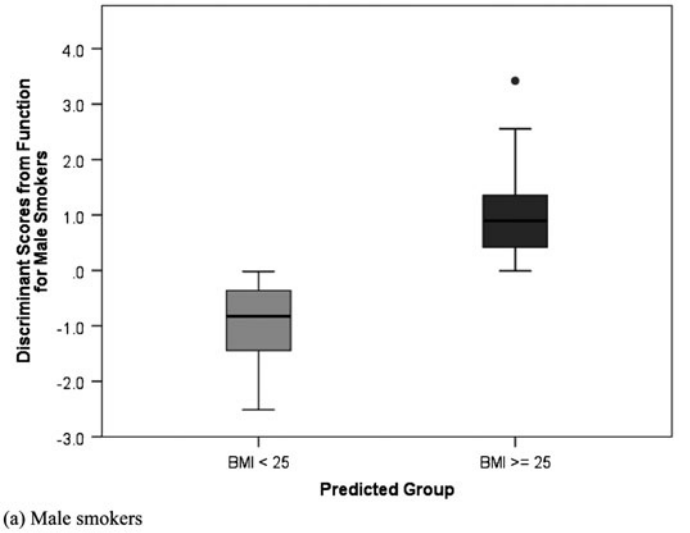
Results for male smokers

Among male smokers ($n = 211$), 51.2% were overweight. Of the 11 tested predictors, 6 were statistically relevant to the discriminant function (see Table 1). These variables significantly differentiated BMI status in male smokers (Wilks' $\Lambda = .768$, $x^2[6] = 54.387$, $p < .001$; eigenvalue = .302; canonical correlation = .482). The centroid for the overweight BMI group occurred at .534, and at −.560 for the normal/underweight BMI group (negative sign reflects the dummy coded weight status variable). The unstandardized coefficient adjusted all cases to an overweight status; cases were retained in the overweight group by a case having an older age, a tobacco-related medical problem, higher inflexibility/avoidance to internal smoking sensations and weight/appetite control smoking expectancies. Additionally, to remain classified as an overweight male smoker, cases demonstrated lower levels of problematic use and less intolerance for physical discomfort. The normal/underweight cases followed the opposite pattern, and were defined by younger age, no tobacco-related medical problems, greater willingness/acceptance to internal smoking sensations, lower weight/appetite regulation expectancies, greater problematic drinking, and greater intolerance for physical discomfort. The discriminant function yielded a correct classification at a rate of 73.5%, which accurately classified overweight BMI male smokers as such with 72.2% sensitivity and normal/underweight BMI male smokers as such with 74.8% specificity. Results revealed that sensitivity (68.5%) and specificity (72.8%) were reliably predicted from the cross-validated model; overall correct classification of cross-validated grouped cases was 70.6%. Plots of the discriminant function scores against the predicted group revealed minimal overlap of the box plots, thus substantial discrimination was revealed (Figure 1(a)).

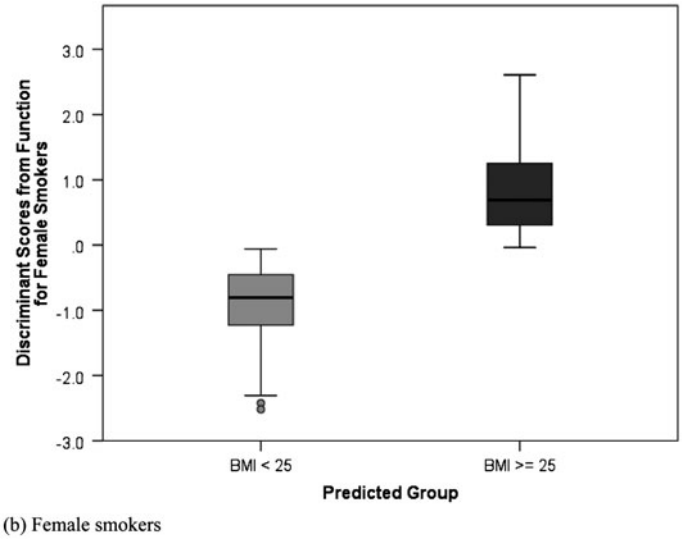
Table 1. Discriminant function results.

Male smokers	BMI < 25 (n = 103) M(SD) *or* n(%)	BMI ≥ 25 (n = 108) M(SD) *or* n(%)	Sig.	Stand. function	Unst. function	Wilks' lambda
Age	32.1 (12.38)	40.8 (13.28)	<.001	.596 (1)	.046	.828
Physical illness	20 (19.4%)	40 (37.0%)	.004	.339 (4)	.764	.788
AUDIT total	8.0 (5.99)	5.6 (5.84)	.003	−.334 (5)	−.057	.787
Cannabis use	69 (67.0%)	52 (48.1%)	.006	–	–	–
FTND	5.0 (2.25)	5.9 (2.03)	.003	–	–	–
MASC	30 (7.27)	32.2 (7.09)	.032	–	–	–
AIS-sensations	12.2 (4.45)	13.7 (4.06)	.011	.295 (6)	.069	.783
SCQ-weight/appetite	3.1 (2.13)	4.2 (2.09)	<.001	.557 (2)	.264	.822
Emotional disorder	28 (27.2%)	28 (25.9%)	.837	–	–	–
DIS total	11.4 (4.92)	11.0 (4.79)	.541	−.436 (3)	−.090	.798
DERS total	75.1 (20.57)	71.5 (17.55)	.176	–	–	–
(Constant)				(rank)	(−2.384)	
Female smokers	**BMI < 25 (n = 80) M(SD) *or* n(%)**	**BMI ≥ 25 (n = 104) M(SD) *or* n(%)**	**Sig.**	**Stand. function**	**Unst. function**	**Wilks' lambda**
Age	35.3 (13.71)	41.3 (12.55)	.002	.383 (4)	.029	.890
Physical illness	18 (22.5%)	37 (35.6%)	.055	–	–	–
AUDIT total	6.2 (5.84)	4.2 (5.47)	.018	−.472 (2)	−.084	.897
Cannabis use	44 (55.0%)	54 (51.9%)	.680	–	–	–
FTND	5.3 (2.05)	5.7 (2.22)	.169	–	–	–
MASC	31.2 (6.41)	32.3 (6.4)	.222	–	–	–
AIS-sensations	12.8 (4.55)	14.4 (4.06)	.017	.430 (3)	.100	.896
SCQ-weight/appetite	4.4 (2.39)	5.3 (2.22)	.007	.641 (1)	.279	.920
Emotional disorder	31 (38.8%)	47 (45.2%)	.383	–	–	–
DIS total	11.5 (5)	12.3 (5.57)	.302	–	–	–
DERS total	76.2 (25.96)	76.2 (24.34)	.990	–	–	–
(Constant)				(rank)	(−3.445)	

Notes: Physical illness (1 = yes, 0 = no); AUDIT total = Alcohol Use Disorder Identification Test (observed/possible range 0–25); Cannabis use = Past 30-days cannabis use (1 = yes, 0 = no); FTND = Nicotine Dependence (possible/observed range 0–10); MASC = Motivational Aspects of Smoking Cessation (observed range 8–40; possible range 0–40); AIS-sensations = Avoidance and Inflexibility Scale-sensations (possible/observed range 4–20); SCQ-weight/appetite = Smoking Consequences Questionnaire – Weight and Appetite Control subscale (observed/possible range 0–9); Emotional Disorder = Any past-year anxiety or depressive disorder (1 = yes, 0 = no); DIS total = Discomfort Intolerance Scale (possible/observed range 0–30); DERS total = Difficulties with Emotion Regulation Scale (possible/observed range 37–162).



(a) Male smokers



(b) Female smokers

Figure 1. BMI classification for male and female smokers from discriminant function.

Results for female smokers

Among female smokers (n = 184), 56.5% were overweight. Of the 11 tested predictors, 4 were statistically relevant to the discriminant function (see Table 1). These variables significantly differentiated BMI in female smokers (Wilks' $\Lambda = .876$, $x^2[4] = 23.928$, $p < .001$; eigenvalue = .142; canonical correlation = .353). The centroid for the overweight BMI group occurred at .329, and at −.428 for the normal/underweight BMI group. The unstandardized coefficient adjusted all cases to an overweight BMI status. Cases were retained in the overweight BMI group by a case having higher weight/appetite control smoking expectancies, higher inflexibility/avoidance to internal smoking sensations, older age, and lower levels of problematic alcohol use. The normal/underweight

BMI smokers were defined by the opposite pattern: lower weight/appetite control smoking expectancies, greater willingness/acceptance of internal smoking sensations, younger age, but greater problematic alcohol use. The discriminant function yielded a correct classification at a rate of 62.0%, which accurately classified overweight BMI female smokers as such with 62.5% sensitivity and normal/underweight BMI female smokers as such with 61.3% specificity. Results revealed that sensitivity (59.6%) and specificity (61.3%) were reliably predicted form the cross-validated model; overall correct classification of cross-validated grouped cases was 60.3%. As shown in Figure 1(b), the plot of the discriminant function scores against the predicted group for female smokers revealed minimal overlap of the box plots, suggesting substantial discrimination properties.

Discussion

More than half (53.7%) of the present sample of treatment-seeking smokers were overweight, defined as a BMI ≥ 25. In male smokers only, having a physical illness was significantly related to classifying smokers as overweight. While prior work has documented that male overweight smokers, relative to normal weight, report stronger motivation to quit smoking and heavier smoking patterns (Chiolero et al., 2007; John et al., 2005; LaRowe et al., 2009), the current findings did not identify that these factors significantly contributed to the discriminant function. We also found that overweight BMI was largely defined by older age (in males and females) and holding strong beliefs about the weight/appetite control properties of smoking among female *and* male smokers. Thus, although the bulk of existing research suggests that weight-related concerns are primarily endorsed among female smokers (e.g. Saules et al., 2008), the current findings suggest that both male and female smokers who believe that smoking will aid in the regulation of weight and appetite, are at a greater likelihood of being overweight – at least from a correlational perspective. The accuracy of these beliefs should be assessed among both male and female smokers, particularly overweight smokers, and addressed in terms of treatment planning for smoking cessation.

Another important finding was the contribution of cognitive inflexibility and avoidance of smoking-related physical sensations (e.g. nicotine withdrawal, craving) in term of its association with BMI status. For both male and female smokers, this tendency to cognitively avoid smoking-relevant physical sensations contributed to the classification of overweight BMI status. These cross-sectional associations are consistent with prior work that has suggested that domain-specific cognitive/experiential avoidance may serve as a risk factor for certain appetitive behaviors (Gifford & Lillis, 2009), and has been targeted in both smoking cessation (e.g. Bricker, Mann, Marek, Liu, & Peterson, 2010; Gifford et al., 2004; Hernández-López, Luciano, Bricker, Roales-Nieto, & Montesinos, 2009) and weight management treatment programs (Forman et al., 2013). By targeting cognitive inflexibility, it is possible that both weight and smoking behaviors could be simultaneously addressed.

Notably, physical discomfort intolerance contributed to the classification of male smokers as normal/underweight BMI. Thus, having a higher tolerance for physical distress contributed to classification of male smokers as overweight. This is somewhat surprising given the work documenting that *lower* tolerance to withstand aversive physical sensations (e.g. discomfort, pain) is associated with motivation to escape/avoid such sensations (via smoking; Leyro, Zvolensky, Vujanovic, & Bernstein, 2008) and that binge eating behavior is often associated with relief of physical discomfort (Birch,

Stewart, & Brown, 2007). It is possible that the engagement in habitual appetitive behaviors (both smoking and overeating) could, in turn, also increase one's perceived capacity to tolerate discomfort over time via a habituation process (e.g. regularly experiencing a full stomach from over eating). Discomfort tolerance in male smokers should be further explored to better understand how tolerance contributes to eating behavior, physical activity, and other behaviors that are directly weight-relevant. Notably, emotion dysregulation or current anxiety/depressive psychopathology were *not* associated with overweight BMI status among male or female smokers, which is somewhat surprising given the relevance of affective psychopathology and emotional vulnerability to both of these problem health behaviors.

Despite theoretical and empirical observations of coupling of problem behaviors (Chiolero et al., 2007), recent cannabis use did not contribute to the classification of overweight BMI status for male or female smokers. In fact, cannabis use was significantly less common among overweight male smokers. Similarly, alcohol use was significantly less problematic among overweight male and female smokers. Indeed, problematic drinking contributed to the classification of smokers as normal/underweight BMI. However, of note, only normal/underweight BMI male smokers reported "hazardous drinking" per the AUDIT, so while lower scores classified smokers as overweight BMI, these absolute scores suggest that drinking behaviors were likely not *problematic* among this group.

There are a number of interpretive caveats. The data analyses were primarily descriptive in nature (cross-sectional). To understand the dynamic interplay between weight gain/loss, weight concerns/expectancies, and smoking behavior, prospective work is needed. Additionally, the current study examined the BMI-smoking relations in a sample of treatment-seeking smokers, given the relevance of weight gain concerns among those smokers trying to quit (Pomerleau et al., 2001). However, these risk processes may not be associated with BMI status in the same way among nontreatment seeking smokers. The current sample was also composed of a relatively homogeneous sample of daily smokers. Given documented disparities in both obesity and smoking in different racial/ethnic minority groups (Caraballo, Yee, Gfroerer, & Mirz, 2008; Ogden et al., 2014), the current associations should be examined in a more heterogeneous smoking sample. Relatedly, the current sample consisted largely of highly-educated individuals (72.5% college educated). The impact of socioeconomic status is also important to consider in the understanding both of these problem health behaviors (Pampel, Krueger, & Denney, 2010), and therefore, could be usefully modeled in future research. Also, we assessed BMI via self-report, which may not be as accurate as directly measuring weight and height (Ezzati, Martin, Skjold, Vander Hoorn, & Murray, 2006). Lastly, while the accuracy and stability of the discriminant function for males and female was good, it is worth noting that the cross-validated discriminant function was more accurate for male smokers relative to female, suggesting that there may be other variables associated with overweight/obese BMI status in female smokers that were not modeled here (e.g. body dissatisfaction, presence of disordered eating pathology; White, Masheb, & Grilo, 2010).

Novel smoking cessation treatments have recently addressed both weight and smoking cessation behavior changes (e.g. Wilcox et al., 2010). Here, many malleable risk factors were identified as being associated with overweight BMI status, including cognitive inflexibility to the experience of smoking-related somatic sensations. This is perhaps one individual difference factor that may be directly targetable in future smoking cessation treatments (e.g. Bricker et al., 2010; Gifford et al., 2004), which may also promote

flexibility in weight control-related cognitions (Gifford & Lillis, 2009). Moreover, holding strong beliefs about the weight/appetite regulation properties of smoking may actually maintain smoking/weight problems in overweight smokers. By providing psychoeducation and cognitive restructuring around maladaptive/inaccurate weight-related smoking expectancies, older overweight smokers, who are already motivated to quit smoking, may be better equipped to do so successfully.

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Note

1. Being overweight was not associated with greater avoidance/inflexibility to smoking thoughts/feelings, or other smoking expectancies (positive reinforcement, negative reinforcement, or negative consequences, thus these factors were not included in the model.

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