NICOTINE DEPENDENCE AND SOCIOECONOMIC STATUS IN HARD CORE SMOKERS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

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2006

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ABSTRACT

Cigarette smoking is the leading cause of preventable death in the United States and extensive scientific evidence has been reviewed to determine its causation of multiple diseases. Nicotine dependence is recognized as a determinant in the maintenance of smoking and the inability to quit. Hard core smokers have been suggested as having increased nicotine dependence and little probability of quitting. Inequalities in cigarette smoking prevalence exist, with smokers more likely to be poor and less educated. Higher socioeconomic status is associated with higher quit rates. Evidence of a social gradient in nicotine dependence has been demonstrated among smokers residing in the United Kingdom.

A secondary data analysis using the 1999-2002 National Health and Nutrition Examination Survey data, a cross sectional health survey of a nationally representative sample of the noninstitutionalized U.S. population. The first two objectives included characterization of variables associated with smoking status (hard core, non-hard core and former smoker) and examining the relationship between current smokers and nicotine dependence, based on serum cotinine
and time to first cigarette. Respondents were age 26 and older. The last objective included examining the existence of a social gradient in nicotine dependence in an American population and determining if this was associated with race/ethnicity and gender.

Our results supported the existence of hard core smokers. Factors associated with nicotine dependence among all current smokers included male gender, younger age, and race. Hard core smoking was associated with having greater nicotine dependence, as measured by time to first cigarette or serum cotinine levels. A social gradient in the American population as a whole was not observed. A reverse social gradient was observed in non-Hispanic black males and females. Findings were intriguing and challenging to interpret. Social determinants experienced by advantaged blacks, such as increased stress and decreased control, possibly contribute to the positive relationship between nicotine dependence and socioeconomic status.
ACKNOWLEDGMENTS

I wish to thank my advisor, Dr. Mary Ellen Wewers, for her support and guidance throughout my graduate program. I am grateful to Mary Ellen for her encouragement, patience and availability, and realize her dedication allowed me to achieve goals previously thought unattainable. Her willingness to read countless drafts and offer suggestions for revisions enabled my writing style to become more mature. Her compassion and understanding were welcomed. I honestly could not have done this without her.

I am indebted to Dr. Amy Ferketich’s patience and help in analyzing the data using SAS. Amy’s support through countless emails exchanged nights and weekends was critical in meeting my deadline. This study could not have been conducted without her willingness to disseminate her knowledge of SAS.

I appreciate the continued professional support of Dr. Pamela Salsberry. Pam initially introduced me to SAS and the NHANES. Her questions and insight provided the foundation of my knowledge and understanding of socioeconomic status and how it is measured, a concept central to my research, as well as race and ethnicity.
I have been very fortunate to work with such a dedicated dissertation committee who provided exemplary examples of educators and researchers.

The training required for this research project was supported by a predoctoral fellowship from Mary Margaret Walther Program, Behavioral Cooperative Oncology Group, as well the Excellence in Research Award from Theta Theta Chapter of Sigma Theta Tau.
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CHAPTER 1

INTRODUCTION

Cigarette smoking is the leading cause of preventable death in the United States.\textsuperscript{1} Extensive scientific evidence has been reviewed to determine its causation of multiple diseases, producing substantial health-related costs to society including smoking-attributable mortality, years of potential life lost, smoking-attributable medical expenditures, and lost productivity costs for adults.\textsuperscript{1-2} Healthcare costs at a given age are as much as forty percent higher for smokers compared to nonsmokers.\textsuperscript{3} Half of all continuing cigarette smokers will ultimately be killed by their behavior if they do not give it up,\textsuperscript{4} whereas the benefits of cessation begin within a year.\textsuperscript{5} Adult cigarette smoking prevalence in the United States has fallen steadily, from 37.4\% in 1970 to 22.5\% in 2002, and approximately one half of ever smokers have quit.\textsuperscript{6-7} However, the pace of the decline is insufficient to meet the 2010 goal of ≤ 12\%.\textsuperscript{6}

Burns and Warner\textsuperscript{8} raise the question whether “those smokers who are left behind” differ in their ability to achieve abstinence compared to those who have quit. The “hardening” hypothesis centers around the belief that the remaining smokers targeted for cessation are hardening, becoming more
resistant to quitting.\textsuperscript{9-10} Intuitively these smokers are more nicotine dependent, as high dependence predicts low rates of cessation.\textsuperscript{9} Those who could quit relatively easily have already done so.\textsuperscript{10-11} Hard core smokers (HCS) have been described as individuals who smoke more heavily and are more dependent.\textsuperscript{11-14}

There is little probability of HCS quitting, despite four decades of health warnings, increasing restrictions on smoking in public places, and the growing stigmatization of smoking.\textsuperscript{10, 14} HCS are especially vulnerable to the consequences of cigarette smoking, because of their substantial exposure to cigarette smoking, through increased pack years. Quitting earlier is associated with increased benefit because of the decreased exposure.\textsuperscript{4} Smoking cessation reduces the risk of dying from smoking attributable diseases, thereby increasing life expectancy.\textsuperscript{2} The increased vulnerability to the many devastating health outcomes from cigarette smoking explains why the HCS population needs greater characterization so effective cessation interventions may be developed.

No generally accepted definition of HCS exists, and several definitions have been used in the literature.\textsuperscript{10-13, 15-16} A synthesis of these definitions includes: 1) Age 26 and older; 2) Smoking \geq 15 CPD; 3) Current daily cigarette smokers for a minimum of 5 years; 4) No quit attempts in past year; and 5) No future intent to quit.\textsuperscript{10-13, 15-16} Younger individuals are excluded since they may still be in the smoking uptake process, and therefore have not achieved a stable level of average daily consumption or solidified their quitting intentions.\textsuperscript{13}
Nicotine Dependence

Smoking consists of multivariate dimensions, including nicotine dependence. Nicotine dependence is recognized as a determinant in the maintenance of smoking and inability to quit.\textsuperscript{10, 17} The term nicotine dependence is preferred over tobacco dependence because abundant scientific evidence is available to document the addictive quality of nicotine.\textsuperscript{18} Disagreement and a lack of a clear definition of dependence has plagued tobacco research partially related to not knowing the precise causes of nicotine dependence, despite existing evidence indicating involvement of both environmental and genetic factors.\textsuperscript{18-20} The Multiple determinants making up smoking behavior, including biological, psychological, and social, among others, are interdependent among themselves.\textsuperscript{19} The complexity and often overlapping definitions contribute to this dilemma.

George and O'Malley\textsuperscript{21} define nicotine dependence as daily smoking, evidence of tolerance (e.g. lack of aversive effects such as nausea) and the presence of symptoms of withdrawal, such as anxiety, irritability, decreased heart rate, insomnia, increased appetite and craving for cigarettes. Additionally, dependent smokers typically smoke their first cigarette within 30 minutes of wakening.\textsuperscript{21}

How is nicotine dependence measured? Hughes\textsuperscript{9} argues the validity of how nicotine dependence is measured as the major issue in assessing evidence for the hardening hypothesis. One measure of nicotine dependence is cigarettes
per day (CPD), however, it is not always valid; other factors such as cost, smoking topography or puffing characteristics, and home/worksite restrictions can all affect CPD.\textsuperscript{5,9} CPD also has a nonlinear correlation with actual nicotine intake.\textsuperscript{15} The Fagerstrom tests (FTQ, FTND) are the most widely used measures of nicotine dependence.\textsuperscript{9} Time to first cigarette of the day (TTF), an item on the Fagerstrom tests, is an important factor in nicotine dependence, given the relatively short plasma half-life of nicotine. Nicotine is typically depleted from the blood upon waking in the morning, and dependent smokers may face discomfort from withdrawal symptoms until they smoke their first cigarette of the day.\textsuperscript{22-23} Of the items on the Fagerstrom tests, TTF carries the most predictive power and predictive validity.\textsuperscript{9}

An excellent biomarker for tobacco exposure and nicotine dependence is cotinine, the major metabolite of nicotine, which can be measured in plasma, saliva and urine.\textsuperscript{24} While cotinine represents a marker of current tobacco use, it also allows for characterization of degree of nicotine dependence. Cotinine is currently the gold standard for both quantifying tobacco exposure and nicotine dependence in research, with the advantage of a significantly longer half life of 17-20 hours over other biochemical indices.\textsuperscript{25-30} Cotinine is oxidized primarily by CYP2A6 and excreted unchanged in the urine,\textsuperscript{28} and is an indirect measure of recent exposure to cigarette smoke, with greater sensitivity and specificity than other biochemical tests, and a high reported correlation with nicotine clearance.
This contributes to cotinine’s face validity as a measure of nicotine dependence. \(^{17}\) A statistically significant linear association between cotinine and the scores of the Fagerstrom test, including TTF cigarette, has also been reported. \(^{23-24, 31-32}\)

Besides nicotine dependence, several variables, including lower income and lower education level, predict lower rates of cessation, suggesting future smokers are more likely to be poor. \(^{9}\) Poorer people lack not only sufficient income but material goods and the means for social participation. \(^{33}\) It is suggested that disadvantaged persons have increased nicotine dependence, therefore making up a larger portion of those smokers considered hard core.

**Socioeconomic status, nicotine dependence and cigarette smoking:**

A considerable body of research indicates inequalities in health are not explained by socioeconomic status (SES) alone, and that interconnected pathways, including psychosocial factors, may play a large role. \(^{34}\) A conceptual framework of the relationships between SES, psychosocial factors (including health practices, social ties, perceptions of control and affective states), and medical care related to health outcomes has been described. \(^{35}\) In this conceptual framework described by Williams, \(^{35}\) SES is a significant determinant of health status, while also directly influencing psychosocial factors. Psychosocial factors, utilized as mediators, are pathways through which the effects on individuals and health are seen. \(^{35}\) Williams posits health practices, including
cigarette smoking, are incorporated under psychosocial factors, and that lower SES-persons have both increased exposure and increased vulnerability to these risky health practices. These components may have direct and interactive effects on health outcomes, with psychosocial factors and medical care potentially having reciprocal action also. A need for future studies including the three major pathways of this model has been identified and the possibility for this model to guide a program of research has been proposed. The current research will focus on a fuller characterization of the relationship between SES and hard core smoking, recognizing that psychosocial factors, such as social ties and affective states, may mediate this association.

Figure 1.1: William’s Conceptual Framework

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The relationship between low SES and poor health, as measured by morbidity and mortality rates, is well established. Unfortunately, there is no agreed upon definition of SES. The most frequently used measures of SES include education and income. Education shapes future occupational opportunities and earning potential, while also providing knowledge and life skills, thus allowing easier access to information and resources to promote health. Education, typically completed in early adulthood, serves as a marker of early life circumstances, although it fails to capture on-the-job-training and other career investments. Income serves not only as an indicator of material resources versus disadvantage, such as the ability to afford health insurance and health care, housing and recreation, and better nutrition (as evidenced by secure and consistent access to nutritious foods, i.e. food security). Income is also used as a level of prestige. Household income, a widely used indicator of SES in the U.S., is more indicative of a standard of living.

Marmot argues low socioeconomic status, i.e. poverty, is more complex than simply a lack of money. “Poor people have worse health not because they have insufficient money but for some other reason,” suggesting income may have a direct effect on material conditions necessary for positive health outcomes, such as social participation and the opportunity to control life circumstances. Indicators of SES provide information about access to social and economic resources. Social inequalities, a key public health problem, are evidenced not only in significant differences between the top and
bottom of society’s social structure but also in a social gradient. Position in this hierarchy, demonstrated in the British Whitehall Studies, is strongly correlated with mortality risk. Persons with the highest poverty rates also have the worst health status.

Inequalities in smoking prevalence exist, as evidenced by persistent class-based disparities and the growing number of smokers in the lower socioeconomic groups. In the beginning, those of higher education levels and socioeconomic status were more likely to smoke cigarettes, however, since the first Surgeon General’s report in 1964 the profile of cigarette smokers has reversed. Cigarette smokers now are more likely to be poor and less educated. The well educated may have higher levels of health literacy, therefore allowing the development of health-promoting and disease prevention behaviors and beliefs. Additionally, the poor may have the least information on the health risks of smoking, the fewest resources, the fewest social supports and the least access to cessation services. Socioeconomic disadvantage is associated with persistent smoking, and higher rates of cessation are associated with higher socioeconomic status. Healthy People 2010’s second goal is to eliminate health disparities among segments of the population, including those with inequalities in income and education.
Psychosocial Factors and Cigarette Smoking

Why are the socioeconomically disadvantaged the least likely to give up cigarettes? It is the association with persistent smoking, and not so much initiation that needs explanation.\textsuperscript{13} Consequently the burden of smoking-related disease falls disproportionately on this population.\textsuperscript{13} Nicotine dependence is the major barrier to quitting from an addiction perspective. Smoking cessation may be particularly difficult for poor people for several reasons, including high nicotine dependence. Physiological and psychological withdrawal symptoms are caused by its deprivation.\textsuperscript{12} Nicotine sufficiently “rewards” smokers to maintain self-administration.\textsuperscript{49} The positive effects produced from nicotine, and an improvement from or a prevention of withdrawal symptoms, only further reinforce smoking.\textsuperscript{50} Nicotine is considered “psychoactive” because its effects on affect and mood are similar to other psychoactive drugs. These psychoactive effects, evidenced by nicotine’s reliable discrimination from placebo, and its reinforced behavior are intertwined.\textsuperscript{51}

Disadvantaged persons may use cigarette smoking to self-medicate, in an attempt to regulate depression, and manage stress and coping resulting from material deprivation.\textsuperscript{13,52} Associations between cigarette smoking and psychiatric disorders, including depression, anxiety disorder and panic disorder, have been reported, with a higher prevalence of smoking from the general population.\textsuperscript{53-54} Evidence exists linking nicotine intake with reductions in negative affect, suggesting individuals afflicted with a psychiatric disorder may have an increased
motivation to smoke.\textsuperscript{55} It is no surprise that past or present depression is associated with failure in quitting smoking.\textsuperscript{54} This suggests hard core smokers may be more likely to have a higher prevalence of affective disorders as compared to other smokers, and this knowledge would directly impact cessation techniques targeting this population.

Fewer social ties are reported by persons of lower socioeconomic classes.\textsuperscript{56} Social support is constructed from informal networks of social ties,\textsuperscript{35} and research has consistently shown an inverse relationship between social support and all cause mortality.\textsuperscript{57} This extends to health damaging behaviors such as smoking.\textsuperscript{57} Graham\textsuperscript{52} suggests smoking serves as a mechanism to participate in society, and this is despite loneliness resulting from financial barriers to a social life. “Smoking acts as both luxury and necessity when material and human resources are stretched”. (\textsuperscript{52}, p. 55)

Social support directly and indirectly affects health, acting as a mediator or buffer. This may help explain the protective effects associated with social support.\textsuperscript{58-59} The relationship between social support and SES-related health disparities has been investigated.\textsuperscript{56} The literature suggests health status may be modified by a variety of protective factors, including social ties. Social support includes real or perceived resources and social relationships, including family, friends or organizations, providing companionship and assistance with daily activities.\textsuperscript{35} Research has reported a better quality of life is associated with having social support.\textsuperscript{60} HCS may have less social support compared to other smokers, influencing their motivation to quit.
Specific Aims

The specific aims of this study sought to increase knowledge about the hard core smoking population. The purpose of the first specific aim was to characterize variables associated with hard core smokers (HCS), current smokers (CS), and former smokers (FS). The second specific aim examined the relationship between smoking status, HCS or CS, and nicotine dependence. It was hypothesized HCS would have higher nicotine dependence, as measured by serum cotinine and TTF cigarette. The third and final aim examined the existence of a relative gradient between socioeconomic status and the level of nicotine dependence, as measured by serum cotinine, in HCS and CS (FS were excluded).

Research Methods and Design

The National Health Survey act was passed in 1956, authorizing the collection of statistical data to assess the health of Americans. To comply, three national health examinations were conducted in the 1960's. Increasing evidence of the link between dietary habits and disease discovered by researchers led to a new emphasis in 1970 and the National Health And Examination Survey (NHANES) was born. It became a continuous program in 1999, obtaining approximately 7,000 people each year to form a nationally representative sample. Respondents of all ages were randomly selected from 15 locations.
Oversampling occurs with older Americans, defined as those greater than age 60, as increasing the knowledge of the health status of older Americans is critical. The dramatic growth in this population has major implications for healthcare needs, public policy and research priorities. African Americans and Mexican Americans are also oversampled.61

Survey Operations:

The health interviews for the NHANES were conducted in respondents' homes. The interviewers use computer assisted personal interviewing (CAPI), which are notebook computers with electronic pens, nearly eliminating the need for paper forms and manual coding operations. The data are transmitted automatically into databases through digital scales and stadiometers. Respondents enter their own responses to certain sensitive questions in complete privacy, allowed by touch-sensitive computer screens.62 In eligible households a signed interview consent form for each respondent to the medical history and/or the family questionnaire is obtained. Consent forms for each survey respondent are also obtained.61

Participation in the NHANES is encouraged in several ways. Interviewers conduct reminders of medical examination appointments and assist with rescheduling broken appointments. Transportation is provided to and from the examination center. Babysitting expenses and adult day care incurred during the examination are reimbursed. Compensation is not provided for completing the
 household questionnaire and all respondents are invited to participate in the mobile examination center (MEC) exam. However, compensation, as well as a report of medical and dental findings, was provided upon completion of the MEC exam. An incentive of $70 was given to each examined adult. Random assignment to either a fasting or nonfasting examination session occurred, and an additional $30 could be earned for going to the correct session. Additional components completed after the examination had incentives ranging from $30- $50.63

Information collected is kept strictly confidential, with privacy protected by public laws. Home exams were offered immediately following the interview for all respondents 50+ confined to their homes. The home exam had fewer requirements than the MEC exam, including a shorter duration, increased flexibility in scheduling, and minimal blood work. Fasting was required for only six hours and never overnight. These were designed to substantially reduce the respondent burden.61

Institutional Review Board (IRB) Approval:

The NHANES Protocol #98-12 was reviewed and approved by the National Center for Health Statistics (NCHS) IRB before data collection in 1999. IRB has conducted annual reviews and approved continuations of the protocol since then. No further approvals were required as no respondents were identifiable in the public use data files. In 2003 IRB became the NCHS Research
Ethics Review Board, otherwise known as NCHS ERB. The Office of Responsible Research Practices at the Ohio State University approved the current study as IRB exempt.

**Sampling:**

Households were randomly selected to be contacted by trained interviewers to administer a screener and relationship questionnaire. CAPI applies the sampling criteria twice during the screener (initial contact visit); once after the household roster is completed to determine if any household members were eligible based on gender. The sampling criteria applied again after ethnicity, race and age were obtained. If members of the household were in specific age and gender categories, income sampling was completed. CAPI selects a dollar amount, based on the number of household members, and if the household total income was less than this amount, members meeting the age and gender categories specified were sampled if they had not already been so.

It was expected the screener and relationship questionnaire would be completed by an English speaking household member age ≥ 18. An alternative option when this was not possible included finding a neighbor to serve as an interpreter. Professional paid interpreters could be used when no one else was available. In addition, a proxy respondent was selected to conduct the interview when the selected respondent had a serious physical or mental condition.
Conditions included hard of hearing, senility, or mental retardation. For adults a spouse was preferred, and it was best if the proxy resided in the same household, although residence elsewhere was acceptable.\textsuperscript{62}

\textit{Inclusion criteria for the proposed study:}

The inclusion criteria were:
1) Respondent for the 1999-2002 NHANES;
2) Age ≥ 26;
3) Smoked > 100 cigarettes in life;
4) Did not report using any other form of nicotine or nicotine replacement therapy.

\textit{Sample Size:}

The 1999-2002 NHANES is composed of a total of 21,004 individuals of all ages. This was reduced to 8,754 respondents at least age 26. Respondents meeting eligibility requirements (\(n = 4,229\)) included: 773 hard core smokers (HCS); 985 current smokers (CS); and 2471 former smokers (FS).\textsuperscript{65}
Dependent variables: Smoking Status

Respondents were asked if they had ever smoked 100 cigarettes in their entire life. Those responding “yes” were asked if they currently smoked cigarettes everyday, some days or not at all, and at what age did they begin smoking fairly regularly. Those responding everyday or some days were asked on average how many CPD they smoked. Respondents no longer smoking were asked how old they were when they last smoked. Respondents were then categorized as HCS, CS or FS. HCS reported smoking everyday, smoking a minimum of 15 CPD and for at least 5 years. Smokers not meeting the criteria for HCS were categorized as CS. CS either smoked <15 CPD daily, or only smoked some days. Additionally, CS did not have to report smoking a minimum number of years. FS reported no longer smoking cigarettes.

Dependent variables: Nicotine dependence

Nicotine dependence was measured by serum cotinine and TTF cigarette. Serum cotinine was determined by an isotope dilution- high performance liquid chromatography (HPLC) /atmospheric pressure chemical ionization (APCI) tandem mass spectrometry. TTF cigarette was dichotomized as < 30 minutes and > 30 minutes. TTF cigarette was included in the 2001-2002 dataset only, as this was not assessed in earlier surveys.
Independent “predictor” variables

Demographic and socioeconomic variables, including race/ethnicity, gender, age, marital status, household income, poverty income ratio (PIR), education and food security were collected. The poverty index ratio (PIR) is a calculated variable based on family size and income using tables published by the Bureau of the Census each year. PIR is considered the best income variable because it is relatively standardized for inflation, among other factors. The primary reporting categories are 0.000-0.999 (below poverty) and 1.000 and above (at or above poverty). Food insecurity, or the inaccessibility to nutritionally adequate food to meet basic needs, has been documented at > 35% for households falling below the federal poverty level. Increased vulnerability to a broad spectrum of consequences is suggested by the presence of food insecurity. The NHANES assesses, identifies and categorizes household food security into four categories, and recognition of food insecurity for the current study will utilize these categories.

A subsample of respondents ages 26-39 completed modules on affective states. The NHANES three modules are adapted from the World Health Organization’s (WHO) Composite International Diagnostic Interview (CIDI) version 2.1. The CIDI is a comprehensive, fully standardized interview used to assess mental disorders and provides diagnoses according to the definitions and criteria of the tenth revision of the International Classification of Diseases (ICD-10) and the fourth edition of the American Psychiatric Association’s Diagnostic
and Statistical Manual of Mental Disorders (DSM-IV). Possible diagnoses for the NHANES included depression, generalized anxiety disorder and panic disorder. The CIDI is used in both clinical and research settings and can be administered by lay interviewers. It was administered during the face-to-face portion of the MEC interview.¹

A social support module was administered to a subsample of respondents ≥ 60 years old. Questions inquiring about financial and emotional support, as well as the number of friends, were used to calculate a social support score, ranging from 0 – 3, with higher scores indicating more social support. Additionally, all respondents were asked the number of household members smoking inside the home.

Data Analysis and Description of Results:

The data analysis and results of this dissertation are presented in a series of three manuscripts located in chapters 2 through 4. The titles and abstracts of each manuscript are provided below.
Abstract

Inequalities in cigarette smoking prevalence exist, with smokers more likely to be poor and less educated. Higher socioeconomic status (SES) is associated with higher quit rates. The overall relationship between low SES and poor health, as measured by morbidity and mortality, is well established. However, research indicates inequalities in health are not explained by socioeconomic status alone; other variables, such as psychosocial factors, may play a significant role. A conceptual framework introduced by Williams posits the relationships between SES, psychosocial factors, and medical care related to health outcomes. The interrelationships among these factors have yet to be determined. This paper will begin to explore the pathways among the variables within psychosocial factors, and will discuss the framework’s application to tobacco research studies. Further understanding of these relationships in the context of smoking may inform prevention and cessation strategies.
Abstract

Background. The existence of hard core smokers, described as having increased nicotine dependence and little probability of quitting, has been suggested. 

Methods. A secondary data analysis using 1999-2002 National Health And Nutrition Examination Survey data, a cross sectional health survey of a nationally representative sample of the noninstitutionalized U.S. population, was conducted on respondents ages 26 and above reporting smoking at least 100 cigarettes in their lifetime (n = 4,222). Objectives included characterization of variables associated with smoking status (hard core, non-hard core and former smoker). The relationship between current smokers and nicotine dependence, based on serum cotinine and time to first cigarette was also examined.

Results. During 1999-2002, 44% of current smoking respondents were categorized as hard core smokers. Hard core smokers were more likely to be poor, unmarried, non-Hispanic white, and male.

Conclusions. Our results support the existence of hard core smokers, indicating these highly nicotine dependent smokers comprise a significantly large portion of today's cigarette smokers, potentially representing a significant challenge for tobacco control efforts.
Abstract

Background. There are persistent class-based disparities in cigarette smoking and evidence of a social gradient in nicotine dependence. However, SES effects, stratified by race/ethnicity and gender, are not known.

Methods. A secondary data analysis using 1999-2002 National Health And Nutrition Examination Survey data, a cross sectional health survey of a nationally representative sample of the noninstitutionalized U.S. population was conducted on respondents age 18 and above reporting current cigarette smoking who were not missing either a serum cotinine sample or poverty income ratio data (N=1,602). Objectives included examining the existence of a social gradient in nicotine dependence and determining if this was associated with race/ethnicity and gender.

Results. A social gradient in nicotine dependence in an American population was not demonstrated. A reverse social gradient was observed in non-Hispanic black males and females.

Conclusions. Findings were intriguing and challenging to interpret. Social determinants experienced by advantaged blacks, such as increased stress and decreased control, possibly contribute to the positive relationship between nicotine dependence and socioeconomic status. We conclude racial/ethnic gender groups warrant further examination in future tobacco research.
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CHAPTER 2

CIGARETTE SMOKING, SOCIOECONOMIC STATUS AND PSYCHOSOCIAL FACTORS: EXAMINING A CONCEPTUAL FRAMEWORK

Cigarette smoking continues to be the leading cause of premature death in developed countries, and is surfacing as a public health concern in most developing countries as well.\(^1\) Over the next 50 years, tobacco use is projected to produce 450 million deaths worldwide.\(^2\) Extensive scientific evidence demonstrates its causation of multiple diseases, producing substantial health-related costs to society, including smoking-attributable mortality, years of potential life lost, smoking-attributable medical expenditures, and lost productivity costs for adults.\(^3^4\) Healthcare costs at a given age are as much as forty percent higher for smokers compared to nonsmokers.\(^5\) Half of all continuing cigarette smokers will ultimately be killed by their behavior if they do not give it up,\(^6\) whereas the benefits of cessation begin within a year.\(^7\)

Inequalities in smoking exist, as evidenced by persistent class-based disparities and the growing number of smokers in the lower socioeconomic groups.\(^8^9\) Socioeconomic disadvantage is associated with persistent smoking, while higher socioeconomic status (SES) is related to an increased likelihood of
The association with persistent smoking, and not so much initiation, is the one needing explanation. A second goal of Healthy People 2010, the U.S. objectives for health, was to eliminate disparities among segments of the population, including those with inequalities in SES. The purpose of this paper is to present a conceptual framework, introduced by Williams, that examines the relationships between SES and psychosocial factors, and to discuss its potential application in smoking research. This paper will illustrate how psychosocial factors, in combination with low SES, significantly influence smoking behavior, using Williams’ conceptual framework as a foundation to guide expansion of these interrelated constructs. Further understanding of the relationships among these variables may inform the development and testing of prevention and cessation strategies.

Williams’ Conceptual Framework

A considerable body of research indicates inequalities in health are not explained by SES alone, and interconnected pathways that include psychosocial factors may play a large role. Williams describes a conceptual framework of the relationships between SES, psychosocial factors (consisting of risky health practices, social ties, perceptions of control, stress and affective states), and medical care related to health outcomes (Figure 2.1). SES is a significant determinant of health outcomes, impacting both psychosocial factors and medical care. Living and working conditions, derived from position in social
structure, are determined by SES.\textsuperscript{13, 15} Williams\textsuperscript{13} posits that persons with lower SES have an increased vulnerability related to psychosocial factors, such as cigarette smoking, a risky health practice. The effects of biomedical factors, consisting of early environmental and genetic features, as well as demographic factors, are recognized. Medical care, encompassing all health services delivered by a range of health care professionals, and psychosocial factors potentially have reciprocal action, influencing one another.\textsuperscript{13, 15}

Figure 2.1 William’s Conceptual Framework\textsuperscript{13}

Psychosocial factors, considered to be mediators, are pathways through which the effects on individuals and health are seen.\textsuperscript{13} These mediators act as a
response to the external environment, representing conduits for social stratification effects. Psychosocial factors may be an important cause of health inequalities, not only causing disease indirectly, by fostering unhealthy practices, but directly through neuroendocrine disturbances influencing disease risk. According to Williams, psychosocial factors are seen as lifestyle characteristics and living circumstances, not as individual traits, and are viewed as “the patterned response of social groups to the realities and constraints of the external environment.” Macleod and Smith consider any exposure potentially influencing health outcomes via a psychological mechanism as a psychosocial factor. Health practices are not completely under individual control, and instead are induced and constrained through social and material context, with psychosocial adversity possibly fostering unhealthy behavior. Regardless of the targeted practice or behavior, health education is more effective in producing change in persons of higher SES. Approximately half of all deaths during 2000 in the U.S. were caused by modifiable behavioral risk factors, such as cigarette smoking, classified under psychosocial factors by Williams (i.e. health practices). Reutter et al. acknowledged a lack of understanding about the explicit pathways among the variables within psychosocial factors by Williams and it is suggested that further investigation of these pathways may increase understanding of cigarette smoking behavior, thus leading to the development of more effective cessation techniques. This paper will examine the interrelationships among SES and psychosocial factors and extend Williams’ conceptual framework as applied to a smoking behavior.
Socioeconomic Status

The relationship between low SES and poor health, as measured by morbidity and mortality, is well established.\textsuperscript{15, 17-20} Unfortunately, there is no agreed upon definition of SES.\textsuperscript{21} The most frequently used measures of SES include education, income and occupation.\textsuperscript{22-23} Education, typically completed in early adulthood, serves as a marker of early life circumstances, although it fails to capture on-the-job-training and other career investments.\textsuperscript{19, 24} Education shapes future occupational opportunities and earning potential, while also providing knowledge and life skills, thus allowing easier access to information and resources to promote health.\textsuperscript{22, 25} Income serves not only as a level of prestige, but also as an indicator of material resources, such as the ability to afford health insurance and health care.\textsuperscript{19, 21-23} Household income, widely used as a measure of SES in the U.S., denotes more of a standard of living.\textsuperscript{24} Occupation has been said to be the link binding education and income. Occupation affects health status both directly and indirectly, through hazardous exposure on the job and influencing health behaviors.\textsuperscript{26} White collar professions, for example, often have workplace restrictions on smoking, exposing workers to the messages of tobacco control.

Marmot\textsuperscript{27} argues that low SES, i.e. poverty, is more complex than simply a lack of money. “Poor people have worse health not because they have insufficient money but for some other reason,” suggesting income may have a direct effect on more than just material conditions, such as social participation.
and the opportunity to control life circumstances, which are necessary for positive health outcomes.\textsuperscript{(27, p. 31)} Lack of social participation, for example, leads to poor health through a lack of social ties, and it is well established that socially isolated persons have worse health.\textsuperscript{28} These social ties and perceptions of control represent psychosocial factors in Williams’ conceptual framework. Indicators of SES provide information about access to social and economic resources.\textsuperscript{24} Social inequalities, a key public health problem, are evidenced not only in significant differences between the top and bottom of society’s social structure but also in a social gradient. Position in this hierarchy, demonstrated in the British Whitehall Studies, is strongly correlated with mortality risk.\textsuperscript{23} Persons with the highest poverty rates also have the worst health status.\textsuperscript{12} Reverse causation, however, has been suggested in the health selection or drift hypothesis, as an alternate explanation for social inequalities in health.\textsuperscript{29} According to this hypothesis, health is a determinant or cause of social position, not a consequence.\textsuperscript{27, 30} Health status may be partially responsible for barriers to social mobility, thus limiting possible improvement in social position.\textsuperscript{29-30}

Socioeconomic Status and Cigarette Smoking

Inequalities in smoking prevalence exist, as evidenced by persistent class-based disparities and the growing number of smokers in the lower socioeconomic groups.\textsuperscript{8-9} Initially, those of higher education levels and socioeconomic status were more likely to smoke cigarettes. However, since the
first Surgeon General's report in 1964, the profile of cigarette smokers has reversed. Cigarette smokers now are more likely to be poor and less educated.\textsuperscript{31} The well educated may have higher levels of health literacy, and may be more responsive to messages of health-promoting and disease prevention behaviors and beliefs.\textsuperscript{12} Additionally, the poor may have the least information on the health risks of smoking, the fewest resources, and the least access to cessation services. Socioeconomic disadvantage is associated with persistent smoking, and now higher SES is associated with higher quit rates.\textsuperscript{10} Consequently the burden of smoking-related disease falls disproportionately on those with lower SES.\textsuperscript{11}

Jarvis and Wardle\textsuperscript{11} assert that the socioeconomically disadvantaged are the least likely to give up cigarettes and suggest that the association with persistent smoking, and not so much initiation, needs further explanation. Smoking cessation may be particularly difficult for poor people for several reasons, including high nicotine dependence. Nicotine dependence is the major barrier to quitting from an addiction perspective. Physiological and psychological withdrawal symptoms are caused by nicotine deprivation.\textsuperscript{32} Nicotine sufficiently “rewards” smokers to maintain self-administration.\textsuperscript{33} The positive effects produced from nicotine, and an improvement from or a prevention of withdrawal symptoms, only further reinforce smoking.\textsuperscript{34} Nicotine is considered “psychoactive” because it produces short-lived alterations on affect and mood,
and these alterations are predominantly mediated by effects in the brain. These psychoactive effects, evidenced by nicotine’s reliable discrimination from placebo, and its reinforced behavior are intertwined.

Nicotine dependence is recognized as one of multiple interdependent determinants in smoking behavior. Abundant scientific evidence exists documenting the addictive quality of nicotine. Hughes argues the validity of how nicotine dependence is measured is a major issue, as several factors may be influential. Cigarettes smoked per day (CPD), for example, are affected by cost and home/worksite restrictions. Smoking topographic factors, such as depth of inhalation, also determine exposure to nicotine. Cotinine, the major metabolite of nicotine, is currently the gold standard for both quantifying tobacco exposure and nicotine dependence in research. Recently cotinine levels (and consequently the level of nicotine dependence) have been reported to be associated with social class. More specifically, disadvantaged smokers have higher cotinine levels as compared to more affluent smokers, when controlling for CPD, suggesting nicotine dependence may reflect the gradient of socioeconomic status.

Psychosocial Factors and Cigarette Smoking

The relationship between low SES and cigarette smoking has been established. Williams framework includes risky health practices, such as cigarette smoking, as a psychosocial factor and has yet to delineate the
interrelationships existing among these separate factors. These pathways warrant further examination. Social ties, perceptions of control, stress and affective states will be discussed in greater detail.

Fewer social ties are reported by persons of lower socioeconomic classes.\textsuperscript{18,41} Social support, a subjective measure of the emotional value received from one’s social system,\textsuperscript{42} is constructed from informal networks of social ties.\textsuperscript{13} This may include real or perceived resources and social relationships, including family, friends or organizations, providing companionship and assistance with daily activities.\textsuperscript{43} Social isolation, the absence of a social network, may result in loneliness, described as a lack of a close, intimate attachment to another person resulting in unmet needs for social and emotional contact.\textsuperscript{42} Social support directly and indirectly affects health, acting as a mediator or buffer. This may help explain the protective effects associated with social support.\textsuperscript{44-45} Persons with a strong social network carry out more self-care, seeking medical attention less often.\textsuperscript{46}

Research has consistently shown an inverse relationship between social support and all cause mortality.\textsuperscript{44} This extends to health damaging behaviors such as smoking, with social supports possibly advocating cessation.\textsuperscript{44} Unfortunately, social supports are not always encouraging of stopping smoking, and higher proportions of negative support are better predictors of relapse.\textsuperscript{47} Negative social support has been reported as directly predicting more illicit drug use and dependence, and the same may be true of cigarettes and nicotine dependence.\textsuperscript{48} Blue collar workers, including those with working class jobs, low
education, and low income, smoke more often, with smoking rates declining more slowly than white collar professions.\textsuperscript{9} Research indicates persons of lower SES may experience social norms less accepting of tobacco control, and coworker discouragement is associated with lower self efficacy with cessation.\textsuperscript{9} Increased exposure to other smokers, both inside and outside the home, is associated with continued smoking.\textsuperscript{47} Exposure is also reported as a factor affecting relapse and failure to initiate cessation.\textsuperscript{47} Graham\textsuperscript{49} suggests smoking serves as a mechanism for the disadvantaged to participate in society, despite loneliness resulting from financial barriers to a social life. “Smoking acts as both luxury and necessity when material and human resources are stretched”. (\textsuperscript{49}, p. 55)

Perceived social support is a multidimensional concept referring to the gratification of basic needs relative to affect, with physiological, psychological and behavioral influences, and may explain the greatest differences between current and former smokers.\textsuperscript{47} A behavioral influence, for example, may include participation in a smoking cessation program. Negative support, discussed previously, may actually contribute to cigarette smoking, whereas positive support could possibly strengthen one’s determination to quit. Social ties, a psychosocial factor in Williams’ framework, may act as a mediator in the relationship between SES and cigarette smoking. The interrelationships among the factors need to be investigated further before prematurely “lumping” them together.

The positive relationship existing between perceived control and both physical and mental health is well established.\textsuperscript{50} The health locus of control
model describes an internal locus of control, indicating greater influence and power over one’s own health, versus an external locus of control or a belief that external factors determine the outcome. Disadvantaged populations have lower perceived control, relying on fate or powerful others to determine the result, whereas high-SES individuals have a greater perceived control over life events. Perceived control is hypothesized as a major contributor in the SES gradient in health. Level of control, an important characteristic of social position, is related to health and many factors relevant to it. Cigarette smoking may help manage less control at work, as control on the job has been reported an important contributor of mortality differentials by occupation.

High perceived control plays a significant role in successful smoking cessation, and may partly explain the socioeconomic differences in quitting. Socioeconomic disadvantage is associated with life-long smoking, and higher rates of cessation are associated with more advantaged populations. The less educated are more likely to have low perceived control, believing in the existence of external constraints. As a result, persistent cigarette smoking is related to the belief cessation will have minimal impact on health. Cigarette smoking may also be used to self-medicate, in an attempt to regulate depression, and manage stress and coping resulting from material deprivation and lack of control over one’s life.

Stress, a physical or emotional condition, occurs in response to external influences. Chronic stresses linked with social position are associated with neuroendocrine mechanisms and have been implicated in the etiology of
numerous physical and psychological illnesses.\textsuperscript{54, 57} Kristenson et al.\textsuperscript{19} suggest the pathway between SES and stress influence disease both directly, in stress-related physiology, and indirectly, by impacting health practices, such as smoking.\textsuperscript{19, 22} Persons of lower SES live and work in more stressful environments, with contributing factors including economic strain, insecure employment, and low control at work.\textsuperscript{22} Stress reactions are usually beneficial, however, sustained activation results in chronically elevated hormone levels leading to negative consequences affecting health.\textsuperscript{19}

Cigarette smoking may be used to cope with stress. Nicotine is most likely responsible for the psychological and behavioral effects of smoking, and stress often precedes smoking initiation.\textsuperscript{56} Research indicates stress may trigger smoking behavior, and is associated with increased smoking and urges to smoke.\textsuperscript{57} Smokers report elevated smoking in response to stress.\textsuperscript{56} Not surprising, smoking prevalence increases among high stress occupations, and smoking intensifies with higher work stress. In fact, current smoking is associated with higher stress.\textsuperscript{58}

Frequently negative affect, including depression, anxiety and panic disorder, are linked with stress.\textsuperscript{56} The underlying causes of mood and anxiety disorders remain unknown, although it is hypothesized these occur as the result of environmental influences in genetically predisposed persons.\textsuperscript{59} Research suggests dysregulation of the stress response, related to heightened stress sensitivity, increases vulnerability to psychiatric illness.\textsuperscript{59} Mentioned previously,
chronic stress has been implicated in the etiology of numerous psychological illnesses. A strong negative relationship between SES, regardless of the indicator used, and all types of mental illness exists.

Associations between cigarette smoking and psychiatric disorders have been reported, with a higher prevalence of smoking from the general population. Depressive symptoms are associated with smoking initiation and experimentation, and are often reported preceding it. However, depression and cigarette smoking may have more of a reciprocal relationship, as smoking also predicts the consequent development of depressive symptoms. Despite the popular self-medication theory, related to nicotine’s psychoactive effects, recent evidence suggests current smoking may increase the risk for psychiatric conditions, such as anxiety and panic disorders, suggestive of reverse causality. Still, evidence does exist linking nicotine intake with reductions in negative affect, suggesting individuals afflicted with a psychiatric disorder may have an increased motivation to smoke, further strengthening the idea of a reciprocal relationship. Smokers believe smoking assists in reducing negative affect, and not surprisingly past or present depression is associated with failure in quitting smoking. Negative affective states, including anxiety and irritability, occur as hallmark symptoms of nicotine withdrawal. Additionally, the possibility genetic factors related to the dopaminergic systems, which is linked to the reinforcing functions of nicotine, cannot be ruled out when examining the association between psychiatric conditions and smoking.
Psychosocial Factors: Interconnected Pathways

In summary, this review demonstrates that explicit interconnected pathways may exist among SES and psychosocial factors, including risky health practices such as cigarette smoking, social ties, perceived control, stress and affective states. SES impacts health outcomes directly, for example through receipt of preventive care, and indirectly, by influencing psychosocial factors, such as smoking. Psychosocial factors potentially mediate and moderate the relationship between SES and health outcomes. These factors are interrelated, with probable reciprocal action occurring amongst them, and also have a mutual association with cigarette smoking. Figure 2.2 presents the conceptual framework described in this paper. SES influences smoking both directly and indirectly, utilizing psychosocial factors as probable mediators and moderators. The psychosocial factors listed are not exhaustive, and it is recognized additional factors surrounding SES, such as environmental challenges, influence the relationship between SES and cigarette smoking. These challenges, for instance the work environment, play an important role in changing risk factors for the major causes of morbidity and mortality. Demographic factors are acknowledged as directly affecting both SES and psychosocial factors.
One example of these shared relationships, discussed previously, involves depression and smoking. Depressive symptoms are reported to precede smoking initiation, however, cigarette smoking also predicts subsequent onset of depressive symptoms. Nicotine intake decreases negative affect, possibly increasing the motivation depressed individuals have to smoke. Cigarette smoking and depression demonstrate a more cyclical versus linear or causal association with one another. These interconnected pathways influence the relationship between SES and cigarette smoking, as well as SES and health outcomes.

The interconnected channels linking other factors are demonstrated by the following examples. Stress, for instance, typically invokes an emotional reaction,
and these reactions have negative or positive effects on mood. Economic stress is suggested to explain the strong negative relationship between SES and mental illness. High perceived control is also associated with high social support. An increased external locus of control, frequently experienced by lower social classes, leads to chronic anxiety, powerlessness, low self esteem and social isolation. Lower perceived control also affects the degree individuals can participate fully in society. Persons with mental illness describe loneliness more often, and this is often attributed to their smaller social networks. These social networks are less reciprocal, consisting of fewer informal social ties, such as family and friends, and more of formal ties (i.e. service providers). Social support is inversely related with mental illness, with poor support possibly aggravating mental health disorders, and good social support improving the course and prognosis of these disorders.

Conclusion

Smoking has begun to decline in high income countries, largely attributable to coordinated research-based tobacco control efforts. In response, multinational tobacco industries have targeted less developed countries for tobacco sales. At the 56th World Health Assembly in May 2003, the world's first public health treaty, the WHO Framework Convention on Tobacco Control (FCTC), was unanimously adopted. The treaty intends to reduce tobacco related deaths and disease worldwide, requiring signatories to impose
restrictions on advertising, packaging and labeling, and to establish clean indoor air controls. To increase research synthesis and dissemination needs, the Global Tobacco Research Network (GTRN) was developed to encourage collaboration among researchers and institutions. Involved organizations include the U.S. Centers for Disease Control and Prevention, the Canadian Institutes of Health Research, the International Tobacco Health Research and Capacity Building Program, as well as the World Health Organization’s Tobacco Free Initiative.

Future studies specific to tobacco research utilizing this conceptual framework are needed, addressing the interrelated pathways within psychosocial factors, as well as testing the framework in its entirety. Different populations, including those from less developed countries, should be examined. Williams’ framework may assist in constructing a model to explain the variance in smokers of these different populations. Additional pathways warrant recognition, such as affective states, with Williams acknowledging psychosocial factors are not an all-inclusive list. The framework is ideal for guiding a research trajectory in cigarette smoking, advancing its theoretical understanding. Research seeking “to identify how psychosocial factors are embedded in social structures and processes” can augment comprehension of different aspects predisposing individuals to smoking initiation, dependence and that later may represent obstacles to cessation.

Nonexperimental research may be either retrospective or prospective in design. Prospective research “goes forward in time” whereas retrospective
research looks to the past, beginning with the dependent variable, attempting to link it to a presumptive cause occurring earlier in time.\textsuperscript{70} Kenkel, Lillard and Mathios\textsuperscript{71} concluded retrospective data on cigarette smoking is an under-utilized but potentially important resource. It will be discussed briefly for that purpose. Secondary data analysis, i.e. retrospective research, answers research questions using existing data.\textsuperscript{72-73} Advantages include cost effectiveness, timeliness and access to large samples.\textsuperscript{72-73} The most significant contribution of secondary data analysis is the clarification of research problems needing further elaboration in knowledge development, including the revision and refinement of hypotheses or other existing measures.\textsuperscript{72}

Several limitations do exist, however, for example large surveys generally result in nominal and ordinal level data, limiting the use of parametric statistics.\textsuperscript{74} The investigator has no control over the data collection process.\textsuperscript{73} The data was originally collected for another purpose; therefore it may be an indirect measure of the concept or question of interest.\textsuperscript{72-73} Temporary quits, for example, may potentially contribute to the misclassification of respondents as nonsmokers during periods of temporary abstinence.\textsuperscript{71} Additionally, theoretical frameworks are not utilized, but should still be identified and integrated into the research process, assisting with determining appropriate research questions and variables to include.\textsuperscript{74} Secondary data analysis is especially useful as an exploratory technique, promoting the development of the research problem, so a primary research study may be designed.\textsuperscript{73}
Challenges include access to a population based survey, inclusive of the multiple components and persons of interest. Population based surveys have large enough sample sizes to ensure adequate power for an investigation into several of the different variables and concepts incorporated in Williams’ framework. Detailed smoking accounts may be obtained, allowing insight into events such as initiation and cessation, as well as the construction of life-time smoking histories. Biochemical verification improves the accuracy of tobacco use status assessment, and retrospectively provides a benchmark to judge the usefulness of self-reports of cigarette smoking. Cotinine, discussed earlier, has excellent specificity for cigarette smoking, except in persons utilizing other forms of tobacco or nicotine replacement therapy. Few population based surveys currently include biochemical measures, however, the National Health And Nutrition Examination Survey (NHANES) in the United States is an exception, including plasma cotinine on most respondents regardless of smoking status. Unfortunately, information on past quit attempts or interest and motivation in future quit attempts is not collected.

A need for future studies utilizing Williams’ framework has been identified, and the possibility for this model to guide a program of research recognized. This paper has illustrated how psychosocial factors, consisting of social ties, perceptions of control, stress and affective states, when individually combined with low SES, significantly influence smoking behavior. The proposed model derived from Williams’ conceptual framework was developed and may be used
as a foundation to guide the expansion of these interrelated concepts. Further understanding of the interrelationships among these variables and smoking may inform the development and testing of prevention and cessation strategies.
LIST OF REFERENCES


CHAPTER 3

HARD CORE SMOKERS

Cigarette smoking is the leading cause of preventable death in the United States. Approximately 440,000 premature deaths are produced annually and $157 billion dollars in annual health-related economic losses occurred during 1995-1999.\(^1\) Smoking prevalence has fallen steadily, from 37.4% in 1970 to 20.9% in 2004, and approximately one half of ever smokers have quit.\(^2\)-\(^3\) Although this is substantially lower than the 24.1% prevalence in 1998, the pace of the decline is insufficient to meet the national health objective of ≤ 12% by 2010.\(^2\) The Surgeon General’s report in 1988 concluded that cigarettes are addicting, and nicotine is the drug in tobacco causing the addiction.\(^4\) Nicotine dependence is recognized as a significant determinant in the maintenance of smoking and a major barrier to quitting.\(^5\)

Warner and Burns\(^5\) raise the question whether “those smokers who are left behind” differ in their ability to achieve abstinence compared to those who have quit. The foundation of this “hardening” hypothesis is the belief that the remaining smokers are hardening, becoming more resistant to quitting.\(^5\)-\(^6\)
Intuitively, the remaining cigarette smokers are more nicotine dependent, since high dependence predicts low rates of cessation.\textsuperscript{9} It has been suggested that less dependent smokers have already quit while hard core smokers (HCS) are more nicotine dependent and have little probability of quitting, despite four decades of health warnings, increasing restrictions on smoking in public places, and the growing stigmatization of smoking.\textsuperscript{5-10}

To date, no generally accepted definition of HCS exists; several characterizations have been used in the literature.\textsuperscript{5-10} A synthesis includes: 1) current daily cigarette smoker for past 5 years; 2) age 26 and older; 3) consumption of $\geq 15$ cigarettes per day (CPD); 4) no quit attempts in past year; and 5) no future intent to quit.\textsuperscript{5,8-9} Younger individuals are excluded since they may still be in the smoking uptake process, and therefore have not achieved a stable level of average daily consumption or solidified their quitting intentions.\textsuperscript{7} Limited evidence for the hardening hypothesis exists, nevertheless, recommendations include further examination with valid measures of dependence.\textsuperscript{5,7}

Socioeconomic disadvantage is associated with persistent smoking, and increased rates of cessation with higher SES.\textsuperscript{11} Poorer persons may have the least exposure to smoking cessation messages and assistance, with the wealthy having more personal resources.\textsuperscript{5-6} The poor may also have increased nicotine dependence, smoking more intensely with more frequent puffing, deeper inhalations and smoking more of each cigarette.\textsuperscript{5} Fewer social ties are also reported by persons of lower socioeconomic classes.\textsuperscript{12-13} Graham\textsuperscript{14} suggests
smoking serves as a mechanism for the poor to participate in society, despite loneliness resulting from financial barriers to a social life. “Smoking acts as both luxury and necessity when material and human resources are stretched”. (14, p. 55)

Increased exposure to other smokers, both inside and outside the home, however, is associated with continued smoking.\textsuperscript{15}

Nicotine has psychoactive effects on affect and mood, evidenced by nicotine’s reliable discrimination from placebo.\textsuperscript{16} Disadvantaged persons may use cigarette smoking to self-medicate, in an attempt to regulate depression, and manage stress and cope with material deprivation.\textsuperscript{14, 17} Associations between cigarette smoking and psychiatric disorders, including depression, anxiety and panic disorder, have been reported, with a higher prevalence of smoking in these patient groups compared to the general population.\textsuperscript{18-19} Evidence exists linking nicotine intake with reductions in negative affect, suggesting individuals afflicted with a psychiatric disorder may have an increased motivation to smoke.\textsuperscript{20}

Nicotine dependence is a major barrier to quitting, and dependence varies among smokers.\textsuperscript{7, 21} Hughes\textsuperscript{7} argues the validity of the measure of nicotine dependence used is the major issue in assessing evidence for or against the hardening hypothesis. An excellent biomarker for tobacco exposure and nicotine dependence is cotinine, the major metabolite of nicotine, which can be measured in plasma, saliva and urine.\textsuperscript{21} Cotinine is currently the gold standard for quantifying tobacco exposure in research, with the advantage of a significantly longer half life of 17-20 hours over other biochemical indices.\textsuperscript{22-23} Cotinine is oxidized primarily by CYP2A6 and excreted unchanged in the urine,\textsuperscript{23} and is an
indirect measure of recent exposure to cigarette smoke, with greater sensitivity and specificity than other biochemical tests, and a high reported correlation with nicotine clearance \((r = 0.91)\).^{22,23}

A statistically significant linear association between cotinine and nicotine dependence, as measured by the scores of the Fagerstrom Test For Nicotine Dependence, has been reported.\(^{21,24}\) Dependent smokers typically smoke their first cigarette within 30 minutes of wakening, and a significant association has also been reported between time to first cigarette, an item on the Fagerstrom test, and cotinine.\(^{25}\) Higher levels of cotinine indicate higher exposure to tobacco smoke constituents, with subsequent increased risk for tobacco attributable morbidity (e.g. heart disease, cancer, chronic obstructive pulmonary disease).\(^{17}\)

Among all current smokers, those who are considered hard core may be at risk for higher morbidity due to higher levels of exposure.

Characterization of HCS may increase understanding of their smoking behavior, leading to the development of more effective and tailored cessation techniques. However, little detailed information on HCS exists.\(^{8}\) The objectives of this study were to 1) characterize variables associated with hard core smokers (HCS), non-hard core smokers (NHCS), and former smokers (FS); and 2) examine the relationship between smoking status (HCS or NHCS) and nicotine dependence. It was hypothesized HCS would have higher nicotine dependence, as measured by serum cotinine and time to first cigarette.
Methods

Sample population

Data were analyzed from the National Health And Nutrition Examination Survey (NHANES), which uses a stratified, multistage probability sample comprised of the civilian, noninstitutionalized U.S. population, with over sampling of low income persons, persons age 60 and above, African Americans and Mexican Americans. The NHANES is conducted by the National Center for Health Statistics, part of the Centers for Disease Control and Prevention. The full health examination, which included a laboratory component for the collection and processing of various biological specimens such as blood, was performed in a mobile examination center (MEC).  

The two most recent data sets, 1999-2000 and 2001-2002, were combined to produce estimates with greater statistical reliability. Current and former smokers, age 26 and above, were included in the characterization of HCS, NHCS and FS. To determine the association between nicotine dependence and HCS/NHCS, only those smokers who participated in the MEC and provided blood for cotinine analyses were included. Respondents reporting use of nicotine replacement therapy or other forms of tobacco (cigars, smokeless tobacco, etc.) were excluded.
Dependent variables: Smoking Status

Respondents were asked if they had ever smoked 100 cigarettes in their entire life. Those responding "yes" were asked if they currently smoked cigarettes everyday, some days or not at all, and at what age did they begin smoking regularly. Those responding everyday or some days were asked on average how many cigarettes were smoked daily. Respondents no longer smoking were asked how old they were when they last smoked. Respondents were then categorized as HCS, NHCS or FS. HCS were defined as smoking everyday, smoking a minimum of 15 CPD and smoking for the past 5 years. Smokers not meeting the criteria for HCS were categorized as NHCS. NHCS either smoked <15 CPD daily, or only smoked somedays. Additionally, NHCS were not required to report smoking for the past 5 years or more. FS reported no longer smoking cigarettes.

Dependent variables: Nicotine dependence

Nicotine dependence, the dependent variable for second objective, was measured by serum cotinine and time to first cigarette (TTF). Serum cotinine was determined by an isotope dilution- high performance liquid chromatography (HPLC) /atmospheric pressure chemical ionization (APCI) tandem mass spectrometry. A serum cotinine level was collected on those respondents who completed the MEC physical examination. TTF was dichotomized as ≤ 30 minutes and > 30 minutes.
Independent “predictor” variables

Demographic and socioeconomic variables, including race/ethnicity, gender, age, marital status, education, and measures of income including poverty income ratio (PIR) and food insecurity were collected. PIR is considered a valued income variable because it is relatively standardized for inflation, and is a calculated variable based on family size and income, using tables published by the Bureau of the Census each year. The current study categorized PIR as poor-near poor as < 2, middle as 2-3.99 and high as ≥ 4. PIR levels were top coded at 5. Food insecurity has been documented as greater than 35% for households falling below the federal poverty level, and its presence suggests increased vulnerability to a broad spectrum of consequences. The NHANES assesses, identifies and categorizes household food security into four categories: 1) fully food secure, 2) marginally food secure, 3) food insecurity without hunger and 4) food insecurity with hunger. A binary variable, food security (categories 1-2) versus food insecurity (categories 3-4), was created for the current study. All respondents were also asked the number of household members, including themselves, who smoked inside the home.

A subsample of respondents ages 20-39 answered questions on affective states, with possible positive diagnostic scores for depression, generalized anxiety disorder and panic disorder. These three modules were adapted from the World Health Organization’s Composite International Diagnostic Interview version 2.1. Only respondents ages 26-39 and categorized as HCS, NHCS or
FS were included. Information on social support was also obtained with questions inquiring about financial and emotional support, as well as the number of friends, asked to a subsample of respondents ages 60 and above. A social support score was then calculated, ranging from 0 – 3, with higher scores indicating more social support.

**Statistical Analysis**

Because the outcome variable, smoking status, was a three-level categorical variable, multinomial logistic regression was used to determine which factors were significantly associated with each category of smokers. Predictor variables were analyzed individually with multinomial logistic regression, and then entered in order of significance. The Hosmer-Lemeshow test and the area under the ROC curve were examined to evaluate goodness-of-fit and discrimination.31

Multiple linear regression was executed to identify factors significant in explaining the variance in nicotine dependence among current smokers, with serum cotinine as the dependent variable. HCS was the primary independent variable. Because TTF was included in the 2001-2002 dataset only, as this was not assessed in earlier surveys, multiple linear regression was again performed on the 2001-2002 sample, both with and without TTF. For both models, predictor variables with the highest adjusted $R^2$ were entered until the maximum adjusted $R^2$ was achieved.32 The regression assumptions were assessed, with the
Shapiro-Wilk Normality and equal variance examined with a plot of the residuals versus fitted values. Variance inflation factors were also calculated to assess multicollinearity.\textsuperscript{32}

In addition, a logistic regression analysis was performed, controlling for age and CPD, with TTF as the dichotomous outcome (\(\leq 30\) minutes, > 30 minutes). Predictor variables were entered in order of significance (p < 0.05), and all significant variables were included. Goodness-of-fit and discrimination were assessed with the Hosmer-Lemeshow test and the area under the ROC curve.\textsuperscript{31}

Statistical analyses were performed using Statistical Analysis Systems software, Version 9.1. All analyses were completed using the 4-year full sample weights and survey design features, unless otherwise noted.

Results

The total sample of the 1999-2002 NHANES included 21,004 respondents, ages 2 months and older. This was reduced to 8,754 respondents at least 26 years old. Approximately 48\% (\(n = 4,222\)) reported ever smoking at least 100 cigarettes. Of these, more than half (\(n = 2,470\)) were former smokers. Current smokers consisted of 56\% NHCS (\(n = 981\)) and 44\% HCS (\(n = 771\)). Daily smoking was reported by 71.5\% of NHCS. HCS reported smoking an average of 24.2 CPD versus 8 CPD by NHCS who smoked daily. NHCS smoking some days reported smoking an average of 5.4 CPD on the days they smoked. Statistically significant differences existed among the 3 groups comprising
smoking status (HCS, NHCS, and FS). There was a greater percentage of non-Hispanic whites among HCS (82.4%) and FS (79.9%) \((p < 0.0001)\). Similarly, there was a greater percentage of males in these groups (HCS 52.7%; FS 54.4%; NHCS 46%; \(p = 0.0104\)). A greater percentage of HCS (42.2%) and NHCS (44.8%) had a PIR < 2, compared to only 26.5% of FS \((p <0.0001)\). Comparably FS reported less food insecurity (6.2%; HCS 15.3%; NHCS 15.6%; \(p <0.0001\)). Affective states and social support scores were nonsignificant between the groups and therefore were not included in any of the final models.

Table 3.1 contains the demographic characteristics of the sample.

_Characterization of Smoking Status (HCS, NHCS and FS)_

The multinomial logistic regression model \((n = 3,484)\) included the following significant predictor variables: households with smoking indoors, age, race/ethnicity, marital status, PIR, age began smoking regularly, education, and gender. The Hosmer-Lemeshow test indicated the model fit the data well and the discriminatory power of the model was excellent. \(^{31}\) Both HCS and NHCS had a higher odds of being younger than age 65. HCS had 59 times (OR 58.49; CI 41.06, 83.31) and NHCS 15 times (OR 15.01; CI 10.96, 20.55) the odds to live with at least one smoker who smoked inside the home. Non-Hispanic blacks (OR 0.52; CI 0.35, 0.76), Mexican Americans (OR 0.33; CI 0.2, 0.53) and other races/ethnicities (OR 0.56; CI 0.32, 0.97) had lower odds of being HCS. NHCS were significantly more likely to be non-Hispanic black (OR 1.99; CI 1.43, 2.76),
Mexican American (OR 2.08; CI 1.45, 2.97) or other race/ethnicity (OR 2.29; CI 1.47, 3.55). Males had higher odds of being HCS (OR 1.44; CI 1.06, 1.97) as well as those with less than a HS diploma (OR 1.56; CI 1.03, 2.36). Poor individuals also were more likely to be HCS, with a PIR of < 2 (OR 1.54; CI 1.03, 2.32) or between 2 and 4 (OR 1.56; CI 1.06, 2.3). Those <18 at initiation had a high odds of being a HCS or NHCS. Divorced, separated or widowed respondents had higher odds of being a NHCS (OR 1.64; 1.17, 2.31). NHCS also had higher odds of being never married (OR 2.42; CI 1.59, 3.68). Table 2 summarizes the results for all the predictor variables.

Smoking Status (HCS vs. NHCS) and Nicotine Dependence

A small percentage (6.2%) of the original sample did not complete the full health examination, therefore excluding them from analyses involving serum cotinine. There were no significant differences in sociodemographic characteristics between those who completed the exam versus those who did not. The distribution of serum cotinine was not normal; therefore these values were square-root transformed for this analysis. Significant predictor variables included number of household members smoking indoors, age, race/ethnicity, marital status, PIR, and gender. The adjusted R² for the full model was 0.1959 (n = 1,066). An interaction between smoking status and race/ethnicity was significant (p = 0.0137). The association between cotinine and race was therefore estimated by smoking status (HCS vs. NHCS), and the association
between cotinine and smoking status was estimated within each category of race. HCS status contributed to higher cotinine levels for each race/ethnicity. Among HCS, blacks had higher cotinine levels than whites. The cotinine level increased as the number of household members smoking indoors increased ($p = 0.0007$). Males had a higher cotinine than females ($p < 0.0001$), and age younger than 65 was associated with higher cotinine ($p = 0.0185$). Table 3 includes the regression coefficients.

Multiple linear regression was also performed using data from the 2001-2002 sample ($n = 641$), both with and without TTF to assess its contribution to the model. TTF was a significant predictor of cotinine ($p < 0.0001$) and the model with TTF had an adjusted $R^2$ of 0.2327 (whereas the model without TTF had an $R^2$ of 0.1791). Although it closely approached statistical significance, HCS was only significant in the model that did not include TTF ($p < 0.0001$) as a variable. Race/ethnicity was significant in both models ($p < 0.0001$), indicating race/ethnicity explained a considerable amount of the variance in serum cotinine levels. Other variables significant in both models included being male, unmarried, ages 45-64, and having two or more smokers inside the home. Table 4 includes the regression coefficients for both models.

Logistic regression was carried out for the 2001-2002 sample with TTF, dichotomized as $\leq 30$ minutes or $> 30$ minutes, as the outcome ($n = 641$). HCS was the primary independent variable, and CPD and age were included as control variables. Smoking the first cigarette within 30 minutes of waking was reported by 78.6% of HCS and 32.1% of NHCS ($p < 0.0001$). HCS (OR 4.29; CI
2.09, 8.81), and those who reported smoking ≥ 40 CPD (OR 9.15; CI 1.77, 47.44) had a higher odds of being nicotine dependent measured by TTF ≤ 30 minutes. Smokers with cotinine in the fourth quartile had higher odds of smoking their first cigarette within 30 minutes of waking (OR 5.07; CI 2.57, 9.99). The discriminatory power of the model was excellent, with the under the ROC curve value 0.812. The Hosmer-Lemeshow test indicated the model fit the data well. Table 5 includes odds ratios and 95% confidence intervals.

Discussion

These analyses characterized variables associated with HCS, NHCS, and FS, as well as identifying factors associated with nicotine dependence among current smokers. HCS comprised a larger percentage of current smokers than previously reported, although by excluding past quit attempts and future quit intentions from our definition we may have potentially overestimated the number of HCS. Similar to previous research, we found HCS more likely to be non-Hispanic white and male from a lower socioeconomic status. Despite the majority of HCS being either married or living with a partner, they had a higher odds of being unmarried compared to FS. NHCS were also more likely to be unmarried. Similar to Augustson and Marcus, older age was not significantly associated with HCS. Both HCS and NHCS were more likely to be younger than age 65. Fewer home smoking restrictions have been reported among HCS, and HCS in the current study permitted household members to smoke indoors.
more often, compared to both NHCS and FS. However, this odds ratio was associated with very wide confidence intervals.

Factors associated with nicotine dependence among current smokers included male gender, younger age, race and HCS smoking status. Hard core smoking was associated with greater nicotine dependence, as measured by TTF or serum cotinine levels. HCS in our sample were more likely to smoke their first cigarette within 30 minutes of waking. TTF ≤ 30 minutes also contributed significantly to the variance in serum cotinine levels. NCHS were more likely to be female and black, Mexican American or other race/ethnicity compared to HCS.

This is the first reported study examining cotinine levels among those defined as HCS. The mean serum cotinine was higher in HCS, after controlling for CPD, further supporting their increased nicotine dependence. Despite past research reporting increased likelihood of HCS using additional tobacco products, we chose to exclude respondents using other forms of tobacco as this could have made interpretation of serum cotinine values more difficult. This eliminated 45 HCS and 42 NHCS from the study.

Non-Hispanic blacks, regardless of smoking status, were more likely to have higher serum cotinine levels than whites, Mexican Americans and other races/ethnicities. Non-Hispanic blacks experience greater smoking related morbidity and mortality. Nicotine, as well as its metabolite cotinine, is metabolized more slowly by blacks. Previous reports indicate the majority of blacks smoke mentholated cigarettes, which may inhibit nicotine metabolism,
contributing to higher cotinine levels among blacks despite smoking fewer CPD.\textsuperscript{34} The type of cigarettes smoked by respondents of the current study was not examined. This may help explain why both black HCS and NHCS had higher cotinine levels than their white counterparts. White et al.\textsuperscript{35} report blacks as smoking fewer than 15 CPD on average, and this may possibly explain why blacks had higher odds of being a NHCS. Prior research has demonstrated HCS as more likely to be non-Hispanic white,\textsuperscript{8-9} possibly because of the minimum of 15 CPD excludes different races/ethnicities. As the construct HCS evolves, the number of CPD might be reconsidered in races/ethnicities that are known to smoke fewer CPD.

The current study was a secondary data analysis, and the majority of the limitations stem from this. A major limitation of the NHANES is the lack of information about quit attempts, however, this was balanced by the availability of serum cotinine for all respondents, allowing the role of nicotine dependence to be examined more fully. Combining high school diploma with GED did not allow these very different classifications to be characterized. Attending but not graduating from high school is associated with an increased prevalence of tobacco use,\textsuperscript{36} and characterizing the contributions of this population could significantly add to understanding of the relationship between levels of education and HCS.

The NHANES did not collect data on stress or perceived control, two important constructs known to influence nicotine dependence.\textsuperscript{37-38} A social support score was calculated only for a subsample of respondents ≥ age 60. This
proved nonsignificant in the current study, perhaps related to the small sample size and the questions’ lack of discrimination, as scores were similar and high across the smoking categories. Affective states, analyzed in a subsample of respondents ages 26-39 only, were also surprisingly nonsignificant, despite higher smoking prevalence reported among persons with psychiatric disorders. Again, asking only a subsample of respondents these questions may have contributed to the nonsignificance. These factors are important considerations when examining rationale behind HCS. Future studies need to examine affective states in HCS.

In conclusion, our results support the existence of hard core smokers, indicating these highly nicotine dependent smokers comprise a significantly large portion of today's cigarette smokers. This study characterized HCS from NHCS as being single, non-Hispanic White, males, of lower SES, with greater nicotine dependence. Future research needs to identify populations with a higher prevalence of HCS, for example those with alcohol dependence and substance abusers, as well as veterans, or individuals with psychiatric illness. Lowering the minimum CPD for different races/ethnicities may identify more HCS in these groups. Identification of HCS populations may inform the development and testing of prevention and cessation strategies for this challenging group of cigarette smokers.
LIST OF REFERENCES


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* Among Daily Smokers

**Table 3.1 Weighted Demographic Characteristics (%) N = 4222**
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<td>≤ 15</td>
<td>0.88 (0.59-1.31)</td>
<td>0.5295</td>
<td>0.45 (0.32-0.63)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>16-18</td>
<td>0.79 (0.54-1.15)</td>
<td>0.2169</td>
<td>0.49 (0.35-0.67)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>&gt; 18</td>
<td>1.0</td>
<td></td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

*FS is the referent group
HCS*FS: Hosmer-Lemeshow p = 0.6643, ROC 0.932 (Unweighted model)
NHCS*FS: Hosmer-Lemeshow p = 0.7491, ROC 0.873 (Unweighted model)

Table 3.2
Multinomial Logistic Regression: Outcome Smoking Status
1999-2002 NHANES
(n = 3,484)
<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>SE of Coefficient</th>
<th>p value</th>
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<tr>
<td><strong>Smokers Inside Home</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.79</td>
<td>0.43</td>
<td>0.0007</td>
</tr>
<tr>
<td>2</td>
<td>1.39</td>
<td>0.41</td>
<td>0.0007</td>
</tr>
<tr>
<td>3+</td>
<td>1.94</td>
<td>0.55</td>
<td>0.0005</td>
</tr>
<tr>
<td>Referent: 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
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<td></td>
</tr>
<tr>
<td>Males (n = 576)</td>
<td>1.31</td>
<td>0.30</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Referent: Females</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26 - 44</td>
<td>1.28</td>
<td>0.49</td>
<td>0.0185</td>
</tr>
<tr>
<td>45 – 64</td>
<td>1.37</td>
<td>0.50</td>
<td>0.0063</td>
</tr>
<tr>
<td>Referent: 65+</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Marital Status</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Divorced, Separated, or Widowed</td>
<td>0.68</td>
<td>0.40</td>
<td>0.0533</td>
</tr>
<tr>
<td>Never married</td>
<td>-0.01</td>
<td>0.41</td>
<td>0.6027</td>
</tr>
<tr>
<td>Referent: Married</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Poverty Income Ratio</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 2</td>
<td>-0.28</td>
<td>0.36</td>
<td>0.9264</td>
</tr>
<tr>
<td>2- 3.99</td>
<td>0.11</td>
<td>0.38</td>
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</tr>
<tr>
<td>Referent: ≥ 4</td>
<td></td>
<td></td>
<td>0.7751</td>
</tr>
<tr>
<td><strong>Race*Smoking Status Interaction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCS</td>
<td>1.65</td>
<td>0.43</td>
<td>0.0001</td>
</tr>
<tr>
<td>Referent: NHCS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCS</td>
<td>1.97</td>
<td>0.56</td>
<td>0.0005</td>
</tr>
<tr>
<td>Referent: NHCS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mexican American</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCS</td>
<td>4.05</td>
<td>0.75</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Referent: NHCS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>HCS</td>
<td>3.68</td>
<td>0.96</td>
<td>0.0001</td>
</tr>
<tr>
<td>Referent: NHCS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Race Non-Hard Core Smokers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Referent: White</td>
<td>1.79</td>
<td>0.53</td>
<td>0.0008</td>
</tr>
<tr>
<td>Black</td>
<td>-3.09</td>
<td>0.57</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Mexican American</td>
<td>-2.50</td>
<td>0.75</td>
<td>0.0009</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Race Hard Core Smokers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Referent: White</td>
<td>2.12</td>
<td>0.46</td>
<td>&lt;0.0001</td>
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<tr>
<td>Black</td>
<td>-0.69</td>
<td>0.64</td>
<td>0.2873</td>
</tr>
<tr>
<td>Mexican American</td>
<td>-0.47</td>
<td>0.71</td>
<td>0.5083</td>
</tr>
<tr>
<td>Other</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

* Model: Adjusted $R^2$ 0.1959

**Table 3.3 Regression Table: Outcome Serum Cotinine Levels**
1999-2002 NHANES
(n = 1066)

78
<table>
<thead>
<tr>
<th></th>
<th>Model 1*</th>
<th>Model 2**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient (SE) p value</td>
<td>Coefficient (SE) p value</td>
</tr>
<tr>
<td><strong>Hard Core Smokers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Referent: NHCS</td>
<td>0.89 (0.47) 0.0576</td>
<td>2.03 (0.43) &lt;0.0001</td>
</tr>
<tr>
<td><strong>Race:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>1.54 (0.47) 0.0010</td>
<td>1.79 (0.48) 0.0002</td>
<td></td>
</tr>
<tr>
<td>Mexican American</td>
<td>-2.31 (0.59) 0.0001</td>
<td>-2.63 (0.61) &lt;0.0001</td>
</tr>
<tr>
<td>Other</td>
<td>-1.47 (0.64) 0.0223</td>
<td>-1.63 (0.66) 0.0134</td>
</tr>
<tr>
<td>Referent: White</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Smokers Inside Home</strong></td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>0.0574</td>
<td>0.0168</td>
</tr>
<tr>
<td>2</td>
<td>0.89 (0.52) 0.0839</td>
<td>0.97 (0.53) 0.0670</td>
</tr>
<tr>
<td>3+</td>
<td>1.23 (0.53) 0.0206</td>
<td>1.44 (0.56) 0.0099</td>
</tr>
<tr>
<td>Referent: 0</td>
<td>1.76 (0.77) 0.0219</td>
<td>2.18 (0.80) 0.0047</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males (n = 351)</td>
<td>1.31 (0.38) 0.0006</td>
<td>1.36 (0.40) 0.0007</td>
</tr>
<tr>
<td>Referent: Females</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26 - 44</td>
<td>0.0976</td>
<td>0.0650</td>
</tr>
<tr>
<td>0.74 (0.55) 0.1820</td>
<td>0.78 (0.56) 0.1665</td>
<td></td>
</tr>
<tr>
<td>45 – 64</td>
<td>1.21 (0.56) 0.0326</td>
<td>1.32 (0.57) 0.0209</td>
</tr>
<tr>
<td>Referent: 65+</td>
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<td></td>
</tr>
<tr>
<td><strong>Poverty Income Ratio</strong></td>
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<tr>
<td>&lt; 2</td>
<td>0.4924</td>
<td>0.8723</td>
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<tr>
<td>-0.58 (0.50) 0.2393</td>
<td>-0.27 (0.52) 0.6026</td>
<td></td>
</tr>
<tr>
<td>Referent: ≥ 4</td>
<td>-0.32 (0.53) 0.5470</td>
<td>-0.17 (0.56) 0.7618</td>
</tr>
<tr>
<td><strong>Marital Status</strong></td>
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<td></td>
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<tr>
<td>Divorced, Separated, or Widowed</td>
<td>0.0625</td>
<td>0.1059</td>
</tr>
<tr>
<td>Never married</td>
<td>1.02 (0.46) 0.0267</td>
<td>0.93 (0.46) 0.0437</td>
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<tr>
<td>Referent: Married</td>
<td>-0.09 (0.56) 0.8675</td>
<td>0.56 (0.61) 0.9252</td>
</tr>
<tr>
<td><strong>Time To First Cigarette</strong></td>
<td></td>
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</tr>
<tr>
<td>&lt; 30 minutes</td>
<td>2.48 (0.44) &lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>Referent: &gt; 30</td>
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</tr>
</tbody>
</table>

* Model 1 Adjusted R² 0.2327   *Model 2 Adjusted R² 0.1791

Table 3.4

Regression Table: Outcome Cotinine
2001-2002 NHANES
(n = 641)
### Table 3.5

Logistic Regression: Outcome TTF Cigarette  
2001-2002 NHANES  
(n= 641)

<table>
<thead>
<tr>
<th></th>
<th>OR</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>26 – 44</td>
<td>1.09</td>
<td>0.54 – 2.2</td>
<td>0.9645</td>
</tr>
<tr>
<td>45 – 64</td>
<td>1.037</td>
<td>0.5 – 2.15</td>
<td>0.8134</td>
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<tr>
<td>≥ 65</td>
<td>1.0</td>
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<td>0.9224</td>
</tr>
<tr>
<td><strong>Cotinine</strong></td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; Quartile</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Quartile</td>
<td>2.94</td>
<td>1.55 – 5.56</td>
<td>0.0009</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; Quartile</td>
<td>2.87</td>
<td>1.45 – 5.71</td>
<td>0.0025</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt; Quartile</td>
<td>5.07</td>
<td>2.57 – 9.99</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Smokers Inside Home</strong></td>
<td></td>
<td></td>
<td>0.6084</td>
</tr>
<tr>
<td>0</td>
<td>1.0</td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>2.94</td>
<td>1.55 – 5.56</td>
<td>0.0009</td>
</tr>
<tr>
<td>≥ 3</td>
<td>1.0</td>
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<tr>
<td>CPD</td>
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<tr>
<td>0 – 19</td>
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<tr>
<td>20 – 39</td>
<td>1.77</td>
<td>0.87 – 3.60</td>
<td>0.1159</td>
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<tr>
<td>NHCS</td>
<td>1.0</td>
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<tr>
<td>HCS</td>
<td>4.29</td>
<td>2.09 – 8.81</td>
<td>&lt;0.0001</td>
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<td><strong>Race</strong></td>
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<tr>
<td>Black</td>
<td>1.66</td>
<td>0.93 – 2.94</td>
<td>0.0846</td>
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<tr>
<td>Mexican American</td>
<td>0.80</td>
<td>0.41 – 1.56</td>
<td>0.5131</td>
</tr>
<tr>
<td>Other</td>
<td>1.04</td>
<td>0.43 – 2.53</td>
<td>0.9280</td>
</tr>
</tbody>
</table>

Hosmer-Lemeshow p = 0.94 (Unweighted model)  
ROC 0.812
Socioeconomic status (SES), as well as race and ethnicity, is strongly linked with morbidity and mortality. Poverty and educational attainment significantly differ by race/ethnicity. Social inequalities, a key public health problem, are evidenced not only in significant differences between the top and bottom of society’s social structure but also in a social gradient. Position in this hierarchy is strongly correlated with mortality risk, with the poorest having the worst health status. Healthy People 2010’s second goal is to eliminate health disparities among segments of the population, including those experiencing health disparities related to race and ethnicity, and income and education.

Smoking is the leading cause of preventable death in the United States, producing approximately 440,000 premature deaths annually. A strong negative social gradient exists for cigarette smoking. Inequalities in cigarette smoking prevalence are evidenced by persistent class-based disparities with cigarette smokers now more likely to be poor and less educated. The poor may also
have the least information on the health risks of smoking, the fewest resources, the fewest social supports and the least access to cessation services.\textsuperscript{11} The better educated may have higher levels of health literacy, allowing the development of health-promoting and disease prevention behaviors and beliefs.\textsuperscript{6} A positive relationship exists between SES and cessation rates, with men more likely to succeed than women in all racial/ethnic groups except whites.\textsuperscript{12-13}

Priority populations for tobacco use reduction include racial/ethnic minority populations, and it is recommended these are stratified by gender.\textsuperscript{14-15} SES accounts for many of the racial differences and variations in health, with gender differences within each racial group larger than the racial differences across groups.\textsuperscript{4} Including the combined effects of SES, race/ethnicity and gender in smoking research is critical for accurate depictions of social inequalities.\textsuperscript{13}

Cigarette smoking is regarded by many as a personal lifestyle choice, despite research recognizing nicotine dependence as the major barrier to quitting from an addiction perspective.\textsuperscript{6, 16} Extensive scientific evidence exists documenting the addictive quality of nicotine.\textsuperscript{16} The socioeconomically disadvantaged are the least likely to give up cigarettes,\textsuperscript{17} and high nicotine dependence may be a significant contributor to this. Nicotine dependence is measured several ways, including cigarettes per day and the Fagerstrom Test for Nicotine Dependence, with time to first cigarette carrying the most predictive power and predictive validity.\textsuperscript{18} Nicotine is typically depleted from the blood upon waking in the morning, and dependent smokers may face discomfort from withdrawal symptoms until they smoke their first cigarette of the day.\textsuperscript{19}
An excellent biomarker for tobacco exposure and nicotine dependence is cotinine, the major metabolite of nicotine, which can be measured in plasma, saliva and urine. Cotinine is currently the gold standard for both quantifying tobacco exposure and nicotine dependence in research, with the advantage of a significantly longer half life of 17-20 hours over other biochemical indices.\textsuperscript{20-22} Cotinine is an indirect measure of recent exposure to cigarette smoke, with greater sensitivity and specificity than other biochemical markers, and a high reported correlation with nicotine clearance.\textsuperscript{22} A statistically significant linear association between cotinine and the scores of the Fagerstrom test, including time to first cigarette, has also been reported.\textsuperscript{23-24}

Besides representing a marker of current tobacco use, biochemical markers such as cotinine also allow for characterization of the degree of nicotine dependence. There is evidence among smokers that the actual cotinine level (and consequently the level of nicotine dependence) is associated with social class.\textsuperscript{17} More specifically, disadvantaged smokers have higher cotinine levels as compared to more affluent smokers. It has been suggested that this relative difference in nicotine dependence and cotinine levels among smokers reflects the gradient of socioeconomic status.\textsuperscript{17} Of significance, higher levels of cotinine indicate higher exposure to tobacco smoke constituents with subsequent increased risk for tobacco attributable morbidity (e.g. heart disease, cancer, COPD).\textsuperscript{17} As such, even among all current smokers, those who are more disadvantaged may be at risk for higher morbidity due to higher levels of exposure. The relationship between biochemical measures of tobacco smoke
and SES has not been well studied, and differences among groups stratified by race/ethnicity and gender have never been reported. Bobak et al. described a strong gradient in men from the Czech Republic with serum thiocyanate, a less accurate indicator of smoke intake; however, differences, were not seen in women.

Jarvis and Wardle report evidence of a gradient in the level of nicotine dependence and socioeconomic disadvantage among smokers in the Health Survey for England. Higher cotinine was observed as disadvantage increased, after adjusting for cigarettes per day. This suggests higher nicotine dependence in the disadvantaged may be one reason for persistent smoking, with increased intake having implications for increased smoking-related disease. The purpose of the current study was 1) to examine the existence of a social gradient in nicotine dependence in an American population and 2) to determine if there is a social gradient in nicotine dependence that is associated with race/ethnicity and gender.

**Methods**

**Sample population**

Data was analyzed from the National Health And Nutrition Examination Survey (NHANES), which uses a stratified, multistage probability sample comprised of the civilian, noninstitutionalized U.S. population, with over sampling
of low income persons, persons age 60 and above, African Americans and Mexican Americans. The NHANES is conducted by the National Center for Health Statistics, part of the Centers for Disease Control and Prevention.\textsuperscript{25}

The two most recent datasets, 1999-2000 and 2001-2002, were combined to produce estimates with greater statistical reliability. Our study sample was limited to respondents age 18 and older who reported smoking at least 100 cigarettes in their entire life and were current smokers, and were not missing either a serum cotinine sample or poverty income ratio data. Serum cotinine samples were collected from respondents completing the medical exam center (MEC) health examination.\textsuperscript{26} Current smokers reported smoking cigarettes everyday or some days. Respondents were asked on average how many cigarettes on average were consumed on the days smoked. Respondents reporting use of nicotine replacement therapy or forms of tobacco other than cigarettes were excluded.

\textit{Dependent variable: Nicotine dependence}

Nicotine dependence was measured by serum cotinine. Serum cotinine was determined by an isotope dilution- high performance liquid chromatography (HPLC) /atmospheric pressure chemical ionization (APCI) tandem mass spectrometry.\textsuperscript{26}
Independent variables

Demographic and socioeconomic variables, including race/ethnicity, gender, age, education, and measures of income including family poverty income ratio (PIR) and food insecurity were collected. Family PIR is considered a valued income variable because it is relatively standardized for inflation, and is a calculated variable based on family size and income, using tables published by the Bureau of the Census each year. The current study categorized family PIR as at or near poverty (< 1.5), middle income (1.5-3.49), and high income (≥ 3.5), with PIR top coded at 5 in the NHANES. Family PIR categories were utilized as the primary independent variables, and examined with serum cotinine levels for the existence of a social gradient. The expected social gradient would indicate an inverse relationship between SES and increased nicotine dependence. Food insecurity has been documented as greater than 35% for households falling below the federal poverty level, and its presence suggests increased vulnerability to a broad spectrum of consequences. The NHANES assesses, identifies and categorizes household food security into four categories: fully food secure, marginally food secure, food insecurity without hunger and food insecurity with hunger.
Statistical Analysis

Descriptive statistics, including frequencies, percentages, and measures of central tendencies, were performed. Next, multiple regression was utilized to examine the existence of a social gradient in nicotine dependence in an American population, with serum cotinine levels as the dependent variable. Multiple regression was performed, stratified by race/ethnicity and gender, to determine if a social gradient in nicotine dependence existed. Statistical analyses were performed using Statistical Analysis Systems software, Version 9.1. All analyses were completed using the 4-year full sample weights and survey design features.

Results

The total sample of the 1999-2002 NHANES included 21,004 respondents, ages 2 months and older. This was reduced to 9,860 respondents at least 18 years old answering cigarette smoking questions. The final sample consisted of 1,441 current cigarette smokers with a serum cotinine specimen and PIR data. The sample had slightly more males (50.5%), with variations among the different races/ethnicities. Except for black females (29.4%), the majority were married or living with a partner. Smoking prevalence consistently decreased with age regardless of race/ethnicity. Level of education varied by gender within the different race/ethnicity categories. Mexican American males had the greatest
percentage with less than a HS diploma (69%), whereas 42.7% of white males had greater than a HS diploma. Slightly more females (36.8%) than males (29.3%) were less than 150% above poverty with Mexican American males having the highest percentage (60.6%) in this category. White males had the greatest percentage having 350% or more above poverty (37.7%). Respondents (n=174) top coded or having the maximum value for family PIR were 90.9% white, 6% black and 3.2% Mexican American. Food insecurity also varied by race/ethnicity and gender. Eighty three percent of white males were fully food secure versus only 47% of Mexican American males. Table 1 contains the demographic characteristics of the sample.

White males consumed the highest number of CPD (mean 21.4) compared to Mexican American females, who only consumed an average of 9.7 CPD. Non-Hispanic black males and females had the highest mean serum cotinine levels, 297.1 and 263.8, respectfully. Mexican American males (mean 164.7) and females (mean 171.8) had the lowest cotinine values. All cotinine levels were adjusted for CPD.

*Social gradient in an American population*

Multiple regression analysis was executed, adjusted for CPD, with serum cotinine level as the dependent variable. Evidence for the social gradient in nicotine dependence did not exist when PIR categories were used as the independent variables. Multiple regression was repeated utilizing alternative
measures of SES, including food insecurity, level of education and household income. The results did not indicate a social gradient. Alternate variables for nicotine dependence, including CPD and time to first cigarette, were also examined. A social gradient in nicotine dependence was not demonstrated when all smokers were included in the analysis (Figure 1).

Social gradient associated with race/ethnicity and gender

Multiple regression analysis was executed again, adjusted for CPD, stratified by race/ethnicity and gender, with serum cotinine level as the dependent variable. A reverse gradient was demonstrated in all blacks ($p = 0.0221$). Similar to the previous objective, multiple regression analyses were repeated using alternative measures of income as well as with different variables for nicotine dependence with unremarkable findings. Figures 2 through 5 illustrate the results for the social gradient in nicotine dependence associated with race/ethnicity and gender.

Discussion

The first objective was to examine the existence of a social gradient in nicotine dependence in an American population; however, we failed to demonstrate such a gradient. This is despite using combinations of alternative variables for both measures of income and nicotine dependence. The second
objective, to determine if a social gradient in nicotine dependence was associated with race/ethnicity and gender, indicated a reverse gradient among all blacks, especially black males. Again, different combinations of indicators of income and nicotine dependence were utilized. Results reported here included all respondents currently reporting cigarette smoking, regardless of when last cigarette was smoked. Additional sub-analyses that included only respondents reporting smoking their last cigarette the same day as the MEC examination were performed, however, the results were not altered significantly.

Black smokers had higher mean serum cotinine levels, adjusted for CPD, than whites, Mexican Americans and other races/ethnicities. Nicotine, as well as its metabolite cotinine, is metabolized more slowly by blacks.\textsuperscript{28-29} Previous reports reveal the majority of blacks smoke mentholated cigarettes, which may inhibit nicotine metabolism, contributing to higher cotinine levels despite smoking fewer CPD.\textsuperscript{29} The type of cigarettes smoked by respondents of the current study was not examined. Higher levels of serum cotinine indicate higher exposure to tobacco smoke constituents with subsequent increased risk for tobacco attributable morbidity and mortality.\textsuperscript{16, 29} This may partially explain why blacks experience greater smoking related morbidity and mortality.

Why was the expected social gradient in nicotine dependence not demonstrated? Bobak et al.\textsuperscript{10} utilized four levels of education among current smokers from the Czech Republic (451 men and 282 women). Only 3 levels of education were available using the NHANES data, with high school diploma and GED combined. A GED is associated with an increased prevalence of tobacco
use, and perhaps a gradient would have emerged if GED and high school 
diploma were two separate categories. Jarvis and Wardle employed a 
deprivation index in the Health Survey for England, similar to the indices utilized 
by Townsend and by Carstairs. Scores ranged from 0 to 5, with higher scores 
indicating greater deprivation. Occupation is an important measure of SES, 
often influencing health behaviors, and occupation data was collected as part of 
the NHANES. Unfortunately, the 2001-2002 NHANES occupation data file was 
inaccessible during analyses of the current study. Good measures of 
disadvantage may not have been available for the current study.

Why was an inverse gradient seen in all blacks? Is this a valid finding if 
good measures of disadvantage were unavailable for an American population? 
The disadvantage of blacks results not only from limited socioeconomic 
resources at the individual level, but also from the lack of neighborhood and 
community wide resources. King states “…race is essentially a social 
concept depicting a form of social stratification…” . Residential segregation, 
for example, restricts socioeconomic attainment by negatively influencing 
education and employment opportunities. A strong relationship exists between 
racial composition of schools and concentrated poverty. Poor whites typically do 
not live in areas of concentrated poverty. Disadvantage is related to poor work 
conditions and residential areas, as well as disempowerment.

Socioeconomic position, such as middle class, may be more temporary 
among blacks, and does not capture their exposure to disadvantage. Racism 
may indirectly affect smoking in blacks, increasing psychosocial stress leading to
increased dependence. Powerlessness (i.e. low perceived control) to influence or improve institutional barriers, with access to employment and health care for example, may contribute to lower quit rates.\textsuperscript{31} Advantaged blacks may smoke more intensively through topography or puffing characteristics because of increased stress and dependence, and decreased control. These social determinants of health, combined with metabolic factors, possibly explain why a reverse gradient was observed in all blacks. A better measure of disadvantage may have demonstrated different findings. Few blacks (n= 46) were in the highest PIR category (≥ 350\% of poverty), and it is not known if a larger sample would have influenced the results significantly.

Mexican Americans had lower mean cotinines, adjusted for CPD, compared to both Whites and blacks. This is consistent with previous findings,\textsuperscript{32} suggesting metabolic factors may play a role. Although a gradient was not demonstrated among Mexican Americans, questions remain regarding the validity of this finding, as the number Mexican Americans with a PIR ≥ 3.5 was very small (n= 24).

In conclusion, this study demonstrated the existence of a reverse gradient among all blacks. The findings were intriguing and challenging to interpret. If these findings are valid, social determinants experienced by advantaged blacks, such as increased stress and decreased control, possibly contribute to the positive relationship between nicotine dependence and socioeconomic status.
Disadvantage is difficult to measure across different races/ethnicities, however, we conclude racial/ethnic gender groups should be examined further in future tobacco research.
LIST OF REFERENCES


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*Cotinine adjusted for CPD

Table 4.1
Weighted Demographic Characteristics (%) N= 1441

98
Figure 4.1  All Current Smokers By PIR (N = 1184)

Figure 4.2  Current Smokers By Gender and PIR (N = 1184)

* Adjusted for CPD
Cotinine* ng/mL

* Adjusted for CPD

Figure 4.3  Race/Ethnicity by PIR (N= 1184)

Cotinine* ng/mL

*Adjusted for CPD

Figure 4.4  Males by Race/Ethnicity and PIR (N= 633)
Cotinine* ng/mL

*Adjusted for CPD

Figure 4.5  Females by Race/Ethnicity and PIR (N= 551)


NCHS (n.d.) *NHANES data*. Hyattsville, MD: USDHHS, CDC.


NCHSED (personal communication August 17, 2005)


