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Exercise self-efficacy moderates the relation between anxiety sensitivity and body mass index and exercise tolerance in treatment-seeking smokers

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ABSTRACT

There is little known about factors that contribute to the comorbidity of cigarette smoking and obesity. The current study sought to test whether exercise self-efficacy moderated the relation between anxiety sensitivity (fear of internal sensations) and BMI and exercise tolerance among cigarette smokers. Smokers ($n = 72$; 50% female; $M_{cpd} = 19.3$, $SD = 10.65$) were recruited to participate in a smoking cessation treatment trial. During medical screen, we measured weight, height, and exercise tolerance (functional capacity) employing a standardized maximal exercise testing protocol. After adjusting for participant sex and cigarettes per day, exercise self-efficacy moderated the association between anxiety sensitivity and BMI, such that the positive association between anxiety sensitivity and BMI was significantly stronger when exercise self-efficacy was low. The same pattern of results emerged for exercise tolerance. Exercise self-efficacy moderated the association between anxiety sensitivity and exercise tolerance, such that the negative association between anxiety sensitivity and exercise tolerance was significantly stronger when exercise self-efficacy was low. Among smokers, anxiety sensitivity may be a risk variable that, directly and indirectly in the context of low self-efficacy for exercise, causes or maintains higher body weight and lower exercise tolerance.

Obesity is associated with increased risk for various medical problems (e.g., heart disease, stroke, type 2 diabetes, certain cancers), and approximately 78.6 million adults (34.9%) in the United States are obese (Ogden, Carroll, Kit, & Flegal, 2014). Additionally, the prevalence of obesity worldwide has more than doubled in the past four decades (World Health Organization, 2015a). Cigarette smoking is also a common problematic health behavior, occurring among approximately 42.1 million adults in the United States (17.8%; Centers for Disease Control and Prevention, 2014), and smoking directly causes around 6 million annual deaths worldwide (World Health Organization, 2015b). The comorbidity of smoking and obesity is associated with a marked increase in risk of mortality relative to normal weight non-smokers (Freedman et al., 2006; Prospective Studies Collaboration et al., 2009). Thus, both problems contribute to and compound risk for morbidity and early mortality. Increasing physical activity is one important modifiable health behavior that can facilitate weight management (United States Department of Health and Human Services, 1996), reduce risk of cardiovascular disease (Fletcher, 1999), and promote smoking cessation (Abrantes et al., 2014; Korhonen, Goodwin, Miesmaa,

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Dupuis, & Kinnunen, 2011; Maddison et al., 2014; Marcus et al., 2005). However, engagement in and adherence to physical activity programs is low (Marcus et al., 2000) and may be affected by a host of biopsychosocial factors (e.g., motivational status, low social support, limited access to physical activity facilities, depression, and anxiety; Ekkekakis & Lind, 2006).

One transdiagnostic psychological process that has been linked to *both* smoking and physical inactivity is anxiety sensitivity. Anxiety sensitivity reflects the fear of the physiological sensations associated with anxiety and somatic arousal (Reiss, Peterson, Gursky, & McNally, 1986). Anxiety sensitivity is associated with increased risk for anxiety and depressive symptoms (Olatunji & Wolitzky-Taylor, 2009), smoking (Leventhal & Zvolensky, 2015), maladaptive eating behavior (Hearon, Quatromoni, Mascoop, & Otto, 2014; Hearon, Utschig, Smits, Moshier, & Otto, 2013), and avoidance of physical activity (Hearon et al., 2014; Smits, Tart, Presnell, Rosenfield, & Otto, 2010). Indeed, data indicate that anxiety sensitivity is associated with lower levels of physical activity when assessed via self-report and ambulatory monitoring (Hearon et al., 2014; Moshier, Szuhany, Hearon, Smits, & Otto, 2015). Theoretically, smokers with elevated anxiety sensitivity may be unwilling to engage in physical activity due to the perceived distressing nature of the sensations evoked during exercise. In turn, such smokers may be prone to avoid exercise, thereby presenting with higher body mass and lower tolerance for exercise (or functional capacity).

Literature also indicates that one of the strongest psychological factors associated with physical activity behavior is self-efficacy (Sherwood & Jeffery, 2000), defined as the extent to which one believes in their ability to execute actions required to achieve specified outcomes (Bandura, 1997). Specifically, *exercise* self-efficacy, or an individual's perceived capability to complete a prescribed physical activity or perform a specific exercise task (McAuley, Lox, & Duncan, 1993), appears to be associated with initial engagement in physical activity routine (Blanchard et al., 2007). Increases in exercise self-efficacy are evident in exercise programs (Higgens, Middleton, Winner, & Janelle, 2014) and changes in exercise self-efficacy can affect self-efficacy for controlled eating (Annesi & Marti, 2011; Annesi, 2011a; 2011b). Data also suggest that various affective symptoms can negatively influence exercise self-efficacy, such as depression (Clum, Rice, Broussard, Johnson, & Webber, 2014; Craft, Perna, Freund, & Culpepper, 2008; Kangas, Baldwin, Rosenfield, Smits, & Rethorst, 2015) and anxiety (Annesi, 2011c). Although exercise self-efficacy is important to physical activity and affective symptoms influence exercise self-efficacy (Clum et al., 2014), there is little empirical work examining how this cognitive process relates to the interplay between anxiety sensitivity and physical activity-relevant factors, or specifically among individuals who are also cigarette smokers. Cigarette smoking may uniquely modify (or exacerbate) the expression of the relationships between anxiety sensitivity and physical inactivity given that health consequences of smoking may potentiate the salience of negative interoceptive experiences.

Drawing from this work, high anxiety sensitive smokers may be particularly likely to avoid exercise or have low tolerance (capacity) for persisting in exercise, especially smokers who have less confidence (self-efficacy) in their ability to complete exercise activities, and may thus be at risk for obesity-relevant factors. Accordingly, among smokers, lower self-efficacy for exercise may serve as an amplifier of the deleterious effect of anxiety sensitivity on overweight/obese status and low exercise tolerance, defined as one's functional capacity for exercise measured by metabolic equivalents (METs). A theoretical heuristic is provided in Fig. 1 to illustrate the proposed associations between these processes.

The current study aimed to replicate and extend previous research by (1) examining the association of anxiety sensitivity with body mass index (BMI) and exercise tolerance (METs during maximal exercise testing) among sedentary cigarette smokers and (2) examining exercise self-efficacy as a moderator of these hypothesized relations. Specifically, we expected the relations between anxiety sensitivity and both BMI and exercise tolerance, respectively, would be stronger among those with lower exercise self-efficacy as compared to those with higher levels of exercise self-efficacy.

1. Method

1.1. Participants

Adult daily smokers were recruited as part of a larger exercise-based smoking cessation treatment trial (Smits et al., 2015). Inclusion criteria for the parent trial included individuals between 18 and 65 years of age, engaging in moderate exercise <2 days per week and ≤ 30 min per session, smoking an average of ≥ 10 cigarettes per day for at least 1 year, elevated anxiety sensitivity (pre-screen score of ≥ 20 on the 16-item Anxiety Sensitivity Inventory [ASI; Reiss et al., 1986]), and self-reporting motivation to quit as ≥ 5 on a 10-point scale. Exclusion criteria included: regular use of other tobacco products; medical conditions preventing exercise (including high blood pressure, blood lipid abnormalities, or BMI ≥ 40); high risk for suicide or current past psychotic disorders; pregnancy, breastfeeding, or plans to become pregnant in near future; alcohol or substance use disorder within the past 6 months; recent (within 3 months) psychotherapy for mood or anxiety disorders; or concurrent use of smoking cessation treatment. Based on these criteria, a total of 136 participants were enrolled in the parent trial.

In the larger trial, participants were randomly assigned to participate in smoking cessation treatment combined with either an exercise or wellness education intervention. The current study included screening and baseline data from only those participants randomized to the exercise condition ($n = 72$; $M_{age} = 42.2$; $SD = 11.20$), as exercise self-efficacy was only assessed among these individuals. Participants were 50.0% female and primarily identified as White (70.8%); fewer identified as Black/African American (25.0%) or other (4.2%). Marital status was reported as single (40.3%), married (27.8%), cohabitating with a partner (16.7%), or divorced/separated (15.3%). In terms of educational attainment, most participants reported completing at least some college or higher (79.2%).

1.2. Measures

1.2.1. Demographics form

A demographic form was used to collect information on sex, age, race, marital status, and educational attainment.

1.2.2. Fagerström Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991)

The FTND is a 6-item self-report assessment of gradations in severity of physiological dependence on nicotine, on which higher scores indicate higher levels of nicotine dependence (possible range 0–10). Scores on the FTND are associated with biochemical indicators of smoking (e.g., salivary cotinine; Heatherton et al., 1991). The internal consistency of the FTND items in the current sample was relatively low (Cronbach's $\alpha = 0.46$), which is not uncommon for this measure (Korte, Capron, Zvolensky, & Schmidt, 2013).

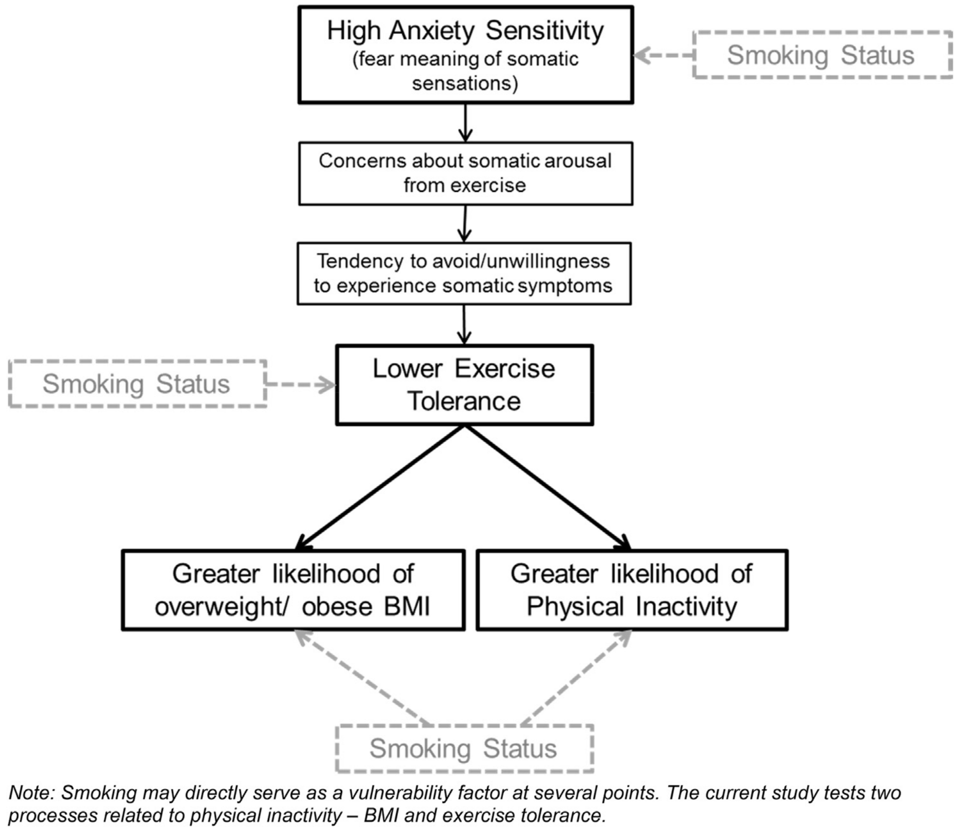

Fig. 1. Heuristic of theoretical associations.

1.2.3. Smoking History Questionnaire (SHQ; Brown, Lejuez, Kahler, & Strong, 2002)

The SHQ is a self-report assessment used to assess smoking history (e.g., onset of regular daily smoking) and pattern (e.g., number of cigarettes consumed per day), as well as quit history. In the present study, the SHQ was employed to describe the sample on smoking history and patterns of use, and average cigarettes per day was used as a covariate in regression models.

1.2.4. Anxiety Sensitivity Index-3 (ASI-3; Taylor et al., 2007)

The ASI-3 is an 18-item self-report measure of the possible negative consequences of somatic-related symptoms (e.g., "It scares me when my heart beats rapidly"). The ASI-3 was derived, in part, from the 16-item ASI (Reiss et al., 1986), and was used at baseline to assess anxiety sensitivity. Responses are rated on a 5-point Likert scale ranging from 0 (*very little*) to 4 (*very much*) and summed to create a total score (possible range 0–52). The ASI-3 has strong and improved psychometric properties relative to previous measures of the construct (Reiss et al., 1986; Taylor et al., 2007). The ASI-3 items demonstrate strong psychometric properties in treatment-seeking cigarette smokers (Farris et al., 2015a). Internal constancy of the ASI-3 items was excellent in the current sample (Cronbach's $\alpha = 0.93$).

1.2.5. Exercise Self-Efficacy (ESE; Marcus, Selby, Niaura, & Rossi, 1992)

The ESE is a 5-item self-report assessment of individuals' beliefs about their ability to engage in an exercise plan when busy, when with friends/family, when sore or tired, in a bad mood, or when exercise is not enjoyable. Items are rated on a scale that ranges from 1 (*not confident at all*) to 8 (*extremely confident*), with higher scores indicating greater exercise self-efficacy (possible range 5–40). The ESE has been demonstrated to differentiate participants at various stages of motivation for physical activity, and has good internal consistency (Marcus et al., 1992). Internal consistency of ESE items in the current study was excellent (Cronbach's $\alpha = 0.91$).

1.2.6. Body Mass Index (BMI)

BMI was calculated based on measured weight and height as an index of body weight ([weight(lbs)/[height (in)]^2 $\times$ 703]) per World Health Organization recommendations (World Health Organization, 2000).

1.2.7. Exercise tolerance

Metabolic equivalents (METs) were used as an index of participants' exercise tolerance and were calculated based on participants' performance (e.g., length of exercise, grade, and speed) during a maximal exercise test completed as part of the medical screening (Jette, Sidney, & Blümchen, 1990). The maximal exercise testing followed the Cornell protocol (Glass et al., 2007), which involves having participants walk on a treadmill, gradually increasing the speed and incline every 2 min for a maximum of 14 min. A certified exercise physiologist conducted the testing and encouraged participants to continue exercise until they reached their maximum exercise capacity.

1.3. Procedure

Treatment-seeking adult daily smokers were recruited through community advertisements in Dallas, Texas. Individuals deemed eligible participated in a medical examination including height/weight measurement and a physical examination to determine whether it was safe to engage in physical activity. Participants eligible after the medical screening were scheduled for an in-person baseline appointment within three weeks of the screening visits, during which self-report assessments were completed, including the ASI-3, ESE, and smoking-relevant measures. Screening and baseline data were used in the current analyses. Informed consent was obtained from all individual participants included in the study. All protocol procedures were approved by the Institutional Review Board at Southern Methodist University.

1.4. Statistical analyses

Data were first checked for assumptions of normality; no violations were detected. Next, regression analyses were used to test the moderating role of exercise self-efficacy on the relation between anxiety sensitivity and the dependent variables. Continuous predictors were mean centered prior to model entry. Analyses were conducted using PROCESS, a conditional process modeling program that utilizes an ordinary least squares-based analytical framework (Hayes, 2013). Anxiety sensitivity (ASI-3) was entered as the predictor (X) and exercise self-efficacy (ESE) was entered as the moderator (M). Participant sex and average number of cigarettes per day were entered as model covariates, based on prior work that has documented sex differences in anxiety sensitivity and physical activity-relevant variables (Hearon et al., 2014; Medina et al., 2014).

Significant effects were plotted visually using a graphical and statistical probing procedure. The uncentered variables were used to facilitate interpretation of scores. First, simple slope analyses were used to test for significant differences in the effect of the anxiety sensitivity on the criterion variables at ± 1 *SD* values of exercise self-efficacy. Second, in order to further characterize the nature of the interaction, the Johnson–Neymann (J–N) technique was utilized (per recommendations by Hayes, 2013). The J–N technique statistically identifies points in the range of the continuous moderator variable where the effect of the predictor on the criterion variable transitions from being statistically significant to non-significant. The J-N technique identifies the value of the moderator variable for which the ratio of the conditional effect to its standard error is equal to the critical *t* score.

2. Results

2.1. Sample characteristics

Participants reported smoking initiation at an average age of 16.3 ($SD = 5.83$) years and smoking daily for an average of 22.5 ($SD = 11.60$) years. Moderate levels of nicotine dependence were reported per the FTND ($M = 5.3$, $SD = 1.95$) and participants reported smoking an average of 19.3 ($SD = 10.65$) cigarettes per day. Table 1 includes descriptive information and inter-correlations among study variables. While all participants were recruited on the basis of having elevated anxiety sensitivity (per the ASI) at the telephone screening ($M = 30.8$, $SD = 8.94$), baseline average scores on the ASI-3 were 18.1 ($SD = 12.40$; observed range of 0–53). These data indicate that while there was no range restriction for baseline ASI-3, anxiety sensitivity did decline after the telephone assessment (see Broman-Fulks, Berman, Martin, Marsic, & Harris, 2009 for previous documentation of this phenomenon). The average BMI was in the overweight range ($M = 26.6$; $SD = 4.79$; range 17.9–39.2) and average METs was 11.1 ($SD = 2.58$; range 3.9–16.4). Female smokers, relative to male, had significantly lower exercise self-efficacy scores ($M = 22.6$, $SD = 7.22$ versus $M = 27.1$, $SD = 7.80$, respectively). There were no significant differences in participant sex in terms of average number of cigarettes smoked per day, anxiety sensitivity, BMI or METS.

Of the 72 participants in the exercise condition, we were missing BMI data (n = 3), METs data (n = 1), ASI-3 (n = 4), smoking history (n = 6), and exercise self-efficacy (n = 23; some participants were inadvertently not given the exercise self-efficacy questionnaire to complete). Little's MCAR test was conducted and was non-significant, indicating that there is no evidence that the data were systematically biased. Hence, missing data were imputed using the expectation-maximization algorithm in SPSS 21.0. In cases in which the N is small and the proportion of missing cases is large, it is recommended that analyses be repeated both with and without the missing data imputed in order to increase confidence in the results (Tabachnick & Fidell, 2013). Thus, analyses were conducted with the imputed dataset and the non-imputed raw dataset. Results from the dataset with imputed missing data were identical in terms of significant and non-significant findings to results from the raw, non-imputed, dataset, thus, below we report the results from the expectation-maximization dataset.

2.2. Results for body mass index (BMI)

Results from the multiple regression predicting BMI are displayed in Table 2. The overall model was significant ($F(5,66) = 2.93$, $p = 0.019$) and accounted for 18.2% of variance in BMI ($f^2 = 0.22$; medium to large effect). There was a significant (negative) association between cigarettes per day and BMI ($b = -0.11$, $p = 0.049$).

Table 1
Bivariate (zero-order) correlations.

Variables	1	2	3	4	5
1. Cigarettes/day[a]	–	0.25*	0.20	−0.29*	0.10
2. Anxiety Sensitivity[b]		–	0.12	−0.02	−0.18
3. Exercise Self-Efficacy[c]			–	−0.16	0.36**
4. Body Mass Index (BMI)[d]				–	−0.40**
5. Exercise Tolerance (METS)[e]					–
Mean/N	19.4	18.1	24.9	26.6	11.1
SD	10.23	12.40	7.80	4.79	2.58

**p < 0.05; *p < 0.01.
[a] Cigarettes/day (Smoking History Questionnaire; item 5).
[b] ESE-Total (Exercise Self-Efficacy Scale –Total score).
[c] ASI-3 Total (Anxiety Sensitivity Index –3 Total score).
[d] BMI (Body Mass Index) – criterion variable.
[e] METs (Exercise Tolerance) – criterion variable.

Table 2
Moderation results.

Criterion Variable: BMI[g]	R^2	*b*	*se*	*t*	*p*
Sex	0.182[a]	−1.31	1.13	−1.16	0.251
Cigarettes/Day		−0.11	0.06	−2.01	0.049
ASI-3		0.04	0.04	0.87	0.387
ESE		−0.12	0.07	−1.66	0.102
ASI-3 × ESE	0.059[b]*	−0.01	0.01	−2.18	0.033
Criterion Variable: METs	R^2	*b*	*se*	*t*	*p*
Sex	0.285[a]	−0.44	0.57	−0.77	0.447
Cigarettes/Day		0.01	0.03	0.001	0.994
ASI-3 Total		−0.05	0.02	−2.42	0.018
ESE-Total		0.14	0.04	3.69	<0.001
ASI-3 × ESE	0.092[b]**	0.01	0.01	2.91	0.005

*p < 0.05; **p < 0.01.
b = unstandardized effect.
Sex (coded 0 = male; 1 = female).
ASI-3 (Anxiety Sensitivity Index –3 Total score).
ESE (Exercise Self-Efficacy Scale –Total score).
BMI (Body Mass Index) – criterion variable.
METs (Exercise Tolerance) - criterion variable.
[a] Total model R_2.
[b] R_2 increase due to interaction.

The effect of participant sex on BMI was non-significant. Results indicated that the main effects of anxiety sensitivity and exercise self-efficacy on BMI were not significant (since ASI-3 and ESE were centered at their mean, these main effects represent the average effect of each variable on BMI across the sample). However, there was a significant interaction between ASI-3 and ESE, which accounted for 5.9% of the variance in BMI ($F(1,66) = 4.73$, $p = 0.033$; $f^2 = 0.06$, indicating a small to medium effect size).

Fig. 2 illustrates the model based estimations of the “simple slopes” (regression lines) showing the relation between anxiety sensitivity and BMI for participants at two levels of the moderator (exercise self-efficacy): ±1 *SD* from the mean of ESE. The form of the interaction revealed that higher anxiety sensitivity was significantly related to higher BMI for those with lower levels of exercise self-efficacy (−1 *SD*; $b = 0.12$, $t = 2.02$, $p = 0.001$), but not for those with higher levels of exercise self-efficacy (+1 *SD*; $b = -0.05$, $t = -0.78$, $p = 0.437$). Specifically, the J-N technique revealed that the conditional effect of anxiety sensitivity on BMI was significant for those with scores ≤17.3 on the ESE (which included 18.1% of our sample). Scores in this range on the ESE are observed among individuals who do not yet engage in exercise (i.e., earlier stage of readiness to change their exercise behavior) [40]. Thus, as exercise self-efficacy decreased, the association between anxiety sensitivity and BMI became stronger, whereas at a score above 17.3, the association between anxiety sensitivity and BMI was non-significant.

2.3. Results for exercise tolerance (METs)

Results from the regression model predicting METs are displayed in Table 2. The model was significant ($F(5,66) = 5.25$, $p = 0.0004$) and accounted for 28.5% of variance in METs ($f^2 = 0.40$; large effect). After adjusting for the non-significant covariate effects of participant sex and average cigarettes per day, results from the model revealed a significant negative association between anxiety sensitivity and METs ($b = -0.05$, $p = 0.018$). Additionally, there was a significant positive association between exercise self-efficacy and METs ($b = 0.14$, $p = 0.0005$). The ASI-3 × ESE interaction was significant, accounting for 9.2% of the variance in METs ($F(1,66) = 8.44$, $p = 0.005$; $f^2 = 0.11$), indicating a small to medium effect size.

The form of the interaction is presented in Fig. 3. Simple slope analysis calculating model based estimates of the relation between ASI-3 and METs indicated that, for individuals with higher levels of exercise self-efficacy, there was a non-significant relation between anxiety sensitivity and METs during the maximal exercise testing (+1 *SD*; $b = 0.01$, $t = 0.06$, $p = 0.952$). However, for those with lower levels of exercise self-efficacy, there was a significant (negative) association between anxiety sensitivity and METs during maximal exercise testing (−1 *SD*; $b = -0.11$, $t = -3.61$, $p = 0.0006$; see Fig. 3), indicating that higher anxiety sensitivity was associated with lower METs. The J-N analysis showed that the relation between anxiety sensitivity and METs was significant for individuals with ESE scores ≤26.2, and that the negative relation was stronger for those with lower levels of ESE; 52.8% of our sample had ESE scores below 26.2. ESE scores in this range are typically observed among individuals who are just starting to exercise [40]. The relation between anxiety sensitivity and METs was not significant for individuals with ESE scores over 26.2.

3. Discussion

The current study examined the association between anxiety sensitivity and two physical activity-relevant variables (BMI and exercise tolerance measured by METs) among sedentary cigarette smokers, and the moderating role of exercise self-efficacy. Consistent with expectation, exercise self-efficacy significantly moderated the association between anxiety sensitivity with BMI and exercise tolerance, suggesting that these relations were specific to individuals with low to moderate levels of exercise self-efficacy. Specifically, the association between anxiety sensitivity and BMI was significant only when smokers had exercise self-efficacy scores that reflected the lack of confidence to initiate exercise (e.g., “I am *not confident at all* that I can participate in regular exercise when ‘I am in a bad mood’ or ‘I am tired’”). Thus, anxiety sensitivity may be more strongly linked to BMI among smokers with low levels of exercise self-efficacy − potentially indicative of a high risk group of smokers who may be likely to avoid exercise. Additionally, having low to moderate confidence for engaging in exercise was associated

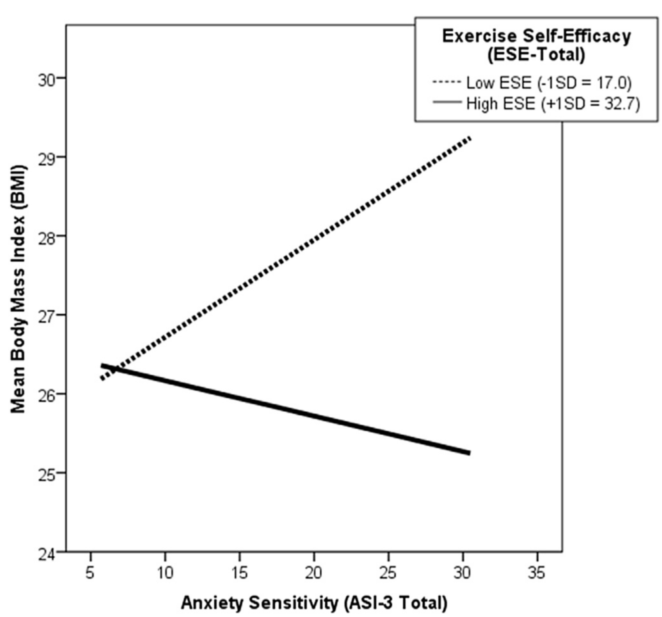

Fig. 2. Conditional association between Anxiety Sensitivity and BMI at different levels of Exercise Self-Efficacy.

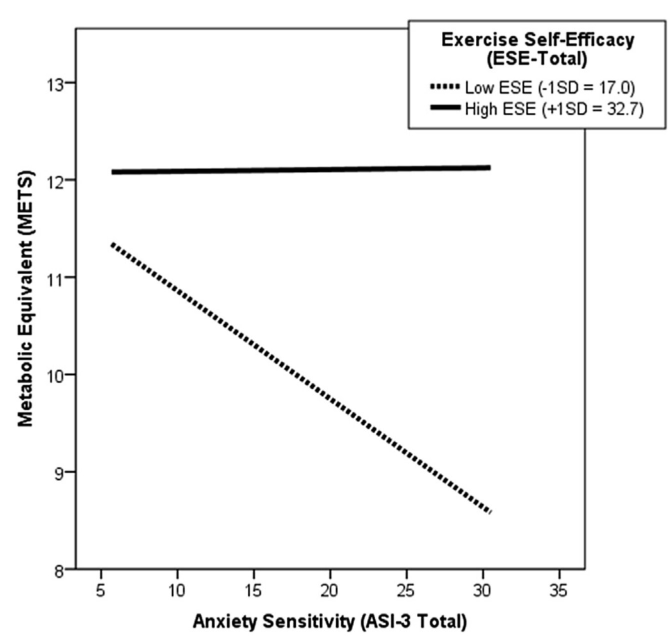

Fig. 3. Conditional association between Anxiety Sensitivity and Exercise Tolerance via Exercise Self-Efficacy.

with a stronger link between anxiety sensitivity and exercise tolerance. As such, even among smokers who held some confidence for exercise, anxiety sensitivity appeared to be strongly associated with low exercise tolerance. The current findings suggest that increasing exercise self-efficacy for those with low to moderate self-efficacy, and facilitating reductions in anxiety sensitivity, could increase engagement in physical activity among overweight smokers. Indeed, clinically addressing exercise self-efficacy and anxiety sensitivity may be important in terms of smoking cessation and weight management.

A number of other findings warrant comment. First, findings indicated that anxiety sensitivity was directly associated with lower exercise tolerance, measured via METs during maximal exercise testing. This is consistent with studies that have found that anxiety sensitivity is associated with physical inactivity (Hearon et al., 2014; Moshier et al., 2015; Smits et al., 2010), and may indicate that smokers high in anxiety sensitivity may be more avoidant of experiences that elicit interoceptive distress (Leventhal & Zvolensky, 2015; Smits, Berry, Tart, & Powers, 2008b). Additionally, there was a positive association between exercise self-efficacy and tolerance for exercise. This finding is consistent with prior work that has found that higher levels of exercise self-efficacy are related to engagement in physical activity (Higgins et al., 2014). In contrast, current findings indicated that anxiety sensitivity was not directly associated with BMI among smokers. This finding is contrary to prior research among non-smokers that has found that anxiety sensitivity is related to higher body weight and maladaptive eating (Hearon et al., 2013), although consistent with other work that found a non-significant association between body weight and anxiety sensitivity (Smits et al., 2010). Additionally, there was no main effect of exercise self-efficacy on BMI, which is somewhat surprising given some work has indicated that lower exercise self-efficacy is associated with higher BMI and waist circumference (Clum et al., 2014; Konttinen, Silventoinen, Sarlio-Lähteenkorva, Männistö, & Haukkala, 2010) and higher exercise self-efficacy is predictive of weight loss and weight loss maintenance (Teixeira et al., 2010). Exercise self-efficacy is posited to be linked with weight loss via several pathways, including increased overall general confidence in ability to manage weight (Teixeira, Going, Sardinha, & Lohman, 2005), transference from self-regulation of one behavior (exercise) to another behavior (eating; Mata et al., 2009), and/or greater commitment and compliance to an established dietary plan (Annesi & Unruh, 2008). However, nicotine may importantly alter the nature of BMI and cognitive-affective processes among smokers. For example, some data suggest that smokers tend to weigh less due to appetite suppression and increased energy expenditure associated with nicotine (Hofstetter, Schutz, Jéquier, & Wahren, 1986). It is possible that there may be other more potent emotional vulnerability processes (e.g., inflexibly responding to smoking-related somatic distress) that may contribute to overweight/obese BMI among smokers (Farris, Zvolensky, Robles, & Schmidt, 2015b). Moreover, during exercise, there may be other experiences (e.g., physical discomfort) that override the influence of exercise self-efficacy (Smits et al., 2010), that more directly affect BMI among smokers. More work is needed to further understand bio-psychological processes linked to smoking and obesity.

It is worth commenting on the reduction in anxiety sensitivity from the telephone assessment (per the ASI) to the baseline assessment (per the ASI-3). While anxiety sensitivity is conceptualized as a dispositional (trait-like) construct (Reiss et al., 1986), several intervention studies have documented this decline in anxiety sensitivity between screen and baseline (e.g., Broman-Fulks et al., 2009; Maltby, Mayers, Allen, & Tolin, 2005). Subsequent studies have shown that this decline is specific to the first two administrations (i.e., scores are stable thereafter), suggesting that inclusion of high anxiety sensitivity smokers in future studies should require positive screens on two administrations (Marsic, Broman-Faulks, & Berman, 2011; Smits et al., 2008a).

There are a number of study caveats. First, the current data were cross-sectional in nature. Therefore, it is unknown how changes in self-efficacy for exercise or anxiety sensitivity affect BMI or exercise tolerance over time. Second, the sample consisted of sedentary, treatment-seeking smokers who were included in a larger study, based on certain characteristics (e.g., self-reported motivation to quit smoking and willingness to enroll in an exercise-based intervention). Thus, the extent to which these characteristics are representative of the larger population of treatment-seeking smokers is unknown. Third, smokers with BMI $\geq$40 were not included in the sample (due to exclusion criteria for parent study). This selection criterion naturally limits generalizability of these findings; however, a BMI of 25–29.9 is considered overweight and BMI of 30 or higher is in the obese range (Centers for Disease Control and Prevention, 2015). Accordingly, 55.8% of our sample was in the overweight/obese range. However, the restricted range in BMI may have affected the observed range of scores on the ESE or METs. Fourth, the sample was relatively small in size; while medium to large effect sizes were observed, replication of these findings would bolster confidence in the observed findings. Fifth, two obesity-relevant variables were modeled (BMI and exercise tolerance), however other relevant variables were not (e.g., maladaptive eating behavior; Clum et al., 2014; Craft et al., 2008). Examining a comprehensive model of psychological factors that contribute to smoking-obesity relation is required.

Overall, the present data suggest that there may be clinical utility in addressing exercise self-efficacy among high anxiety sensitive smokers to help address BMI and exercise tolerance. Future work is also needed to identify the mechanisms explaining the observed effects. It may be possible that among high anxiety sensitive smokers, increasing exercise self-efficacy could be related to greater willingness to engage in physical activities that may elicit discomfort or reduce reactivity to negative affective states, indirectly affecting indicators of health such as BMI and exercise tolerance.

Compliance with ethical standards

Conflict of interest: The authors declare that there is no conflict of interest.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

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