Abstract

Background: Studies relating cigarette smoking and body weight yield conflicting results. Weight-lowering effects in women and men have been associated with smoking, however, no effects on weight have been proven. This study examined the association between cigarette smoking and relative weight in adolescent males and females as they age into young adults.

Methods: Data from the National Longitudinal Survey of Youth—a nationally representative survey conducted annually—was used for this analysis. The sample consists of 4,225 males and females observed annually from 1997 at age 12 to 17 through 2011 at age 27 to 31. Hierarchical Generalized Models (HGM) assesses the impact of smoking on the likelihood of having higher BMI controlling for demographic, household and environmental impacts. The second estimation considers the possibility that smoking is endogeneous and utilizes a multinominal instrument (IV) for smoking level.

Results: HGM models reveal a negative association between cigarette smoking and BMI for both males and females. Individuals who smoke more have lower BMI compared to infrequent or non-smokers. General health rating, region of residence and income were used instrument for smoking in a linear two-stage IV specification. The instrument is highly correlated with BMI and results mirror the HGM. Finally, models run on early, middle and advanced adolescents show that the relationship diminishes over time. The relationship between BMI and smoking decreases as female’s age, but increases for males.

Conclusion: Empirical models confirm an association cigarette consumption and BMI in both males and females. This negative relationship varies with age. It is important to identify health risks-obesity-and modifiable risk factors-smoking-that contribute to health disparities among adolescents. However, the increase in one risky behavior leading to the decrease in the prevalence of the other complicates the issue. The higher prevalence of frequent cigarette uses among both adolescents and young adults of lower BMI suggest that smoking could be used curb or suppress appetite.

Introduction

Obesity rates have risen rapidly since the 1990s and currently exceed 30% in most age groups [1, 2]. Overweight and obesity, especially in children and young adults, are now regarded as one of the main public health challenges [3–5]. At the same time over 4.7 million middle and high school students currently use tobacco [6]. While adolescent tobacco use has declined substantially over the last 40 years, nearly one in 20 high school seniors smoke daily [7]. Substantial racial, ethnic and regional differences exist in smoking rates. White teens are more likely to smoke than are black or Hispanics [8]. Smoking is more typically in nonmetropolitan areas, and in the South and Midwest [9].

Despite efforts, physicians and policy makers have not succeeded in reversing the trend of adolescent smoking or obesity [10, 11]. The awareness of overweight, smoking and other lifestyle choices in public health campaigns, commercial retail industries, and the media have been more prevalent since the early 2000s. Research indicates that public perception of overweight and obesity has been influenced by this focus, but public disfavor for smoking persists [12].

While the negative health impacts benefits of smoking are unquestionable, the strong probability of subsequent weight gain has raised concerns about an unintended effect of anti-smoking policies on obesity rates. Chou, Grossman, and Saffer [13] purport that this resulting weight gain is simply “the price that must be paid to achieve goals that are in general favored by society.” Indeed, the association between smoking and body weight has become a central issue in the obesity literature, but the accumulating evidence present conflicting results.

While previous research provides varied results regarding the relationship between BMI and smoking at various ages, this study provides a comprehensive analysis of adolescent smoking at three stages of youth development. It incorporates longitudinal, nationally representative data and incorporates two different statistical methods to assert the robustness of the relationship.
This analysis not only examines the relationship between cigarette smoking and BMI controlling for age, region of residence and other confounding variables, but also to test whether this relationship changes as adolescents age into young adults. This paper proceeds with a brief discussion of these issues and the existing literature in Section II. Section III outlines the data and analytical methods employed. Next, Section IV summarizes the empirical results and, finally, Section V discusses the results and primary conclusions.

Background

Some, but not all, previous studies found that cigarette smokers weigh less than nonsmokers and former smokers are no heavier than nonsmokers [14]. Others find a direct link between smoking and substantial weight gain [15-25] Others find that a substantial decrease in cigarette smoking has only a small effect on the prevalence of obesity [26,27]. Fang, Ali, and Rizzo [28] reveal a moderately negative relationship between cigarette smoking and BMI, but the negative relationship could be attributable to simultaneity and should be interpreted with caution [29].

Much of the trouble in previous analyses involves lack of an identification strategy or appropriate instrument for endogenous factors. The motivation of initiating and maintaining smoking among adolescent females is quite different than males [30-32]. Weight concerns among adolescent females-who are more concerned with weight than males-may be one such factor [33,34]. More females consider themselves overweight than males [35] and believe that smoking helps control weight [34,36] leading them to use smoking as a method of weight control [37-41].

Studies examining the relationship between BMI and smoking in adults, show that cigarette smokers had a lower BMI. Heavy smokers and never-smokers had similar BMI [42,43]. Nicotine has been found to have slight metabolic effects and suppress appetite [44,45]. In longitudinal analyses, continuing smokers had a smaller increase in BMI than those who gave up smoking [44]. In those who quit smoking, there was a significant, positive relationship between number of cigarettes smoked and the subsequent increase in BMI. The impact of smoking on body weight could dissipate over time. Long-term smokers (20+ years) are heavier than never or former smokers, and heavy smokers are more likely to be obese than other smokers and nonsmokers [46,47].

While smoking is correlated with lower BMI for adults, this trend has not been observed in younger smokers (ages 16-24 years) [48]. The weight control effects of smoking may not be consistent among individuals in their developmental years or in the initial stages of use. Smoking has a reported antiestrogenic effect in youth, which may reduce fat deposition leading to weight loss (Pauly 2008:49).One study finds a positive impact of smoking on youth BMI, but highlights gender differences with females being more likely to initiate smoking and sustaining weight effects thereafter [50].

In additional to the impact on body weight, the motivation for adolescent smoking is also unclear [51,52]. A variety of factors have been identified as possible explanatory factors in use of substances other than smoking [53,54]. Expectancy or trepidation for future events is among the most reliable correlates of substance experimentation, use, abuse, and dependence [53]. Identifying factors that may mediate or moderate the smoking behavior is crucial for guiding the development of enhanced tobacco-control intervention targeting adolescents.

Methodology

The CDC recommends using BMI percentiles-designed to capture the weight status of adolescents upon reaching young adulthood-to classify the body weight of individuals under age 18 and simple BMI values to classify weight of adults. Since respondents are age 12 to 17 in the first panel year, and quickly age beyond 19, BMI or the corresponding categorical ranking was used to classify weight in this analysis. BMI is highly correlated with body fat and can be used to classify individuals as underweight, healthy weight, overweight, or obese using a nationally accepted rubric [14]. Among adults, BMI appears to be a satisfactory measure of body fat especially if comparing across race and ethnicity [55,56].

BMI is assessed using data from the National Longitudinal Survey of Youth 1997 (NLSY97)-a longitudinal panel that follows a sample of 8,984 American youth from 1997 to 2011. After 2011, the survey became biennial. While 2013 and 2015 are publicly available, this study will focus only on those consecutive survey years.

BMI was calculated from self-reported height and weight. To maintain a balanced panel, the sample includes only respondents with a BMI value in each year of the panel. While measurement and misspecification error is a concern in self-reported data, the data was cleaned to remove errant, inconsistent, and illogical values of height and weight. If BMI values were missing due to omitted height, height was imputed from nearby observations wherever possible. Full height is achieved relatively early in the panel; thus, imputations were unlikely to cause bias the sample-4,205 individuals. BMI and other means are listed in Table 1. Minimum BMI minimum is 12.5-underweight-and maximum is 55-overweight or obese-with an average of 25 and 26 for men and women respectively. BMI increases with age due to biological growth and weight gain but rates vary by race and gender [57].

Analysis tests the relationship between BMI and cigarette smoking and are performed separately for men and women due to inherent biological differences and varying growth rates. BMI increases substantially over the panel with biological growth and increases in body fatness (Figure 1). These data are consistent with other samples showing that BMI is comparatively higher among Hispanic males and black females. They also experience steeper growth trajectories (also found by Ogden and Kumar [58]. The proportion of underweight decreased with age among all racial and ethnic groups and BMI levels remained high through adulthood (Figure 1).

Average household size is 3.5 persons, but decreases with age. Seventy-five percent of the sample resides in an urban area, compared to 80 percent of the US population [59]. Dummy variables, northeast and south, represent regional residence, and the income/poverty ratio accounts for income level. Ratios below 1 indicate an income below poverty, while ratios of one or greater indicate income at least at the poverty level. The average ratio in the sample is between five and six-above poverty level. General health score classifies overall health as 1= excellent, 2= very good, 3=good, 4=fair or 5=poor. The higher the rating, the lower the general level of health. On average, men and women rate
their general health as 2 to 3 or “good”. While the survey includes many questions about drinking, smoking, sleep and exercise, much of the data is incomplete or only specified in a handful of panel years. To obtain a valid indicator of adolescent smoking, number of days smoked was chosen as the most completely, accurate measure. Response indicates whether they smoke zero or 1 to 5, 6 to 10, ..., or 26 to 30 days a month. Most respondents indicate that they are non-smokers, smoking zero out of 30 days. Among those who report smoking, the average number of days smoked is between 20 and 21.

Smoking categories correspond to the American Heart Association labels of never-smokers or non-smokers, light smokers, moderate smokers and heavy smokers based on both average number of cigarettes and days smoked. The table below shows the average frequency and proportion of men in women in each weight and smoking category. Most respondents are normal weight or overweight and report being non-smokers. The greatest public health concern lies with the 18 percent of men and 16 percent of women who are both obese and smoke heavily.

Table 2 provides cross frequencies of smoking and weight categories. Most respondents in all weight categories are non-smokers. Between 15 percent of men and 20 percent of women are heavy smokers. There appear to be more underweight and obese heavy smokers than other groups especially for women, but it is difficult draw conclusions based on percentage allocations.

Data are first analyzed using a Hierarchical Generalized Model (HGM). HGMs are appropriate only when the outcome of interest is not normally distributed, such as weight category, an appropriate

![Figure 1: NLSY97: Average Male and Female BMI by Age.](image)

![Table 2: NLSY97: Proportion of Weight Category by Smoking Frequency.](table)

### Table 1: NLSY97: Mean Statistics by Gender.

| Variable          | Male N | Male Mean | Male Std Dev | Male Min | Male Max |
|-------------------|--------|-----------|--------------|----------|----------|
| BMI               | 29,786 | 25.83     | 5.21         | 14.137   | 54.81    |
| Age               | 29,786 | 22.76     | 4.55         | 11       | 32       |
| Black             | 29,786 | 0.22      | 0.41         | 0        | 1        |
| Hispanic          | 29,786 | 0.19      | 0.39         | 0        | 1        |
| South             | 29,786 | 0.36      | 0.48         | 0        | 1        |
| Northeast         | 29,786 | 0.16      | 0.37         | 0        | 1        |
| Urban             | 29,786 | 0.75      | 0.44         | 0        | 1        |
| Household Size    | 29,783 | 3.51      | 1.67         | 1        | 19       |
| Income/Poverty    | 20,842 | 390.09    | 376.71       | 1        | 3,227    |
| General Health    | 29,780 | 1.98      | 0.91         | 1        | 5        |
| Body Perception   | 29,654 | 3.20      | 0.74         | 1        | 5        |
| Days smoked in    | 10,479 | 20.57     | 11.65        | 1        | 30       |
| last 30           |        |           |              |          |          |
| Smoking Category  | 29,786 | 0.81      | 1.20         | 0        | 3        |
| Weight Category   | 29,786 | 1.65      | 0.80         | 0        | 3        |

| Female Variable   | Female N | Female Mean | Female Std Dev | Female Min | Female Max |
|-------------------|-----------|-------------|----------------|------------|------------|
| BMI               | 27,830    | 24.86       | 5.72           | 12.53      | 54.87      |
| Age               | 27,830    | 22.67       | 4.60           | 11         | 32         |
| Black             | 27,830    | 0.25        | 0.43           | 0          | 1          |
| Hispanic          | 27,830    | 0.19        | 0.39           | 0          | 1          |
| South             | 27,830    | 0.38        | 0.49           | 0          | 1          |
| Northeast         | 27,830    | 0.16        | 0.36           | 0          | 1          |
| Urban             | 27,830    | 0.77        | 0.42           | 0          | 1          |
| Household Size    | 27,829    | 3.64        | 1.72           | 1          | 15         |
| Income/Poverty    | 19,597    | 354.29      | 359.84         | 1          | 3,227      |
| General Health    | 27,827    | 2.17        | 0.83           | 1          | 5          |
| Body Perception   | 27,776    | 3.48        | 0.78           | 1          | 5          |
| Days smoked in    | 8,701     | 21.04       | 11.58          | 1          | 30         |
| last 30           |           |             |                |            |            |
| Smoking Category  | 27,830    | 0.73        | 1.17           | 0          | 3          |
| Weight Category   | 27,830    | 1.48        | 0.83           | 0          | 3          |

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error distribution needs to be incorporated into the model. Previously presented by Bell, Ene, Smiley and Schoeneberger, HGM is a two-level organizational model with a polytomous outcome—the BMI category of youth drawn from a nationally representative longitudinal sample of American youth. HGMs accommodate categorical, non-normally distributed response variables. When dealing with this type of model, the assumptions of normally distributed, homoscedastic errors are violated. Therefore, model employs a transformation of the BMI category using a cumulative logit link function and a multinomial distribution. These models are used to assess the relationship between hierarchical BMI categories, smoking and demographic controls.

Research concerning the association between smoking and body weight lacks consistency and has several weaknesses [20,29,22]. For example, estimation of the impact of smoking on body weight, like all statistical models, could be biased unobserved personal characteristics that motivate smoking [60,61].

The absence of a mechanism for modeling the endogeneity of smoking choices has challenged researchers has been confronted in various ways [62]. When the unobservable motivations for smoking are omitted variables correlated with included regressors, standard estimation methods will generally be inconsistent. Though alternative consistent estimators may exist in special circumstances, it is suggested here that a nonlinear instrumental-variable strategy offers a reasonably general solution to such estimation problems. A variety of different instruments have been used to control for smoking decision—Vietnam war draft [63], infant neurodevelopment [64] and schooling and earnings [65]—by utilizing a two-stage, maximum likelihood estimation. While the instruments vary in their exact specification, the incorporate common elements of regional, social, economic and health measures. The instrument in this study follows the same logic. Smoking behavior is instrumented using region, income, age and general health status. The logic of the instrumentation equation is simple—higher smoking rates in the south, high cost of cigarettes and related taxes, and the negative health impacts of cigarette use.

Results

Table 3 lists estimation results from the HGM specification. Since underweight is the reference category, estimates model the probability of having a lower BMI category. The negative age coefficient on indicates that as age increases, respondents have a lower likelihood of having a low BMI category. In other words, BMI increases with age. Most regional and geographic coefficients are insignificant. Smoking is insignificant for females suggesting that as smoking frequency increases, so does the probability of having a lower BMI category.

Table 3: NLSY97: HLG Results by Gender.

| Male | | Female | |
|------|------|------|------|------|
| Value | | Value | | | smoking Category | | | | Observations | | Observations | | |
| 0 | Underweight | 115 | 0 | Underweight | 278 | | | | | | | |
| 1 | Normal Weight | 3,605 | 1 | Normal Weight | 3,353 | | | | | | | |
| 2 | Overweight | 2,602 | 2 | Overweight | 1,419 | | | | | | | |
| 3 | Obese | 1,370 | 3 | Obese | 1,235 | | | | | | | |

Modeling the probability of having a lower BMI Category

| Effect | Male | Female | |
|--------|------|------|------|
| Intercept (Normal) | -1.8481*** | 0.4531 | 0.3189 | 0.4367 |
| Intercept (Over) | 8.1182*** | 0.4526 | 9.7646*** | 0.4825 |
| Intercept (Obese) | 12.1022*** | 0.4905 | 13.2557*** | 0.5149 |
| Smoking | 0.004543 | 0.00459 | 0.008554* | 0.005218 |
| Age | -0.3586*** | 0.01255 | -0.3188*** | 0.01283 |
| South | -0.042 | 0.2053 | -0.1393 | 0.2116 |
| Northeast | 0.2858 | 0.3008 | 0.2843 | 0.2865 |
| Black | 0.1025 | 0.3683 | -3.14*** | 0.4171 |
| Hispanic | -1.3365*** | 0.3669 | -0.8869** | 0.408 |
| Urban | 0.1991 | 0.1122 | -0.1711 | 0.1158 |
| Household Size | 0.01609 | 0.02822 | -0.00449** | 0.03001 |
| logIncome/Poverty | 0.03824 | 0.04167 | 0.0382** | 0.04456 |

Dependent Variable: BMI Category

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Racial and ethnic variables appear highly deterministic. Hispanic males are significantly less likely than white males to be low BMI while black women are less likely to be low BMI, all else held constant. This is consistent with other studies who found that black women and Hispanic men are heavier due, in part, to body size preference [66]. Demographic and socioeconomic factors, such as race, ethnicity and income, contribute significantly to health disparities among adolescents and young adults [67,68]. For women, household size and income are negatively and positively, respectively, related to BMI category, but not among men. Adolescent women in large households are less likely to be low BMI and those with a higher income are more likely.

Results from the two-stage regression are given in Table 4. The first stage regresses age, region of residence, race/ethnicity and household size on smoking and BMI. Results show that older age, being in the South, being Hispanic, and having a higher income are associated with a lower likelihood of being classified as underweight and a higher likelihood of being classified as overweight or obese. The second stage regression shows that smoking is negatively associated with BMI category, with a Wald Chi-Square of 41.761 for smoking. The dependent variable for smoking is defined as the smoking status of the individual. For BMI category, it is defined as follows:

Table 4: NLSY97: 2SLS Results by Gender.

| Stage 1: Analysis of Variance | Stage 1: Analysis of Variance |
|-----------------------------|-----------------------------|
| Source                      | Source                      |
| Sum of Squares              | Sum of Squares              |
| Mean Square                 | Mean Square                 |
| F Value                     | F Value                     |
| Model                       | Model                       |
| 32292                      | 36333                      |
| 8072.9387                  | 9083.3424                  |
| 62.97***                   | 74.41***                   |
| Error                       | Error                       |
| 985309                     | 766511                     |
| 128.21202                  | 122.07538                  |
| Corrected Total             | Corrected Total             |
| 1017601                    | 802845                     |

| Stage 1: Model Fit          | Stage 1: Model Fit          |
| Root MSE                   | Root MSE                   |
| 11.32307                   | 11.04877                   |
| R-Square                   | R-Square                   |
| 0.0317                     | 0.0453                     |
| Dependent Mean             | Dependent Mean             |
| 20.90468                   | 21.65468                   |
| Adj R-Sq                   | Adj R-Sq                   |
| 0.0312                     | 0.0446                     |
| Coeff Var                  | Coeff Var                  |
| 54.15626                   | 51.02257                   |

| Stage 1: Parameter Estimates | Stage 1: Parameter Estimates |
|-----------------------------|-----------------------------|
| Variable                    | Variable                    |
| Parameter                   | Parameter                   |
| Standard                    | Standard                    |
| t Value                     | t Value                     |
| Intercept                   | Intercept                   |
| 13.59121***                | 14.788***                  |
| 1.12                       | 1.17929                    |
| 12.09                      | 12.54                      |
| Age                         | Age                         |
| 0.15279***                 | 0.20625***                 |
| 0.04                       | 0.03884                    |
| 4.12                       | 5.31                       |
| South                       | South                       |
| 2.01406***                 | 2.18845***                 |
| 0.14                       | 0.15085                    |
| 14.28                      | 14.51                      |
| General Health Rating       | General Health Rating       |
| 0.75664***                 | 0.57644***                 |
| 0.27                       | 0.28974                    |
| 2.82                       | 1.99                       |
| logIncome/Poverty           | logIncome/Poverty           |
| -0.19443                   | -0.65774***                |
| 0.12                       | 0.12707                    |
| -1.57                      | -5.18                      |

| Stage 2: Response Category | Stage 2: Response Category |
|---------------------------|---------------------------|
| Category                  | Category                  |
| Range                     | Range                     |
| Frequency                 | Frequency                 |
| Underweight               | Underweight               |
| <=18.5                    | <=18.5                    |
| 115                       | 278                       |
| Normal Weight             | Normal Weight             |
| 18.5<BMI<25               | 18.5<BMI<25               |
| 3604                      | 3535                      |
| Overweight                | Overweight                |
| 25<=BMI<30                | 25<=BMI<30                |
| 2802                      | 1418                      |
| Obese                     | Obese                     |
| >=30.0                    | >=30.0                    |
| 1369                      | 1235                      |

| Stage 2: Model Fit         | Stage 2: Model Fit         |
| Interceptor Only           | Interceptor and Covariates |
| Intercept Only             | Intercept and Covariates   |
| AIC                        | AIC                        |
| 16800.02                   | 14192.721                 |
| 16271.4                    | 13627.4                   |
| SC                         | SC                         |
| 16820.863                 | 14212.959                 |
| 16820.9                   | 13708.4                   |
| -2 Log L                   | -2 Log L                   |
| 16794.020                  | 14186.721                 |
| 16247.4                   | 13603.4                   |

| Stage 2: Parameter Estimates | Stage 2: Parameter Estimates |
|-------------------------------|-------------------------------|
| Variable                      | Variable                      |
| Parameter                     | Parameter                     |
| Standard                      | Standard                      |
| Wald Chi Square               | Wald Chi Square               |
| Intercept_0                   | Intercept_0                   |
| -0.6781***                   | -0.2549                      |
| 0.2238                       | 0.2211                       |
| 9.1798                       | 1.3292                       |
| Intercept_1                  | Intercept_1                  |
| 3.5676***                    | 3.2908***                    |
| 0.211                       | 0.221                       |
| 286.0026                     | 221.8288                     |
| Intercept_2                  | Intercept_2                  |
| 5.2498***                    | 4.4713***                    |
| 0.2157                      | 0.2243                      |
| 592.3094                     | 397.4238                     |
| Smoking                      | Smoking                      |
| 0.0127***                   | 0.00408*                    |
| 0.00197                    | 0.00226                     |
| 41.1761                     | 3.2599                      |
| Age                          | Age                          |
| -0.1223***                  | -0.1123***                  |
| 0.00645                    | 0.00696                     |
| 359.4032                    | 260.5239                    |
| Black                        | Black                        |
| 0.0538                     | 0.00575                     |
| 0.0552                      | 0.0109                      |
| Hispanic                    | Hispanic                    |
| -0.0339                     | 0.0997                      |
| 0.0633                     | 0.0698                     |
| 0.286                      | 2.0381                      |
| Urban                       | Urban                       |
| -0.1945***                  | -1.0698***                  |
| 0.0618                     | 0.0701                     |
| 9.9102                     | 232.901                     |
| South                       | South                       |
| -0.4853***                  | -0.3454***                  |
| 0.0623                     | 0.0714                     |
| 60.7172                     | 23.4023                     |
| Household Size              | Household Size              |
| -0.017                     | -0.0575***                  |
| 0.0138                     | 0.0151                     |
| 1.5104                     | 14.5525                     |
| logIncome/Poverty           | logIncome/Poverty           |
| -0.1***                    | 0.0241                     |
| 0.0216                     | 0.0229                     |
| 21.3912                     | 1.1074                      |

Significance: * = 10%, ** = 15%, *** = 1%
size, and income-poverty ratio on smoking frequency. Stage 1 results show all covariates significant for females and most for males. Smoking frequencies increase with age, southern residence and general health. An increase in smoking—a probable cause of poor health—corresponds to a poorer health rating, all else held constant. Income has an inverse relationship with smoking frequency indicating the smoking rates decline as income increases. The residuals from Stage 1 are retained and used to approximate smoking frequency in Stage 2. The Stage 2 regression model is run as a categorical dependent variable model with the created instrument. The instrumented value appears to be a valid instrument and is highly correlated with BMI category.

Consistency of results reinforces the strength of the relationship between smoking and body weight and suggests that any endogeneity bias is not a substantially problem. Smoking frequency is negatively related to weight, but age and race/ethnicity are positively related. Minority groups have a lower probability of being in a low weight category—a sensible result given that they tend to have high average BMI. As expected, the probability of low BMI decreases with age for men and women, but increases with household size among women. Men have a negative correlation between weight and income.

There appears to be a relationship between BMI and smoking, but does it vary with age? Young adults and adolescents might behave or respond differently to external stimuli. To test the robustness of the HGM and 2SLS models to age and BMI changes, models were run separately at three different points in the age distribution—age 12 to 17, 20 to 25 and 27 to 32. Results are listed in Appendix I. As males age, smoking increases in significance become more deterministic. For females, the opposite occurs—there is a strong relationship between BMI category and smoking for that age 12 to 17, but it decreases with age.

Discussion and Conclusion

This paper addresses the following research areas:

1. How prevalent is overweight among males and females during the adolescent years?
2. Does this prevalence vary across demographic/household/geographic characteristics?
3. What is the relationship between smoking frequency and BMI?
4. Does the relationship between smoking and BMI change between adolescence and young adulthood?

Analysis showed that males and females gain weight with age and obesity/overweight become more prevalent over time. Smoking rates remain low, but persist steadily throughout adolescence. Household and geographic patterns play little role in BMI determination. Race, age and ethnicity are highly deterministic and positive—older and minority respondents have comparatively higher BMI. Household size plays a small role for females and income for males.

Finally, smoking and BMI are inversely related—lower BMI respondents smoke more. Higher BMI respondents tend to be light or non-smokers. When similar analysis was conducted in young, middle and older adolescents, males showed that the relationship between BMI and smoking frequency became stronger over time while women showed that smoking frequency became less deterministic. Causality falls outside the scope of the analysis, but reports show significantly higher smoking rates among men, but faster BMI increases among women. Therefore, both female smokers and non-smokers are likely to be increasing BMI more rapidly and the differential between the two groups could narrow. The disparity between male smokers and non-smokers could be growing as more males continue to smoke later in life or are unsuccessful quitters. This analysis shows a significant behavioral impact on BM, but the age-related relationship for men and women merits further analysis.

Significance for Public Health Research

While the weight lowering effects if cigarette smoking among adults is well documented, results among adolescents have been mixed. Previous studies have been plagued by the endogeneity of smoking in weight growth studies. This study overcomes these difficulties by utilizing both standard hierarchical generalized regression and instrumental variables. Both models confirm the negative relationship between BMI and smoking frequency but show that the strength of the relationship varies as adolescents age. The strong age variation explains the mixed results found in earlier works. Understanding the cause behind adolescent weight disparities has important public health implications for designing and tailoring intervention programs.

Ethical Approval Disclosure

This manuscript does not contain any studies with human participants or animals performed by the author.

References

1. Flegal KM, Graubard BI, Williamson DF, Gail MH. Cause-Specific Excess Deaths Associated with Underweight, Overweight, and Obesity. JAMA: Journal of the American Medical Organization. 2007; 298: 2028-2037.
2. Mokdad AH, Serdula MK, Dietz WH, Bowman BA, Marks JS, Koplan JP. The Spread of the Obesity Epidemic in the United States, 1991-1998. JAMA: Journal of the American Medical Association. 1999; 282: 1519-1522.
3. Cunningham S, Kramer M, Narayan K. Incidence of childhood obesity in the United States. The New England Journal of Medicine. 2014; 3: 403-411.
4. Gottmaker S, Taveras E. Who becomes obese during childhood-Clues to prevention. New England Journal of Medicine. 2014; 370: 475-476
5. World Health Organization. Global strategy on diet, physical activity and health. Childhood overweight and obesity. 2014a.
6. Singh T, Arrozola RA, Corey CG, Husten CG, Neff LJ, Homa DM. Tobacco Use Among Middle and High School Students - United States, 2011-2015. Morbidity and Mortality Weekly Report. 2016; 65: 361-367.
7. Johnston L, O'Malley P, Miech R, Bachman J, Schulenberg J. Monitoring the Future national survey results on drug use, 1975-2016: Overview, key findings on adolescent drug use. Ann Arbor, MI: Institute for Social Research, The University of Michigan. 2017.
8. Kann L, McManus T, Harris WA, Shanklin SL, Flint KH, Hawkins J, et al. Youth Risk Behavior Surveillance-United States, 2015. MMWR Surveillance Summaries. 2016; 65: SS-6.
9. Department of Health and Human Services. (2015). Results from the 2014 National Survey on Drug Use and Health: Detailed Tables. Tables 2.52B, 2.53B. Rockville, MD: U.S. Department of Health and Human Services, Substance Abuse and Mental Health Services Administration, Center for Behavioral Health Statistics and Quality.
10. Roberto C, Swinburn B, Hawkes C, Huang T, Costa S, Ashe M, et al. Patchy progress on obesity prevention: Emerging examples, entrenched barriers, and new thinking. The Lancet. 2015; 385: 2400-2409.

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11. Swinburn BA, Sacks G, Hall KD, McPherson K, Finegood DT, Moodie ML, et al. The global obesity pandemic: Shaped by global drivers and local environments. The Lancet. 2011; 378: 804-814.

12. Johnson F, Cooke L, Croker H, Wardle J. Changing perceptions of weight in Great Britain: Comparison of two population surveys. British Medical Journal. 2008; 337: a494.

13. Chou SY, Grossman M, Saffer H. "An Economic Analysis of Adult Obesity: Results from The Behavioral Risk Factor Surveillance System" Journal of Health Economics. 2004; 23: 565-587.

14. Flegal KM, Shepherd JA, Looker AC, Graubard BI, Borred LG, Ogden CL, Harris TB, et al. "Comparisons of Percentage Body Fat, Body Mass Index, Waist Circumference and Waist-Stroke Ratio in Adults." American Journal of Clinical Nutrition. 2009; 89: 500-508.

15. Coates TJ, Li V. "Does Smoking Cessation Lead to Weight-Gain: The Experience of Asbestos-Exposed Shipyard Workers" American Journal of Public Health. 1983; 73:1303-1304.

16. Manley RS, Boland FJ. "Side-Effects and Weight-Gain Following a Smoking Cessation Program" Addictive Behaviors. 1983; 8: 375-380.

17. Klesges RC, Ward KD, Ray JW, Catter G, Jacobs DR Jr, Wagenknecht LE. "The Prospective Relationship between Smoking and Weight in a Young, Biracial Cohort: The Coronary Artery Risk Development in Young Adults Study" Journal of Consulting and Clinical Psychology. 1998; 66: 983-993.

18. Froom PS, Melamed J Benbassat. "Smoking Cessation and Weight Gain" Journal of Family Practice. 1998; 46: 460-464.

19. Froom P, Kristal-Boneh E, Melamed S, Gofer D, Benbassat J, Ribak J. "Smoking Cessation and Body Mass Index of Occupationally Active Men: The Israeli CORDIS Study" American Journal of Public Health. 1999; 89: 718-722.

20. Shimokata H, Muller DC, Andres R. Studies in the Distribution of Body Fat: Effects of Cigarette Smoking" JAMA: Journal of the American Medical Association. 1989; 261:1169-1173.

21. Moffatt RJ, Owens SG. "Cessation from Cigarette Smoking: Changes in Body Weight, Body Composition, Resting Metabolism and Energy Consumption" Metabolism. 1991; 40:465-470.

22. Williamson DF, Madans J, Anda RF, Kleinman JC, Giovino GA, Byers T. Smoking Cessation and Severity of Weight Gain in a National Cohort. New England Journal of Medicine. 1991; 324:739-745.

23. Klesges RC, Winders SE, Meyers AW, Eck LH, Ward KD, Hultquist CM. "How Much Weight Gain Occurs Following Smoking Cessation? A Comparison of Weight Gain Using Both Continuous and Point Prevalence Abstinence" Journal of Consulting and Clinical Psychology. 1997; 65: 286-291.

24. Klesges RC, Meyers AW, Klesges LM, La Vasque ME. "Smoking, Body Weight, and Their Effects on Smoking Behavior: A Comprehensive Review of the Literature". Psychological Bulletin. 1989; 106:204-230.

25. Hudmon K, Gritz E, Clayton S, Nisenbaum R. "Eating Orientation, Postcessation Weight Gain, and Continued Abstinence among Female Smokers Receiving an Unsolicited Smoking Cessation Intervention". Health Psychology. 1999; 18: 29-36.

26. Flegal KM, Troiano RP, Pamuk ER, Kuczmarski RJ, Campbell SM. "The Influence of Smoking Cessation on the Prevalence of Overweight in the United States". New England Journal of Medicine, 1995; 333:1165-1170.

27. Eisenberg D, Quinn B. Estimating the Effect of Smoking Cessation on Weight Gain: An Instrumental Variable Approach. Health Services Research. 2006; 41: 2255-2266.

28. Fang H, Ali M, Rizzo J. Does Smoking Affect Body Weight and Obesity in China? Economics and Human Biology. 2009; 7: 334-350.

29. Yen S, Chen Z, Eastwood D. Lifestyles, Demographics, Dietary Behaviors, and Obesity: A Switching Regression Analysis. Health Services Research. 2009; 44: 1345-1369.

30. Fullerton J, French S. Cigarette smoking for weight loss control among adolescents: Gender and racial/ethnic differences. Journal of Adolescent Health. 2003; 32: 306-313.

31. Potter BK, Pederson LL, Chan SS, Aubut JA, Koval JJ. Does a relationship exist between body weight, concerns about weight, and smoking among adolescents? An integration of the literature with an emphasis on gender. Nicotine and Tobacco Research. 2003; 6: 397-425.

32. Virdine J, Anderson C, Pollak K, Wetter D. Gender differences in adolescent smoking: Mediator and moderator effects of self-generated expected smoking outcomes. American Journal of Health Promotion. 2006; 20: 383-387.

33. Attie I, Brooks-Gunn J, editors. Weight concerns as chronic stressors in women. Free Press; NY: 1987.

34. George VA, Johnson P. Weight loss behaviors and smoking in college students of diverse ethnicity. American Journal of Health Behavior. 2001; 25: 115-125.

35. Winter A, de Guia N, Ferrence R, Cohen J. The relationship between boy weight perceptions, weight control behaviors and smoking status among adolescents. Canadian Journal of Public Health. 2002; 93: 362-365.

36. Klesges R, Elliott V, Robinson L. Chronic dieting and the belief that smoking controls body weight in a biracial, population-based adolescent sample. Tobacco Control. 1997; 6: 89-94.

37. Camp DE, Klesges RC, Relyea G. The relationship between body weight concerns and adolescent smoking. Health Psychology. 1993; 12: 24-32.

38. French, S, and C Perry. Smoking among adolescent girls: Prevalence and etiology. Journal of the American Medical Women’s Association. 1996; 51: 25-28.

39. French S, Perry C, Leon G, Fullerton J. Weight concerns, dieting behavior, and smoking initiation among adolescents: A prospective study. American Journal of Public Health. 1994; 84: 1818-1820.

40. Gerend M, Boyle R, Peterson C, Hatsu kami D. Eating behavior and weight control among women using smokeless tobacco, cigarettes, and normal controls. Addictive Behaviors. 1998; 23: 171-178.

41. Klesges R, Mizes J, Klesges L. Self-help dieting strategies in college males and females. International Journal of Eating Disorders. 1987; 6: 409-417.

42. Jesser A, Buemann B, Toubro S, Skovgaard IM, Astrup A. The appetite suppressant effect of nicotine is enhanced by caffeine. Diab etes, Obesity and Metabolism. 2005; 7: 327-333.

43. Sneve M, Jorde R. Cross-sectional study on the relationship between body mass index and smoking, and longitudinal changes in body mass index in relation to change in smoking status: the Tromso Study. Scandinavian Journal of Public Health. 2008; 36: 397-407.

44. Perkins K, Espstein L, Stiller R, Sexton J, Jacob R. Metabolic effects of nicotine in smokers and non-smokers. NIDA Research Monograph Index. 1989; 95: 469-470.

45. Kvaavik E, Meyer H, Tverdal A. Food habits, physical activity and body mass index in relation to smoking status in 40-42-year-old Norwegian women and men. Journal of Preventive Medicine. 2004; 38: 1-5.

46. Chiolerio A, Jacot-Sadowski I, Faeh D, Paccaud F, Cornuz J. Association of cigarettes smoked daily with obesity in a general adult population. International Journal of Obesity. 2007; 15: 1311-1318.

47. Clair C, Chiolerio A, Faeh D, Cornuz J. Dose-dependent positive association between cigarette smoking, abdominal obesity and body fat: cross-sectional data from a population-based survey. BMC Public Health. 2011; 11: 23.

48. Mackay DF, Gray L, Pell JP. Impact of smoking and smoking cessation on overweight and obesity: Scotland-wide, cross-sectional study on 40,036 participants. BMC Public Health. 2013; 13: 348.

49. Windham GC, Mitchell P, Anderson M, Lasley BL. Cigarette smoking and effects on hormone function in premenopausal women. Environmental Health Perspectives. 2005; 113: 1285-1290.
50. Young K, Graff M, North K, Richardson A, Mohlike K, Lange L, et al. Interaction of smoking and obesity susceptibility loci on adolescent BMI: The National Longitudinal Study of Adolescent to Adult Health. BMC Genetics. 2018; 16: 131.

51. Harris KM, Gordon-Larsen P, Chantala K, Udry JR. Longitudinal trends in race/ethnic disparities in leading health indicators from adolescence to young adulthood. Archives of Pediatric Adolescent Medicine. 2006; 160: 74-81.

52. Dierker L, Merelstein R. Early emerging nicotine-dependence symptoms: A signal of propensity for chronic smoking behavior in adolescents. Journal of Pediatrics. 2010; 156: 818-822.

53. Tyas S, Pederson L. Psychosocial factors related to adolescent smoking: A critical review: A critical review of the literature. Tobacco Control. 1998; 7: 409-420.

54. Anderson CB, Pollak KI, Wette DW. Relations between self-generated positive and negative expected smoking outcomes and smoking behavior: An exploratory study among adolescents. Psychology of Addictive Behavior. 2002; 16: 196-204.

55. Burkhauser RV, Cawley J. Beyond BMI: The Value of More Accurate Measures of Fatness and Obesity in Social Science Research. Journal of Health Economics. 2008; 27: 519-529.

56. Mei Z, Grummer-Strawn LM, Pietrobelli A, Goulding A, Goran MI, Dietz WH. Validity of body mass index compared with other body-composition screening: Indexes for the assessment of body fatness in children and adolescents. American Journal of Clinical Nutrition. 2002; 75: 978-985.

57. Gallagher D, Visser M, Sepulveda D, Pierson RN, Harris T, Heymsfield SB. How useful is Body Mass Index for Comparison of Body Fatness across Age, Sex and Ethnic Groups. American Journal of Epidemiology. 1996; 143: 228-239.

58. Kumar BN, Holmboe-Ottesen G, Lien N, Wandel M. Ethnic differences in body mass index and associated factors of adolescents from minorities in Oslo, Norway: a cross-sectional study. Public Health Nutrition. 2004; 7: 999-1008.

59. American Community Survey 2011-2015.

60. Leigh JP, Schembri M. Instrumental Variables Technique: Cigarette Price Provided Better Estimate of Effects of Smoking on SF-12. Journal of Clinical Epidemiology. 2004; 57: 284-293.

61. French MT, Popovici I. That Instrument is Lousy! In Search of Agreement When Using Instrumental Variables Estimation in Substance Use Research. Health Economics. 2011; 20: 127-146.

62. Kasteridis P, Yen ST. Smoking Cessation and Body Weight: Evidence from the Behavioral Risk Factor Surveillance Survey. Health Services Research. 2012; 47: 1580-1602.

63. Walique D. Does education affect smoking behaviors? Evidence using the Vietnam draft as an instrument for college education. Journal of Health Economics. 2007; 26: 877-895.

64. Wehby GL, Prater K, McCarthy AM, Castilla EE, Murray JC. The Impact of Maternal Smoking during Pregnancy on Early Child Neurodevelopment. Journal of Human Capital. 2011; 5: 207-254.

65. Angrist J, Imbens G. Two-Stage Least Squares Estimation of Average Causal Effects in Models with Variable Treatment Intensity. Journal of the American Statistical Association. 1995; 90: 431-442.

66. Cachelin FM, Rebeck RM, Chung GH, Pelayo E. Does Ethnicity Influence Body-Size Preference? A Comparison of Body Image and Body Size. Obesity Research. 2002; 10: 159-166.

67. Eberhard M. Rural health of black Americans, a complex frontier. In: Livingston I, ed. Praeger Handbook of Black American Health (2nd Edition): Policies and Issues Behind Disparities in Health. Westport, Conn: Praeger Publishers. 2004.

68. Pamuk E, Makuc D, Heck K, Reuben C, Lochner K. Health, United States, 1998 with Socioeconomic Status and Health Chartbook. Hyattsville, MD: National Center for Health Statistics. 1998.