Abstract

Introduction: Tobacco use in chronic obstructive lung disease (COPD) is associated with worse COPD outcomes. This study aimed to demonstrate that smoking cigarettes, e-cigarettes, and cigars is associated with increased risks of pneumonia in COPD and higher dependence to tobacco products.

Methods: A retrospective cohort study was conducted using the Population Assessment of Tobacco and Health (PATH) study during Waves 4 and 5. Adults who self-reported a diagnosis of COPD in Wave 5 were included (n=990). The exposure of interest was past 30-day cigarettes, e-cigarettes, or cigar smoking in Wave 4. Study outcomes were pneumonia in Wave 5 and tobacco dependence index scores in Waves 4 and 5. Multivariable Relative Risk Regression was conducted to determine the relative risks of pneumonia and high tobacco dependence in the tobacco product groups.

Results: Overall, the COPD cohort was age 65 and older (48.3%), female (57.1%), and had hypertension (52.0%), high cholesterol (34.7%), and pre-diabetes and diabetes (23.8%). Cigar smoking was associated with a 30% increased risk of pneumonia in COPD individuals (adjusted RR 1.30, 95% CI: 1.01-1.67). There was a significant, increased risk of high tobacco dependence during Wave 5 among past 30-day cigarette smokers (adjusted RR 3.32, 95% CI: 1.59-6.56). Cigarette and e-cigarette use were not significantly associated with pneumonia.

Conclusion: Cigar smoking is associated with an increased risk of pneumonia in individuals with COPD. Although cigar smokers may be less tobacco product dependent

versus cigarette smokers, smoking cigars was the tobacco product most associated with acquiring an infection.

Keywords: tobacco, smoking, COPD, pneumonia, dependence

1. Introduction

Tobacco smoking is the leading cause of preventable disease and death worldwide [1]. Among smokers, 73% of their diagnosed smoking-related conditions are chronic lung diseases [1]. Smoking cessation efforts and public health interventions have been essential [2]. Rates of tobacco smoking have declined, such as cigarette smoking being prevalent at 25.5% in 1990 to 13.7% in 2018 in adults in the U.S. [3].

Overall, smoking cessation studies and policies are still required, especially for populations at higher risks of tobacco use and the negative health consequences [4]. In terms of cigarettes, the proportion of cigarette smokers has increased in populations including adults age 45 and older, Hispanics, and low socioeconomic status groups [4]. Smoking e-cigarette, cigar and pipe products is an additional concern [4]. For example, e-cigarettes have not only increased in popularity in the U.S., but also are linked to becoming addicted to nicotine products and potentially transitioning to smoking cigarettes [5].

Chronic obstructive lung disease (COPD) is linked closely to smoking, characterized by chronic respiratory symptoms due to lung airflow limitations in the setting of lung inflammation and destruction [6]. As this lung condition progresses in severity, complications become more likely including COPD exacerbations, recurrent infections, and pneumonia [7].

Smoking cessation efforts that address populations with COPD have been demonstrated as the treatment strategy for COPD most strongly associated with lowering mortality and preventing an individual's disease severity from further

progressing [8]. However, for individuals with COPD that do not stop or reduce their smoking, it is not clear how using tobacco products may lead to common COPD complications such as pneumonia. The implications that smoking has on pneumonia have been derived from population-based studies in adults, with tobacco consumption, of any product type, being associated with increased odds of pneumonia in a case-control study conducted by Jordi et al [9]. Their study findings were limited by evaluating only adults without COPD [9], and a subsequent population-cohort study by Braeken et al. was conflicting by revealing that adult COPD patients had comparable risks of pneumonia in current cigarette smokers compared to never smokers [10]. Since it is unclear how cigarette smoking and also how the other, less commonly studied tobacco products directly impact the COPD disease course [11] in regards to the lung infections that develop, a further evaluation of tobacco use and associated health consequences in individuals with COPD is necessary.

This retrospective study clarifies the association between using tobacco products with the risk of pneumonia in individuals with COPD. The primary objective was to demonstrate that the active use of cigarettes, e-cigarettes, and cigar smoking are associated with a higher pneumonia risk in COPD. Secondary objectives include exploring how dependence on tobacco products affect individuals over longitudinal periods, particularly for active tobacco smokers despite having this underlying respiratory condition of COPD.

2. Methods

2.1 Data sources

This retrospective cohort study analyzed public-use data on adults age 18 or older who participated in both Waves 4 and 5 of the Population Assessment of Tobacco (PATH) study. Wave 4 and Wave 5 were conducted during December 2016 to January 2018 and December 2018 to November 2019 respectively [12]. The PATH study is an ongoing U.S.-based cohort study by the National Institute of Drug Abuse of the National Institutes of Health in partnership with the Center for Tobacco Products of the U.S. Food and Drug Administration [12]. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed [13].

In the PATH study, multistage, address-based, area-probability sampling and audio computer-assisted self-interviews were used to collect nationally representative self-reported data on tobacco use patterns and associated health behaviors [12]. Weighted estimates, using Wave 5 single-wave weights, represented the U.S. civilian, noninstitutional adult population [12]. The PATH study response rates of adults in the Wave 4 survey was 73.5% and in the Wave 5 survey was 69.4% [12]. Additional details of the PATH studies are provided elsewhere [14].

2.2 Measures

In Wave 4, survey participants were asked on their current tobacco use status including if they “have smoked a cigarette within the past 30 days,” “have used an electronic nicotine product within the past 30 days,” or “have smoked a cigar product within the last 30 days.” In Wave 5, participants were asked about underlying health conditions including: “in past 12 months, doctor, nurse or other health professional said you had a lung or respiratory condition: COPD.” A cohort was created based on respondents involved in both Waves 4 and 5 to the PATH study and only individuals with a COPD

diagnosis in Wave 5 (n=1056) were included (Supplemental Figure 1). Participants were excluded due to missing responses to the exposure variables of past 30-day cigarette and e-cigarette smoking, missing responses to the pneumonia outcome, and missing or non-positive sample weights (Supplemental Figure 1).

The primary outcome measure of pneumonia was obtained from the PATH study Wave 5 in which survey participants provided a numerical response to the "number of times you have been on antibiotics for lung-related infection in the past 12 months." This discrete, numerical covariate included responses that ranged from 0 to 365 possible times in a 12-month period. This outcome variable was redefined as having pneumonia for responses of 1 to 365 times and not having pneumonia for responses of 0 times.

Tobacco dependence scores were obtained from responses to a 16-item questionnaire developed by Strong and colleagues [15]. This tobacco index score can be scaled from values 0 to 100 and has been validated for predicting tobacco use over a two-year period from September 2013 to October 2015, during PATH study Waves 1 and 2 [15]. Scores more than 56.25 (66^{th} percentile) were defined as high tobacco dependence, and scores of 56.25 and lower were defined as low-moderate tobacco dependence used for further analysis [16].

All other covariates/confounders were collected from PATH study Wave 4. This included the survey respondent's age category (18-24, 25-34, 35-44, 45-54, 55-64, or 65 and older), sex (male or female), and 12-month use of alcohol (yes or no). Concurrent health comorbidities of interest include a diagnosis by a health professional in a clinical setting during the last 12 months for the following conditions: high blood pressure, high cholesterol levels, pre-diabetes or diabetes, congestive heart failure, and stroke. These

comorbidity covariates were all categorized by whether they had received or had not received one of these diagnoses, or an unknown category for missing or incomplete responses (yes or no or unknown).

2.3 Statistical Analysis

Data analyses were performed between October 2024 and April 2025. Weighted percentages with standard errors were calculated for categorical covariates that include past 30-day cigarette, e-cigarette, and cigar smoking, and for the baseline demographic and health comorbidity variables. Multivariable Relative Risk Regression [17] was conducted to evaluate the association between weighted past 30-day cigarette smoking, e-cigarette smoking, and cigar smoking with the outcomes of pneumonia and high tobacco dependence. Three relative risk regression models were developed: (1) unadjusted analysis of weighted tobacco product use with pneumonia and high tobacco dependence, (2) Analysis that adjusted for weighted age category and sex covariates, (3) Analysis that adjusted for weighted age category, sex, 12 month alcohol use, and comorbidities of high blood pressure, high cholesterol levels, diabetes, congestive heart failure, and stroke. Multivariable regression models were conducted using log-binomial distributions as per the methods described by Lindquist [17]. Weighted analysis was performed using the Fay's balanced repeated replication with an adjustment factor of 0.3, which incorporated study weights and replicate weights from the Wave 5 single-wave weights dataset [18]. Respondents with missing responses on the tobacco dependence index covariate were not excluded from analysis, and rather missing responses were derived from the multiple imputation methods of approximate Bayesian bootstrap imputation (Supplemental Figure 1) [19]. Relative risks were obtained from

multivariable relative risk regression analysis, with associated 95% confidence intervals calculated. SAS software 9.4 was utilized for all study analysis [20].

3. Results

The respondents meeting study criteria was n=990 (Supplemental Figure 1). Individuals with a self-reported diagnosis of COPD at Wave 5 included in this study were overall older in age, with a weighted percentage of close to 80% respondents in the age categories: ages 55 to 64 years (31.4%) or 65 years and older (48.3%) (Table 1). 57.1% of weighted individuals were female versus 42.9% males, and 51.4% reported alcohol consumption in the last 12 months (Table 1).

Multiple comorbid health conditions were present in individuals with COPD (Table 1). 52.0% of weighted individuals had a self-reported diagnosis of hypertension. Other common reported diagnoses included high cholesterol (34.7%) and pre-diabetes or diabetes (23.8%). Congestive heart failure and stroke were reported by 13.2% and 6.3% of weighted individuals respectively (Table 1).

3.1 Tobacco use and risk of developing pneumonia

The reported past 30-day use of cigarettes, e-cigarettes, and cigars during Wave 4 is listed in Table 2. Cigarette smoking was the most common, with a weighted percentage of 46.9% individuals who smoked cigarettes in the past 30-days. The second most common tobacco product was e-cigarettes with a weighted past 30-day use of 9.4% individuals. The weighted percentage of cigar smoking in the past 30-days was 7.4% of individuals (Table 2).

In terms of risk of pneumonia, cigar smoking had the strongest association with developing pneumonia for individuals with a self-reported COPD diagnosis (Table 2). After adjusting for age category, sex, alcohol use, and health comorbidities, individuals with COPD who were past 30-day cigar smokers were at a 30% higher risk of pneumonia versus non-cigar users with COPD (adjusted RR 1.30, 95% CI: 1.01-1.67) (Table 2).

Cigarette smoking was associated with a higher risk of pneumonia in the setting of COPD adults, however this association did not remain statistically significant across multivariable analyses (Table 2). After adjusted analysis, the association between past 30-day cigarette use and risk of pneumonia in COPD was not statistically significant (adjusted RR 1.03, 95% CI: 0.82-1.28) (Table 2).

Past 30-day e-cigarette use was not significantly associated with an increased risk of pneumonia for individuals with COPD (Table 2). After adjusting for confounders, past 30-day e-cigarette smokers did not have a significantly increased adjusted risk of pneumonia in COPD, compared to individuals who were not using e-cigarettes (adjusted RR 1.01, 95% CI: 0.79-1.29) (Table 2).

3.2 Tobacco products and associations with tobacco dependence

The tobacco dependence reported by individuals with COPD, as per Wave 4 tobacco product use, is shown by the relative risks of reporting high dependence to tobacco during Waves 4 and 5 (Table 3). Past 30-day use of cigarettes, e-cigarettes, and cigars during Wave 4 were each associated with an increased risk of high tobacco dependence reported in Waves 4 and 5, although not all associations were statistically significant after multivariable analyses (Tables 3).

Past 30-day cigarette smoking in individuals with COPD was the tobacco product most associated with an increased risk of high tobacco dependence, however this risk was only statistically significant in Wave 5 after adjusting for age category, sex, and other confounders (Tables 3). In Wave 4, this association was not statistically significant following adjusted analysis (adjusted RR 2.79, 95% CI: 0.61-12.79) (Table 3). In Wave 5, past 30-day cigarette smokers with COPD was associated with an adjusted 222% increased risk of high tobacco dependence compared to non-cigarette users with COPD (adjusted RR 3.22, 95% CI: 1.59-6.56) (Table 3).

Following adjusted analysis, e-cigarette use was not associated with a significantly increased adjusted risk of high tobacco dependence, in Wave 4 (adjusted RR 1.15, 95% CI: 0.96-1.39) and Wave 5 (adjusted RR 1.15, 95% CI: 0.96-1.39) (Table 3). Cigar use was associated with increased adjusted risks of reporting high tobacco dependence that was statistically significant in Wave 4 (adjusted RR 1.44, 95% CI: 1.13-1.84) and in Wave 5 (adjusted RR 1.37, 95% CI: 1.14-1.65) (Table 3).

4. Discussion

In a nationally representative sample of adults that had self-reported a COPD diagnosis, the prospective association of cigarette, e-cigarette, and cigar use with the risk of pneumonia was evaluated. Past 30-day cigar use was associated with an increased risk of pneumonia in the setting of COPD, which was a result that was expected since smoking cigars has been negatively associated with lung function and signs of airflow obstruction [21]. An increased risk of having high tobacco dependence during the study period occurred among most past 30-day tobacco user groups, suggesting that nicotine dependence is a chronic and possible lifetime concern for individuals with COPD [22].

The study population of interest is consistent with other national survey-based studies that evaluated characteristics of adults with COPD [23-24]. Briefly, COPD is prevalent in older adults, females, and smokers [23], and in individuals who also have hypertension, hypercholesterolemia, and diabetes [24]. Past 30-day use of cigarettes, e-cigarettes, and cigars in this COPD cohort was high, with higher percentages versus the general adult U.S. population surveyed in the 2018 National Health Interview Survey [25].

Past 30-day cigar smokers with COPD were associated with a 30% increased adjusted risk of pneumonia compared to non-cigar users with COPD. Although studies are limited on COPD outcomes that are linked to tobacco products other than cigarettes, cigars have been associated with worse respiratory health outcomes in more general populations [21]. In a PATH study-based cohort analysis by Sharma et al. that excluded adults with COPD, cigar smoking was shown to worsen functionally important respiratory symptoms and the control of asthma-specific symptoms when compared to non-smokers [26]. Pertinent to pneumonia, adequate lung function and immunity are necessary to prevent pathogen growth and infections from developing [27]. The use of cigars that impairs lung function could lead to adults with COPD to be more at risk of pneumonia.

Conversely, cigarette smoking was not associated with a higher risk of pneumonia in the setting of COPD. The effects of cigarettes on COPD disease progression is well established [28], including the clinical improvements that result from complete cessation of smoking [29]. However, this relationship is not entirely clear in terms of COPD complications such with the risk of pneumonia. Cecere et. al compared current versus former versus never smokers, and a decreased risk of pneumonia hospitalization

occurred only among never cigarette smokers [30]. For COPD populations, including in this study representative of adults with COPD, few amounts of individuals have never smoked during their lifetime. The analyses of past 30 day cigarette users suggest individuals continue to have a comparable risk of acquiring pneumonia regardless if they are actively smoke cigarettes once they have an established history of COPD and smoked cigarettes previously.

E-cigarette use was also not associated with an increased risk of pneumonia in this study. A small, retrospective cohort study (n=39) has suggested that e-cigarette was associated with both harm reduction and clinical improvements in COPD over a 60-month period [31]. However, based off this evaluation of adults with COPD in the PATH study, the risks of pneumonia were overall comparable without any statistically significant evidence of benefit or harm despite an individual's use of e-cigarettes.

In terms of tobacco dependence, actively using cigarettes, cigars, or e-cigarettes was associated with an increased risk of high tobacco dependence in COPD adults. It has been demonstrated that adults with COPD are dependent to tobacco products such as cigarettes, and that the proportion of individuals who quit smoking decreases with older age [32], which was a partial confounder on the associations between tobacco product use and tobacco dependence. This study provides additional clarification that cigar smoking compared to non-cigar use was associated with increased risks of high tobacco dependence in COPD, but the risk of high tobacco dependence was still considerably greater in cigarette smokers with COPD. Future studies are necessary to evaluate why certain tobacco products have greater associations with tobacco product dependence, and yet, more importantly, to evaluate the reason that choosing to use

certain tobacco product such as cigars is what affects an individual with COPD's risk of pneumonia.

4.1 Limitations

Limitations exist due to the aspects of self-reported data and components omitted in the PATH study design. Study results are based off of self-report responses to requiring antibiotic treatment for a lung-related infection in the past 12 months and responses to the tobacco dependence index developed by Strong et al [15]. However, the outcome of pneumonia is a common complication that occurs in adults with COPD [33], with many respondents in the PATH study who reported having multiple lung infections. By redefining the study outcome as a binomial variable helps to simplify analysis and reduce the misclassification biases on this outcome variable once redefined as either having pneumonia events or not having pneumonia. Additionally, the utility of the 16-item tobacco dependence score has been well-validated despite being based on self-reported data [15-16]. In the publicly accessible PATH study dataset, certain covariates that would be relevant to COPD outcomes were not obtained including an individual's pack year history of smoking tobacco products, formal lung function testing such as spirometry, COPD treatment and inhaler use status, and prior microbiology testing or infectious organisms cultures. However, given the methodology and the nationally representative PATH study on adults in the U.S., the associations regarding tobacco product use, risk of pneumonia, and tobacco dependence remain generalizable to individuals of a wide range of COPD severities and health statuses. Study findings regarding tobacco product use and the implications have relevance for COPD adults

whether or not they may have extensively smoked previously or received regular healthcare evaluations and treatments for COPD.

5. Conclusions

In this longitudinal analysis of the prospective association between cigarette, cigar, and e-cigarette use and pneumonia in adults with COPD, past 30-day cigar smokers had an increased risk of pneumonia compared to non-cigar smokers. This risk of pneumonia was statistically significant including after adjustment for confounding factors including an individual's age and health comorbid status. Although tobacco dependence is highly prevalent in COPD populations, with cigarette smokers shown to have the highest risks for being dependent to tobacco, interventions and policies directed at cigar smoking are needed to prevent the negative health effects that this tobacco product has on lung-related health and complications.

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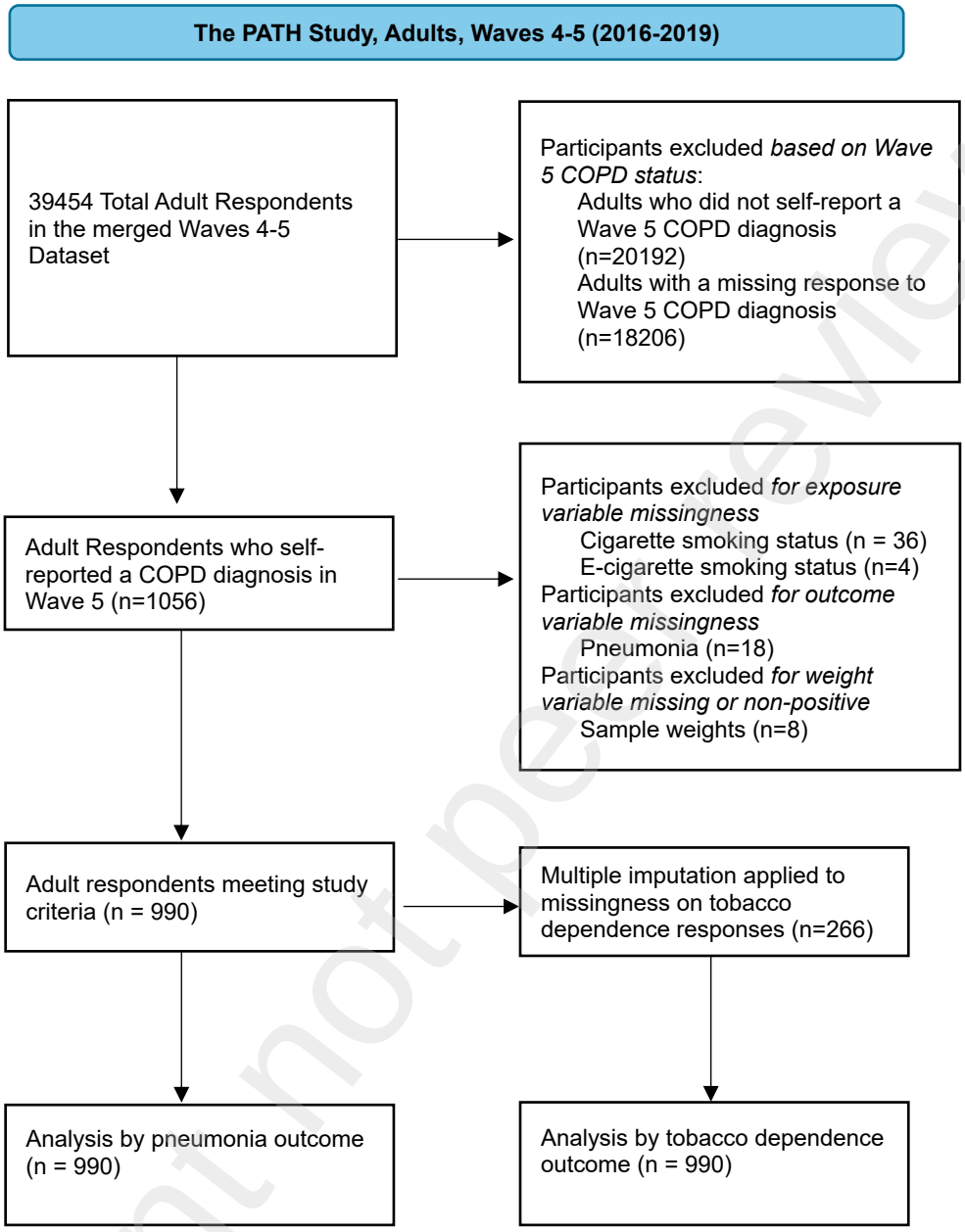

Figure 1. Flow Diagram For Adults Self-Reporting a COPD Diagnosis At Wave 5 With Exclusion of Missing Data

Table 1. Weighted Demographic Characteristics and Health Comorbidities of Participants of PATH Study (Waves 4-5, 2016-2019) with a Wave 5 Self-Reported COPD Diagnosis.

Characteristic	Weighted % (SE)
Age, y	
18-24	0.2 (0.1)
25-34	1.1 (0.4)
35-44	4.3 (0.6)
45-54	14.7 (1.4)
55-64	31.4 (2.3)
≥65	48.3 (2.6)
Sex	
Male	42.9 (2.5)
Female	57.1 (2.5)
Alcohol Consumption	
Yes	51.4 (2.4)
No	46.4 (2.4)
Past Medical History	
Hypertension	52.0 (2.5)
High Cholesterol	34.7 (2.4)
Pre-diabetes or Diabetes	23.8 (2.1)
Congestive Heart Failure	13.2 (1.7)
Stroke	6.3 (1.4)

Table 2. Tobacco Product Use In Wave 4 (2016-2018) and Relative Risk Of Having Pneumonia In Wave 5 (2018-2019) of the PATH Study.

	Past 30 Day Tobacco Product Users		
	Cigarettes	E-cigarettes	Cigars
Weighted User % (SE)	46.9 (1.8)	9.4 (0.8)	7.4 (0.9)
Unweighted Sample Size	690	139	103
Crude RR (95% CI)	1.33 (1.02-1.73)	1.17 (0.89-1.55)	1.48 (1.18-1.87)
Adjusted RR* (95% CI)	1.03 (0.82-1.30)	0.98 (0.77-1.26)	1.34 (1.09-1.64)
Adjusted RR+ (95% CI)	1.03 (0.82-1.28)	1.01 (0.79-1.29)	1.30 (1.01-1.67)

**Relative risk regression adjusted for weighted age category and sex*
+Adjusted for weighted age category, sex, alcohol use, hypertension, high cholesterol, pre-diabetes or diabetes, congestive heart failure, and stroke

Table 3. Tobacco Product Use in Wave 4 (2016-2018) and Relative Risk Of Having High Tobacco Dependence in Waves 4 (2016-2018) and 5 (2018-2019) of the PATH Study.

	Past 30 Day Tobacco Product Users		
	Cigarettes	E-cigarettes	Cigars
Wave 4 Dependence			
Crude RR (95% CI)	4.91 (2.46-9.80)	1.86 (1.58-2.20)	1.88 (1.57-2.26)
Adjusted RR* (95% CI)	3.06 (0.78-12.04)	1.33 (1.04-1.70)	1.51 (1.33-1.71)
Adjusted RR+ (95% CI)	2.79 (0.61-12.79)	1.22 (0.97-1.55)	1.44 (1.13-1.84)
Wave 5 Dependence			
Crude RR (95% CI)	3.64 (2.70-4.91)	1.52 (1.24-1.87)	1.67 (1.39-2.02)
Adjusted RR* (95% CI)	3.24 (2.18-4.84)	1.16 (0.97-1.39)	1.35 (1.14-1.60)
Adjusted RR+ (95% CI)	3.22 (1.59-6.56)	1.15 (0.96-1.39)	1.37 (1.14-1.65)

**Relative risk regression adjusted for weighted age category and sex*
+Adjusted for weighted age category, sex, alcohol use, hypertension, high cholesterol, pre-diabetes or diabetes, congestive heart failure, and stroke