AN EPIDEMIOLOGICAL ANALYSIS OF THE RISK FACTORS ASSOCIATED WITH ADULT HEARING LOSS

Capstone Project

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ABSTRACT

Hearing loss is a widespread, and often untreated problem amongst adults in the United States (US). In fact, it is estimated that 16% of adults in the US – approximately 30 million Americans – have some degree of hearing loss (Agrawal, Platz, and Niparko, 2008). Therefore, the primary purpose of this study is to examine the risk factors associated with adult hearing loss in the US. This document investigated risk factors and there interactions in an attempt to determine "why" and "in whom" adult hearing loss occurs. The risk factors examined in this study include: age, gender, race, education, cigarette smoking, and alcohol drinking. After examining the epidemiological/risk factor literature, several resounding themes/trends were observed, which included: that age (increasing), gender (male), and race/ethnicity (white participants) were all strongly associated with adult hearing loss, Non-Hispanic black participants demonstrated a protective association with adult hearing loss, and a protective association was observed with moderate consumption of alcohol. The clinical utility of the current risk factor assessment is the provision of tools to help design effective programs to decrease the impact of adult hearing loss and improve quality of life.

DEDICATION

I dedicate this capstone document to my wonderful family – especially my parents, who instilled in me the value of education and the importance of hard work. I would also like to thank to my friends for their invaluable patience and encouragement throughout this process.

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LIST OF ABBREVIATIONS (IF NECESSARY)

dB	Decibel
OR	Odds Ratio
RR	Risk Ratio
E	Risk factor (exposed) without hearing loss
$\underline{E}$	Risk factor (exposed) with hearing loss
N	No risk factor (not exposed) without hearing loss
$\underline{N}$	No risk factor (not exposed) with hearing loss
Hz	Hertz
US	United States

CHAPTER 1

Introduction

Hearing loss is now widely accepted as the third most prevalent chronically handicapping health condition, affecting an estimated 25%-40% of US citizens aged 65 years and older (Yueh, Shapiro, MacLean, & Shekelle, 2003). In addition, Cruickshanks et al. (1998b) noted that both the prevalence and incidence of hearing loss increases as a function of age (Agrawal, Platz, & Niparko, 2008; Li, Healy, Drane, & Zhang, 2006; Pearson et al., 1995). The significance of these high prevalence and incidence rates indicates that adult hearing loss, both as a result of age and other risk factors, has become and will continue to be a major health issue (Strawbridge, Wallhagen, Shema, & Kaplan, 2000). This documented decline in adult hearing acuity has been associated with many risk factors including: noise exposure, genetic predisposition, lifestyle characteristics, chronic/cardiovascular disease, and socioeconomic status. This documented influx of hearing-impaired adults has created a major public health problem requiring the need for an assessment of potential risk factors.

The hearing impairment and the resulting handicaps observed in adult patients can most often be attributed to a complex interaction of various risk factors (Agrawal et al., 2008). The risk factors assessed in this study include: age, gender, race, education, cigarette smoking, and alcohol drinking. Some of these risk factors have deleterious effects on an individual's hearing acuity, and have been shown to result in handicaps such as: difficulties with speech understanding, anatomic insults, psychosocial and psychological handicaps, and a decrease in overall quality of life (Ries, 1994). Additionally, Yueh et al. (2003) noted that despite the prevalence and impairment associated with hearing loss, only 9% of general practitioners offer hearing testing to patients 65 years and older. Likewise, Kochkin (2010) reports that only 25% of adults with admitted hearing loss own hearing aids. Within this group, 40% of adults with moderate to severe hearing loss own hearing aids and 9% of adults with milder hearing losses own hearings aids. For these reasons, the ability to use patient information to detect subclinical disease states and/or to predict future health issues has great appeal (Li et al., 2006). Additionally, this examination of risk factor data should yield strategies for the implementation and/or improvement of evidence-based public health programs aimed at preventing hearing loss. The issues related to risk factor "control" will also be discussed within this document to ensure that all reported information is valid or as free of confounding variables as possible.

The purpose of this capstone document is to examine and report the risk factors associated with adult hearing loss in the US. Therefore, an understanding of the risk factors, their severity, and interactions (e.g. co-morbid conditions vs. a causal relationship) will provide evidence-based information regarding how hearing loss might be prevented or delayed. The clinical utility of this study's risk factor assessment/evaluation should provide both the audiologic and public health fields with the tools needed to design more effective treatment strategies to help improve quality of life for adults in the US. Lastly, awareness of risk factors may enable clinicians to make precise diagnoses, give more accurate prognoses for patients with hearing loss, and help monitor patient response to given treatment options.

Population / Age-Shift

Prior to a discussion of the risk factors associated with adult hearing loss, it is important to describe the affected population. According to the World Health Organization, by the year 2025 there will be approximately 1.2 billion individuals worldwide over the age of 60 (Sprinzl & Riechelmann, 2010). This impending shift in population demographics (age) marks a transition in which the US and the rest of the world will soon have a greater proportion of adults than younger individuals. The aging of the US population has been largely attributed to an increase in life expectancy, and to a lesser degree increases in age-adjusted hearing loss and decreases in fertility (Sprinzl & Riechelmann, 2010). This influx of adult hearing loss should facilitate an examination of the risk factors related to hearing loss, as well as an investigation into improved/more readily accessible treatment options. It is also of importance to note that the current US age group moving toward elderly adulthood (ages 65 and greater) often termed the "baby boomers," will likely have increased demands pertaining to "why" they have hearing loss and how it can be treated (Sprinzel & Riechelmann, 2010).

CHAPTER 2

Discussion of Epidemiological Terms / Methodology

It is important to explain the epidemiological terminology and measurement tools utilized in the examination/discussion of the risk factors associated with adult hearing loss. This section will explain the calculation and interpretation of: prevalence, Odds Ratio (OR), and Risk Ratio/Relative Risk (RR). This section should provide readers from a non Public-Health background with an understanding of this terminology to assist in the comprehension of the risk factor assessment and discussion.

First, the calculation of the Odds Ratio (OR), which is a quantitative measure of association between exposed and unexposed groups will be discussed. The OR demonstrates the probability that an event or disease state (e.g. adult hearing loss) will occur versus the probability that the event (disease state) will not occur. Therefore, the assessment of ORs in this document enables comparisons to be made between the odds of hearing loss occurring in an exposed group of adults (i.e. exposed/possesses a risk factor) versus an unexposed group of adults (i.e. not exposed/ not possessing the given risk factor). The calculation of the OR is a two-step process. First the investigator must determine the odds of developing the condition/disease state. This is determined by dividing the number of people with a given risk factor or exposure (e.g. smoking, gender) who eventually developed hearing loss (the condition – denoted by the E in Equation #1) by the number of adults with the given risk factor who did not develop hearing loss (denoted by E in Equation #1). This calculation provides the numerator for the equation that determines the OR (see Equation #1 below). Second, the investigator must determine the odds of developing hearing loss in an adult without the given risk factor. This is calculated by dividing the number of adults without the given risk factor who developed hearing loss (denoted by $\underline{N}$ in Equation #1) by the number of adults not exposed to the risk factor who did not develop hearing loss (denoted by N in Equation #1). This second calculation provides the denominator for the equation that determines the OR of a given risk factor. Next, interpreting the numeric OR results will be discussed. If the OR is equal to 1, then the odds of hearing loss are the same in the two groups (i.e. the risk factor has no effect). When the OR is >1, the odds of the outcome are greater in the group with the exposure (i.e. the exposure has a harmful effect). Lastly, if the OR is <1, the odds of the outcome (hearing loss) are lower in those with the exposure (i.e. the exposure has a preventive effect). For example, a study by Li et al. (2006) reported an OR of 1.96 for the association between being an adult male and having hearing loss. This OR indicates that the probability of having hearing loss in males was 1.96 times the odds in females (comparison group). The OR is utilized in a majority of epidemiological research to determine how strongly (or weak) a given risk factor is associated with the outcome of interest (e.g. hearing loss).

Equation #1:

$$(\underline{E}/E) / (\underline{N}/N)$$

In addition to the OR, the Risk Ratio/Relative Risk (RR) is another quantitative statistic often reported in epidemiological research. The RR also provides information regarding the association between given risk factors in exposed and unexposed groups. However, the RR yields information regarding probability or how many times more likely the given outcome (e.g. hearing loss) occurs among adults with the given risk factor. The RR is calculated by dividing the incidence of the risk factor (exposed) group (denoted by $\underline{E}$ – seen in the numerator in Equation #2) by the incidence of the group without the given risk factor (unexposed – denoted by $\underline{N}$ – seen in the denominator in Equation #2). Therefore, if the RR were equal to 1 then the risk of hearing loss would be equal between adults that present with risk factors (exposed) and those that do not (unexposed). However if the RR is >1, the risk is greater (harmful) for adults with the given risk factor or exposure; and if the RR is <1, the risk of the outcome is lower (protective) for the adults with the given risk factor or exposure. For example, a study by Cruickshanks et al. (1998a) reported a RR of 1.61 for the association between smoking cigarettes and adult hearing loss, which indicates that the incidence of adult hearing loss was 1.61 times that of the incidence of adult hearing loss in nonsmokers.

Equation #2:

$$(\underline{E}/\underline{N})$$

It is important to note that ORs and RRs should not be used or reported interchangeably. First, it is crucial to remember that when calculating or examining epidemiological research, that ORs are comparing the "odds" of an association, and that RRs are comparing the risk or probability of an event (Pepe, Janes, Longton, Leisenring,

& Newcomb, 2004). Secondly, it is important to identify the study design of the epidemiological research being examined. The identification of study design is especially important, because the RR can only be calculated for cohort studies where the overall prevalence of the outcome is known. Therefore, the RR cannot be calculated and thus should not be reported in a case-control study. However, the OR can be calculated for cohort, case-control, and cross-sectional studies, making it a much more appealing statistical measure. In addition to its ability to be used in multiple study designs, the OR also helps to limit confounding variables by adjusting for certain risk factors associated with both the outcome and the exposure (Pepe et al., 2004). However, in certain statistical insistences, the OR and the RR can mirror each other. This phenomenon is most often seen when the outcome in the study population is rare (Viera, 2008). Lastly, it is important note that both the OR and RR are used in epidemiological research to limit confounding variables from influencing associations between risk factors and health outcomes.

METHODOLOGY

The methodological process used to complete the literature review of the risk factors associated with adult hearing loss is outlined below. First, a comprehensive literature search of peer-reviewed studies was performed using scholarly search-engines (e.g. PubMed, Google Scholar). Next, in order to obtain information pertaining to each risk factor, multiple search terms were utilized to ensure comprehensive acquisition (e.g. smoking and adult hearing loss). The search also included studies cited in bibliographies, The Ohio State University Library, and PubMed/Google Scholar's "related articles." The peer-reviewed literature acquired for this document includes studies published between

1990 and 2011. Next, in order to perform a systematic review of the literature and ensure relevant information, we set the following inclusion criteria: studies that identified hearing loss by pure-tone averages (PTA), studies that investigated the risk factors of interest (e.g. age, gender, etc) with respect hearing loss, studies that utilized the OR or RR to appropriately quantify the probability of having adult hearing loss (harmful vs. protective) – with appropriate confidence intervals (e.g. 95 %), and studies that employed adult participants (>18 years of age). Our exclusion criteria were as follows: studies published in non peer-reviewed journals, studies with exceptionally small sample sizes, studies with participants under the age of 18, and studies that did not attempt to control for confounding variables or other risk factors. After the collection of literature was completed, the studies were then grouped by risk factor. Once grouped by risk factor, the studies were divided into two groups: one group reporting a positive association between the given risk factor and adult hearing loss (i.e. ORs >1 - harmful), and a second group which reported no association or a protective effect with respect to hearing loss (i.e. ORs ≤ 1). The studies were then examined to determine: each risk factor's association (if any) with adult hearing loss, the effect or magnitude of each risk factor, and the relationships between risk factors.

Confounding/Associations

It is also important to discuss the cautious nature that should be applied when reporting associations between a given risk factor and adult hearing loss. For example, when using ORs we are comfortable reporting that the odds of having adult hearing loss is 1.96 (OR = 1.96) times greater in males than females in a study conducted by Li et al. (2006). This finding implies an association (statistically significant) between male individuals and the presence of adult hearing loss. However, it is important to remember that confounding variables such as a skewed sample or other risk factors not examined could have contributed to this apparent association (Viera, 2008). Thus, we did not conclude that any risk factor associations were present based on data from one study only. By compiling results from multiple studies, we helped ensure that any associations reported are reliable and have been replicated. And in fact, in order to "truly" estimate the magnitude of a given risk factor, a randomized-control study or prospective cohort study would need to be performed. However, a majority of the studies examined for this document utilized multivariate adjusted ORs and/or logistic regression analysis to ensure accurate and consistent results. This is a technique to isolate the contribution of individual risk factors when multiple factors are present. This statistical measurement enabled us to compare participants who for example, smoked cigarettes or consumed alcohol with participants who did not smoke cigarettes or consume alcohol. Additionally, these calculations provide the ability to make more complex comparisons such as risk factor associations (e.g. individuals that smoke cigarettes also consume alcohol, and vise versa). A valid comparison can then be made because the studies have adjusted for the possibilities of confounding variables.

Audiometric Considerations

In order to measure the resulting hearing loss (if any) due to the presumed effect of a given risk factor, an audiologic evaluation was performed in a majority of the studies examined within this document (all other being self-repot, Li et al., 2006). However, due to the examination of multiple risk factors and varying study design/methodology, there is some variation across the literature with respect to how hearing loss is measured and quantified. For example, a large majority of the literature reviewed conducted a "traditional" audiometric assessment including: a trained examiner (often an audiologist) using a sound-isolating test booth, otoscopic examination, calibrated equipment, supra-aural headphones or insert earphones, acquisition of air conduction thresholds in both right and left ears using the Hughson-Westlake method, test frequencies ranging from 500-8000 Hz, and calculation of the Pure Tone Average (PTA) – "standard" three frequency PTA consisting of 500, 1000, and 2000 Hz – "speech frequency" PTA consisting of 500, 1000, 2000, 4000 Hz. In addition to audiometric evaluation techniques, the quantification of degree of hearing loss varied slightly across the studies examined. However, a strong majority of the studies employed the following quantifications: normal hearing ≤ 25 dB HL, mild hearing loss >25 dB HL and ≤ 40 dB HL, moderate hearing loss >40 dB HL and ≤ 70 dB HL, and severe hearing loss > 70 dB HL. In addition to the quantification of hearing loss, certain conditions were excluded which included: a history of hearing loss from birth, a history of otosclerosis, audiometric evidence of conductive hearing loss, and those with incomplete audiometric data. The use of the aforementioned assessment methods, quantifications of hearing loss, and exclusion criteria enabled a confident discussion of the likelihood that a given risk factor was or was not associated with adult hearing loss.

CHAPTER 3

Risk Factor Data

AGE

The first risk factor associated with adult hearing loss is the effect of age. Age related hearing loss, or presbycusis, is widely defined as the age-related degeneration of the cochlea with the cumulative effects of extrinsic damage (e.g. noise and other ototoxic agents) and intrinsic disorders (e.g. systemic disease) (Sixt & Rosenhall, 1997). However, this study utilized research that attempted to control for both extrinsic and intrinsic affects in order to examine how a risk factor like age effects hearing loss. The deleterious effect of age with regard to adult hearing acuity has been well document in both the audioloigc and epidemiologic literature. In fact, hearing loss is now considered the third most prevalent chronically handicapping condition in older adults, with an estimated prevalence somewhere between 25% and 40% (in US adults over the age of 65, Yueh et al., 2003). Additionally, a strong majority of the research reviewed confirmed that prevalence rates increased as age increased (direct relationship between hearing loss and age). This is demonstrated in research conducted by Cruickahanks et al. (1998b) which reported that the prevalence of hearing loss increased to a range of 40%-66% in participants older than 75 years old, and more than 80% in participants older than 85 years.

In order to examine the relationship between age and adult hearing loss, this study reviewed five studies discussing the association. After a thorough review of the research, we discovered that each piece of literature reported an association between age (the risk factor) and adult hearing loss. In this section, each of the five studies will be discussed individually, as the stratification of age groups varied across the research. The first study to be discussed was conducted by Lin, Thorpe, Gordon-Salant, & Ferrucci (2011) and reported that age has a significant association with the presence of adult hearing loss. Using the World Health Organization's definition for hearing loss, the researchers first determined the prevalence of hearing loss in participants age 70 and older to be 63.1%. The most significant increase (statistically significant) in the prevalence of hearing loss was observed between the 70-74 year old age group (45.6%) and the 75-79 year old age group (67.6%). However, a non-statistically significant increase between the 80-84 year olds (78.2%) and ≥ 85 year old age group (80.6%) was observed. Next, the authors utilized multivariate adjusted ORs, the standard statistical/epidemiological method of controlling for confounders (described above – "Confounding / Associations"), to quantify the likelihood of association between age and adult hearing loss. The ORs were determined to be: 1.00 for participants ages 70-74 (reference group), 2.65 for participant ages 75-79, 4.30 for ages 80-84, and 4.97 for ages 85 and older.

In an attempt to further explore the association between age and adult hearing loss, Lin, et al. (2011) performed analysis using hearing loss as a continuous variable (not dichotomous – using linear regression models and ß coefficients to determine average change in hearing thresholds). However, similar results were obtained (ß similar to ORs coefficients) indicating that regardless of the statistical analysis used (ORs or ß coefficients) age remained significantly associated with adult hearing loss. Lastly, we wanted to note that increasing age was associated with hearing loss for all PTA conditions (e.g. speech PTA and high frequency PTA), but more significant hearing loss was observed at higher test frequencies (e.g. 4000-8000 Hz).

The next study to be discussed was conducted by Agrawal et al. (2008). As mentioned above, this study like all others found that age was significantly associated with hearing loss. However, the participants used in this study were much younger (age range of 20-69 years) than the participants in Lin et al. 2011. Using the 20-29 year olds as a reference group (OR = 1), Agrawal et al. (2008) reported the following adjusted ORs for bilateral hearing loss: 3.3 for ages 30-39, 9.5 for ages 40-49, 33 for ages 50-59, and 101 for ages 60-69. The authors also reported adjusted ORs for high-frequency hearing loss which were: 2.1 for ages 30-39, 6.7 for ages 40-49, 14 for ages 50-59, and 50 for ages 60-69. The large ORs observed in both the bilateral and high- frequency hearing loss conditions demonstrate a dramatic association between age and the presence of adult hearing loss. A significant association remained when the authors controlled for additional variables (i.e. noise exposure and cardiovascular risk), however the OR data was not provided. However, a much weaker association (but still significant) was observed with age for unilateral hearing loss. The unilateral hearing loss ORs were as follows: 1.1 for ages 30-39, 4.0 for ages 40-49, 4.0 for ages 50-59, and 5.0 for ages 60-69. The unilateral hearing loss ORs follow the same trend as both the bilateral and high-frequency results (i.e. increase with age), but are much smaller, indicating a weaker association. This study is especially important because it demonstrates the dramatic progressive nature of hearing loss.

Next, the “Beaver Dam, Wisconsin” study conducted by Cruickshanks et al. (1998b) will be discussed. This population-based epidemiological study, much like the Framingham Cohort, investigated the prevalence and risk factors associated with adult hearing loss. The authors reported that hearing loss was very common among the study’s adult participants, affecting 46% of participants aged 48-92 years. Additionally, Cruickshanks et al. (1998b) stated that both the risk (OR) and prevalence of hearing loss increased significantly with age. This is demonstrated by increased ORs (1.88) with respect to age, in which the ≥ 80-year-old age group displayed a hearing loss prevalence of 89.5%, and that for every 5 year increase in age the risk of hearing loss increased by 90%. Additionally, Cruickshanks et al. (1998b) reported that the measured hearing thresholds were slightly poorer for lefts ears than right ears at test frequencies above 250 Hz and that thresholds increased (got poorer) at higher test frequencies in each successive age group.

Lastly and in agreement with all previous research discussed, Li et al. (2006) documented that age is significantly associated with adult hearing loss. The multivariate adjusted ORs are as follows: 1.0 for ages 65-69 (comparison group), 2.09 for ages 70-79, and 4.88 for ages ≥ 80, which are in agreement with all previously reported results.

GENDER

Next, gender as a risk factor for adult hearing loss is explored. As reported above, an age-associated decline in hearing acuity in the absence of otological disease and/or noise-induced hearing loss (NIHL) is well documented and agreed upon. However, hearing loss comparisons between genders are complicated by the fact that there is a limited amount of "true" presbycusic hearing loss, particularly among women (Pearson et al., 1995). Additionally, research exploring gender differences has consistently reported a "gender reversal," in that women have better pure-tone thresholds than men at frequencies above 1000-2000 Hz and that men have better pure-tone thresholds than women at frequencies below 1000-2000 Hz. Therefore, five studies which utilized multivariate adjusted ORs in an effort to limit confounding influences and examine gender as a risk factor for adult hearing loss are reviewed.

First, a longitudinal study conducted by Pearson et al. (1995), which followed both men and women for up to 23 years, found that the hearing acuity of men declined approximately two times faster than women at most ages and test frequencies. In addition, the longitudinal data collected by Pearson et al. (1995) indicates the epidemiological evidence of the aforementioned "gender reversal" with respect to the location and degree of pure-tone hearing loss between genders. Pearson et al. (1995) supported the presence of a "gender reversal" by demonstrating that at 1000 Hz there is no significant gender difference in thresholds or ORs (data not shown), while at test frequencies above 1000 Hz female thresholds are better than the male thresholds with the difference becoming larger as the test frequency increased. Additionally, the authors stated that hearing acuity among males begins to decline by age 30 at all test frequencies, whereas the age of onset for hearing loss among females is largely frequency dependant. In women, longitudinal decline in hearing acuity was noted at 500 and 8000 Hz at age 30, with all other frequencies affected by age by 65. However in men, this study reported hearing acuity declines significantly at age ≥ 20 for 500 Hz, and at all other test frequencies for men 30 years and older. It is important to note though, that the ORs associated with hearing loss are much higher in older men than in younger men, and largely affected high frequencies (ORs not provided). Pearson et al. (1995) then reported that the largest gender differences in hearing acuity occurred at 3000 and 4000 Hz. The thresholds at 3000 and 4000 Hz declined (got poorer) at a rate of approximately 10 dB HL/decade faster in 50-year old men than in age-matched women. However, women were shown to have significantly faster rates of hearing loss (than men) at low frequencies and at younger ages. These OR differences were no longer significantly different by age 80 in both men and women. Lastly, Pearson et al. (1995) noted that the observed gender difference in adult hearing loss should not be attributed to the traditional generalization that men are exposed to more harmful noise (e.g. occupation, military, leisure) than women because of this study's adjustment for confounding variables and thorough population screening.

Cruickshanks et al. (1998b) also found that males had a much higher risk of hearing loss when compared to age-matched female participants. In fact, this population-based study of adults ages 48-92 reported an adjusted male OR of 3.65 and a female OR of 1.88, indicating a significant association between gender and adult hearing loss for both males and females (with male ORs being larger). In agreement with Pearson et al. (1995), these researchers also noted that the male participant's hearing acuity decreases at a greater rate than age-matched female participants in the middle to high frequencies (2000-8000 Hz).

The third article examining the relationship between gender and adult hearing loss was performed by Li et al. (2006), and examined data from the Third National Health and Nutrition Examination Survey. After a thorough analysis of the data, the authors reported a multivariate adjusted OR of 2.17 for men and an OR of 1.00 for women (reference group). In agreement with the other research discussed, Li et al. (2006) results indicated that being a male adult is both a strong and consistent risk factor associated with adult hearing loss.

Next, Lin et al. (2011) who analyzed data from the 2005-2006 cycle of the National Health and Nutritional Examination Survey reported that the odds of adult hearing loss were significantly associated with the male sex. Lin et al. (2011) calculated a multivariate-adjusted OR of 1.67 for male participants (relative to females), which they deemed large enough to indicate a significant association between the male sex and adult hearing loss. The authors also found that gender differences were most apparent at higher test frequencies (4000-8000 Hz), which is consistent with the research discussed above. Additionally, gender was analyzed as a continuous variable (not dichotomous – ß coefficients) and different test frequencies where included in the PTA range (e.g. standard vs. speech vs. high frequency), which showed that male participants were significantly associated with adult hearing loss at both “speech” (ß = 4.23) and “high frequency” (ß = 11.5) PTA ranges.

Finally, Agrawal et al. (2008) also utilized hearing loss data from the National Health and Nutrition Examination Survey (1999-2004). This data was complied from participants ages 20-69, and its results are in strong agreement with the findings discussed above. Additionally, these researchers investigated gender as risk factor using three different conditions, which were: bilateral hearing loss, unilateral hearing loss, and high-frequency hearing loss. Using female participants as the reference group (OR = 1), Agrawal et al. (2008) reported multivariate adjusted ORs as follows: 2.4 (bilateral hearing loss), 2.0 (unilateral hearing loss), and 5.5 (high frequency hearing loss). These OR results all demonstrate a significant association between the male gender and adult hearing loss when compared to females in this study population. The 5.5 OR observed in the high frequency hearing loss condition is in strong agreement with the high prevalence rates of hearing loss for adult males living in the US (especially older adult males).

RACE

The third and final demographic risk factor to be examined is the relationship between race/ethnicity and adult hearing loss. This section will report results from research exploring the possibility that a specific race may be more or less likely to have hearing loss. The specific races that will be examined include: white (non-Hispanic), black (non-Hispanic), Mexican/other Hispanic, and "other." In order to examine the possibility of an association, we reviewed four cross-sectional studies, which reported data for a majority of the racial/ethnic groups listed above. Furthermore, all of the articles reviewed utilized self-report methods to formulate the specific racial/ethnic groups. For this section, the findings will be discussed by racial/ethinic group.

The first racial/ethnic group to be examined in this section is the "white – non-Hispanic" (hereafter, white) participant group. The four articles reviewed (Agrawal et al., (2008), Lin et al., (2011), Li et al., (2006), and Helzner et al., (2005)) all utilized the white participant group as the reference or comparison group. Therefore, the white participant group was given an OR of 1. The research reviewed all explained that the white participant group was used as a reference so that other racial/ethnic associations could be explored. However, three of the research articles did report prevalence data indicating that adult hearing loss was most common in the white participant groups. The prevalence of adult hearing in the white racial/ethnic group were reported as follows: 64.4% (Lin et al., 2008), 18% (speech-frequency hearing loss) 36% (high-frequency hearing loss) (Agrawal et al., 2008), and 65.2% (Helzner et al., 2005).

Next, the results observed for the “black – non-Hispanic” (hereafter, black) racial/ethnic group will be reported. The first article to be examined was performed by Lin et al. (2011) and reported that the black participant group demonstrated a strongly protective association against adult hearing loss. The multivariate adjusted OR was 0.32, which indicates that this group’s odds of having hearing loss are significantly lower than those of the white participant group. Furthermore, Lin et al. (2011) reported the prevalence of hearing loss in the black participant group (ages ≥ 70) to be 43.3%, while the white participant group (ages ≥ 70) prevalence was reported to be 64.4%. In agreement, a study conducted by Agrawal et al. (2008) stated that the ORs were determined to be: 0.4 (bilateral hearing loss), 0.5 (unilateral hearing loss), and 0.3 (high frequency hearing loss), when compared to the white reference group. As described above, these ORs also indicate a protective association for black study participants. The authors reported that the prevalence of hearing loss was 8% (speech-frequency hearing loss) and 19% (high-frequency hearing loss). These prevalence statistics were smaller than those reported in white participants (18% (speech) - 36% (high-frequency), Hispanic participants (10% (speech) – 24% (high-frequency), and other participants (16% (speech) – 27% (high-frequency)). The next article to be examined was performed by Li et al. (2006), and also determined that when compared to the other racial/ethnic groups, black participants were less likely to develop adult hearing loss. The ORs for the racial/ethnic participant groups within this study were reported as follows: 1.00 (white – comparison group), 0.62 (black), and .78 (other). As with the previous research examined, this study also supports a protective effect for black participants. Lastly, Helzner et al. (2005) reported multivariate adjusted ORs of 0.7 for the black participant group and 2.84 for the white participant group (no other racial ethnic groups were examined in this study). Additionally, Helzner et al. (2005) stated that the white participant group was 63% more likely to develop adult hearings loss than the black participant group in this study population. As with Li et al. (2006), this study did not report race/ethnicity specific prevalence data. Overall, there appears to be a significant protective advantage of black over whites in terms of lower rates (ORs/prevalence) of adult hearing loss. The effect is significant and consistent across the literature.

The third racial/ethnic group being explored is the Mexican/other Hispanic participant groups (hereafter, Hispanic). Research conducted by Lin et al. (2011) reported a univariate (not adjusted for all study variables) OR of 1.03, indicating a neither harmful nor protective association with adult hearing loss. The Hispanic participant group’s OR (1.03) is very similar to the white participant group OR (1.0). However when compared to the black OR (.32), both white and Hispanic groups displayed a higher probability of having adult hearing loss. In agreement, the prevalence of hearing loss in the Hispanic group was reported to be 65.1%, which is very similar to the white participant group at 64.4%. The prevalence numbers of these two groups are significantly higher than the black participant group at 43.3%. The second study that examined the Hispanic participant group’s likelihood of developing adult hearing loss was performed by Agrawal et al. (2008). These researchers determined that the multivariate adjusted ORs for this group were: 0.7 (bilateral hearing loss), 0.8 (unilateral hearing loss), 0.6 (high-frequency hearing loss), when compared to the white reference group. In comparison, these reported ORs are slightly larger (more harmful) than the ORs observed in the black participant group (see above). However, the Hispanic group demonstrated lower ORs (more protective) than the “other” racial/ethnic group in both the bilateral and high-frequency conditions (ORs were the same in the unilateral hearing loss condition - .8 and .8 for the right and left ears). Next, the prevalence of hearing loss in the Hispanic participant group was reported to be: 10% (speech-frequency hearing loss) and 24% (high-frequency hearing loss). These prevalence statistics were smaller than those reported in white participants (18% (speech)- 36% (high-frequency), and “other” participants (16% (speech) – 27% (high-frequency)). However in agreement with the reported ORs, the Hispanic participant group displayed a slightly higher prevalence of adult hearing loss when compared to the black participant group. Only two studies were examined for this racial/ethnic group due to differences in categorization across the research reviewed. For example, Li et al. (2006) had only three racial/ethnic categories (white, black, and other), therefore no data could be reported.

The last racial/ethnic group to be discussed within this document is the “other” participant group. This group is comprised of study participants who did not identify their racial/ethnic status as: white, black, or Hispanic. Therefore, these individuals of mixed racial/ethnic heritage were combined and examined as a whole. Although the combination of race/ethnic groups yields results that are rather ambiguous (in terms of specific race/ethnicity), the combination is necessary for the statistical calculations (an appropriate N is needed for statistical power/weight). The first study reviewed was conducted by Lin et al. (2011), which reported a univariate (not adjusted for all study variable) OR of 1.62. This OR result indicates that the “other” participant group has a slight (harmful) association with adult hearing loss, and therefore did not display a protective association (as seen in black participants). This OR (1.62) was larger than both the black and Hispanic group’s ORs (in comparison to the reference group) indicating that this group’s likelihood of having adult hearing loss is greater. In agreement, the prevalence of hearing loss in the “other” group was reported to be 74.6%, which is higher than all other participant groups (especially black participants). Next, a study by Agrawal et al. (2008), who also examined an “other” participant group determined that the multivariate adjusted ORs for this group were: 1.3 (bilateral hearing loss), 0.8 (unilateral hearing loss), 0.7 (high-frequency hearing loss), when compared to the reference group. In comparison, these reported ORs are slightly larger (more harmful) than the ORs observed in the black and Hispanic participant groups (in all hearing loss conditions - see above). However, the lower ORs (< 1) observed in both the unilateral and high-frequency hearing loss conditions indicated a slightly protective association (though not statistically significant) between “other” group participants and adult hearing loss. Additionally, the prevalence of hearing loss in the “other” participant group was reported to be: 16% (speech-frequency hearing loss) and 27% (high-frequency hearing loss). These prevalence statistics were smaller than those reported in white participants (18% (speech)- 36% (high-frequency). However in agreement with the reported ORs, the “other” participant group displayed a higher prevalence of adult hearing loss when compared to the black and Hispanic participant groups. The third article examined was conducted by Li et al. (2006), who also determined that when compared to the other racial/ethnic groups (white and black participants – no “Hispanic” population in this study), the "other" participants demonstrated a greater likelihood of having adult hearing loss than the black participant group. The ORs reported for the racial/ethnic groups examined were: .78 (other), .62 (black), and. 1.0 (white – reference group). As with the previous research examined, this study also supports a slight but non-significant protective association between individuals in the "other" participant group and adult hearing loss. Lastly, only three studies were examined for this racial/ethnic group due to differences in categorization and racial/ethnic group inclusion across the research reviewed. For example, Helzner et al. (2005) had only two racial/ethnic categories (white and black).

EDUCATION

The level of education completed as a risk factor for adult hearing loss was also examined within this study. The risk factor information was acquired by way of a trained interviewer administering a questionnaire to each participant, for all research used in this section. The participant groups for a majority of the literature reviewed included: less than high school (< high school), high school (including general equivalency diploma), and some college or more (> high school). In order to perform a more effective and methodical examination of the risk factor data, we will report the OR results for each educational level.

The first educational level and participant group to be examined will be the "less than high school" participant group. Within this group, we reviewed four different articles; however, due to differences in the reference/comparison groups some variability in the results was observed. First, Lin et al. (2011) and Agrawal et al. (2008) utilized (< high school) as its reference group. Therefore in these two studies, this group was assigned an OR of 1.00 to allow for statistical comparisons with the other participant groups. However, these authors did report their measured prevalences of hearing loss in this group, which were 70.1% (weighted percentage – Lin et al., 2011) and 24% (weighted – speech frequency hearing loss) / 40% (weighted – high frequency hearing loss). These prevalence numbers were the highest among all education levels, indicating that a majority of adult hearing loss is present in adults who did not complete high school. Using a different reference group, “some college or more,” Cruickshanks et al. (1998b) reported an OR of 2.42. This OR is representative of the comparison between the “some college or more” group and the “less than high school” group, indicating a strong (detrimental) association between not completing high school and having adult hearing loss. In contrast, research performed by Li et al. (2006) utilized an “at or above high school” group as their reference/comparison group. Therefore, Li et al. (2006) were able to compare the “at or above high school” group with the “less than high school” group, which yielded an OR ratio of 1.12. This OR indicates that no association (protective or harmful) between completing higher levels of education and adult hearing loss exists. These studies (Cruickshanks et al., 1998b & Li et al., 2006) did not report prevalence data.

The second educational level to be examined is the “high school” (including general equivalency diploma) participant group. First, research conducted by Lin et al., (2011) reported a univariate (not adjusted) OR of .70, indicating a slightly protective association with adult hearing loss. Likewise, the authors reported that the prevalence of hearing loss in this group is 62.3% (weighted), indicating a lower prevalence of adult hearing loss than the “less than high school” study population. In agreement, Agrawal et al. (2008) observed multivariate adjusted ORs of: 0.4 (bilateral hearing loss), 0.9 (unilateral hearing loss), and 0.6 (high-frequency hearing loss). The prevalence of adult hearing loss for this group was reported as 17% (weighted – speech frequency hearing loss) and 35% (weighted – high frequency hearing loss), which is also lower than the "less than high school" population (as seen above). Next, Cruickshanks et al. (1998b) investigated the "high school" group and reported an adjusted OR of 1.89, further supporting an association between a lack of scholastic education and adult hearing loss. It should be noted that, although Lin et al. (2011) and Agrawal et al. (2008) reported smaller (minimally protective) ORs and Cruickshanks et al. (1998b) reported larger (detrimental) ORs their results convey the same meaning (that an association exists for this risk factor – participants reporting higher educational levels have less adult hearing loss and participants with less education have more hearing loss). Lastly, the Li et al. (2006) study used this group as its reference group and therefore reported an OR of 1.00 (no association).

The final risk factor group explored within this section will include the participants that completed "some college or more." For this participant group Lin et al. (2011) reported a univariate OR of 0.60 (protective), which was statistically significant. Additionally, the authors reported the prevalence of adult hearing loss to be 58.5% (weighted), which was the lowest prevalence measured in any of the educational levels/risk factor groups in their study. Likewise, Agrawal et al. (2008) observed multivariate adjusted ORs of: 0.3 (bilateral hearing loss – statistically significant), 0.6 (unilateral hearing loss), and 0.5 (high-frequency hearing loss). The prevalence of adult hearing loss for this group was reported as 13% (weighted – speech frequency hearing loss) and 28% (weighted – high frequency hearing loss), which is also lower than any of the other education levels/risk factor groups in their study. These ORs and prevalence data are consistent with the research reporting a minimal protective association between “some college or more” and adult hearing loss (or a harmful association between “less than high school”) and having adult hearing loss. Lastly, both Li et al. (2006) and Cruickshanks et al. (1998b) used this group as its reference group and therefore reported an OR ratio of 1 (as stated above).

SMOKING

The next risk factor to be examined is cigarette smoking and its relationship with adult hearing loss. Currently, it is estimated that 45.1 million adults smoke cigarettes in the US (Giovino, 2007). There is an abundance of evidence indicating that cigarette smoking is a well-known risk factor for many adult-health issues, such as lung cancer and cardiovascular disease. However, the literature exploring the association between cigarette smoking and adult hearing loss has been rather variable. Therefore, in this section we will: first examine the research collection and stratification methods, then report the data supporting an association with smoking, and conclude with a discussion of the research that found no association between smoking and adult hearing loss.

We will first discuss the research that reported an association between cigarette smoking and adult hearing loss. All five of the studies reporting an association utilized a population-based cross sectional study design to acquire its risk factor and comparison data (e.g. Gopinath et al., 2010). Additionally, a strong majority of research performed a baseline smoking assessment to determine: if the participants smoke, at what age participants started/stopped, and quantity of cigarettes smoked per day. This data enabled the researchers to determine the number of pack-years smoked by a study participant. The level of exposure was then termed in pack-years which was calculated by multiplying the participant's amount of time smoked (in years) by the usual quantity of cigarettes smoked per day and dividing that number by 20 (the number of cigarettes in a pack). Then the participants were stratified in to three groups: nonsmoker, ex-smoker, and current smoker. After the collection and calculation of the data was complete, each study was able to determine the likelihood of an association. We will next report the observed results from each study for each participant group (e.g. non-smokers, current smokers, and ex-smokers).

Gopinath et al. (2010) reported that when non-smokers (31.6% of the study participants) were compared with current (30.4% of the study participants) and ex-smokers (34.9%) with any degree of hearing loss, current smoking was marginally associated with adult hearing loss. The OR was determined to be 1.40 when adjusted for confounding variables indicating a marginally significant association between smoking cigarettes and adult hearing loss. However, the association between smoking and adult hearing loss was not more pronounced when taking into account the number of pack-years smoking (no dose-response effect), which is in agreement with similar research performed by Gates et al. (1993), discussed below. Gobinath et al. (2010) also reported that current smoking was not significantly associated with severe hearing loss. Additionally, Gopinath reported that no significant association was observed when stratified gender ORs were compared. Lastly, although Gopinath et al. (2010) reported a marginally significant association between cigarette smoking and hearing loss, the authors are unwilling to confirm a "true" association. Next we will examine a cross-sectional study by Cruickshanks et al. (1998a). Both the study design and observed results were similar to Gopinath et al. (2010). However, Cruickshanks et al. (1998a) reported that current smokers demonstrated an adjusted OR of 1.70, indicating a significant association and that this participant group is 1.7 times more likely to have hearing loss when compared to non-smokers. Cruickshanks et al. (1998a) also reported that ORs increased as the number of pack-years smoking increased (OR was 1.30 for ≥ 40 pack-years), and that ORs were higher (1.94) for nonsmokers living with a current smoker. The third study supporting an association was performed by Agrawal et al. (2008) and employed a cross-sectional study design similar to the research discussed above. The authors reported that an adjusted OR of 1.5 was observed in the "heavy smoker" participant group (≥ 20 pack-years of cumulative exposure) when compared to "non-smokers" (reference group). These results are in strong agreement with the literature discussed above and add to the growing amount of literature reporting an association between smoking and adult hearing loss. However, Agrawal et al. (2008) also investigated the frequency ranges thought to be affected by smoking. Their research demonstrated that "heavy smokers" possessed significantly poorer hearing sensitivity at both lower and higher test frequencies (500-1000 Hz and 4000-8000 Hz) when compared to non-smokers. In fact, the authors note that "heavy smokers" had thresholds that were 4-5 dB poorer than non-smokers at test frequencies 4000-8000 Hz. Lastly, Itoh et al. (2001) conducted a case-control study using age-matched participants ranging from age 60 to 80. The researchers reported and adjusted OR of 2.23 for current smokers smoking (< 20 cigarettes/day) and an adjusted OR of 2.01 for current smokers (smoking ≥ 20 cigarettes/day). It is important to note, that the similar ORs observed for the < 20 and ≥

20 cigarettes/day groups demonstrates that a dose-response effect was not observed, meaning that, in this study, participants smoking ≥ 20 cigarettes/day did not displayed increased hearing loss.

In direct contrast, studies performed by Gates et al. (1993), Lin et al. (2011), and Li et al. (2006), reported that no association between cigarette smoking and adult hearing loss exists. Similar to the research supporting an association above, Gates et al. (1993) and Lin et al. (2011) used non-smokers as the reference group. Therefore, the non-smokers were assigned an OR of 1.00 to facilitate comparison among the smoker groups. First a cross sectional study performed by Gates et al. (1993), observed a current smoker adjusted OR of 1.19 indicating no association with adult hearing loss (when compared with non-smokers). Likewise, when examining the former smoker participant group Gates et al. (1993) reported an adjusted OR of 1.03 demonstrating a neither harmful nor protective relationship with adult hearing loss. The second article that reported no association between smoking and adult hearing loss was conducted by Li et al. (2006). The researchers reported that former smokers demonstrated an OR of 1.49, indicating a marginal association between smoking and adult hearing loss. However, Li et al., (2006) reported that current smokers displayed an OR of .98 (with non-smokers as the reference groups). The lack of association observed in the current smokers groups (OR = .98 – which not > 1.00), was attributed to differences in smoking group categorization prior to data collection. In agreement, Lin et al. (2011) reported a multivariate adjusted OR of .94 for current smokers and an OR of 1.08 for the former smoker participant group. The non-significant OR results observed in these three studies suggest that no association exists between smoking and adults hearing loss.

ALCOHOL

After examining the association between smoking and hearing loss, the relationship between consumption of alcohol and adult hearing loss was explored. It is currently estimated that 50.9% of US adults (18 years and older) drink some form of alcoholic beverages on a regular basis (Gopinath et al., 2010). Similar to smoking, the amount of alcohol consumed will vary across each study participant and the general adult population. Therefore, consumption amounts were stratified across all research examined in an attempt to: investigate the possibility of an association with the risk factor, identify a dose-response effect associated consumption (e.g. heavy, moderate, and non-drinker), and limit the presence of confounding variables.

Three articles were examined in a attempt to determine if an association between alcohol drinking and adult hearing loss exists. First and as mentioned above, the researchers had to stratify the amount of alcohol consumed to determine: if an association existed (harmful or protective), if it was the result of a certain consumption volume (dose-effect), and/or did simply drinking alcohol facilitate the association. In an effort to stratify and quantify the amount of alcohol consumed (if any) by each study participant, all of the literature utilized an interviewer-administered questionnaire. The research examined for this risk factor used a data collection and stratification model very similar to that observed in Li et al. (2006) study. Therefore, alcohol consumption was assessed by questions regarding the frequency of drinking alcohol (days/week) and the usual number of drinks per day when alcohol was consumed. Study participants were then stratified into three groups: non-drinkers, moderate drinkers (consume 1-4 drinks on a typical drinking day), and heavy drinkers (consume 5 or more drinks on a typical drinking day). After defining the "drinker" groups we can now examine and report the OR results from the each of the three strata (e.g. non-drinker, moderate drinker, and heavy drinker).

In all three articles examined, the authors utilized the non-drinkers as the reference group. Li et al. (2006) reported a multivariate adjusted OR of .85 for moderate drinking groups. The authors then noted, that after adjustment and logistic regression a protective association remained between moderate drinking adult hearing loss. In strong agreement with the Li et al. (2006), Itoh et al. (2001) found that moderate drinking also yielded a protective effect. Itoh et al. (2001) reported a multivariate adjusted OR of .55, demonstrating an even more significant protective association with adult hearing loss than observed in the Li et al. (2006) study. Likewise, Gopinath et al. (2010) reported a multivariate OR of .66, which demonstrated that a moderate consumption of alcohol provides a significant protective association between drinking and the presence of adult hearing loss. Furthermore, these authors observed that the protective effect increased with increasing severity of hearing loss.

Lastly, the heavy drinking participant groups will be examined. Li et al., (2006) reported a multivariate adjusted of 1.38 indicating that no association between heavy drinking and adult hearing loss. Similar results were reported by Itoh et al. (2001), who found a multivariate adjusted OR of .96 for this participant group. Gopinath et al. (2010) did not report heavy drinking OR results.

CHAPTER 4

Discussion of Risk Factors

After reporting the quantitative risk factor results, the following will now be examined: which risk factors were most harmful and/ or protective (the magnitude of effect), the relationship between/across risk factors, and the overall findings/observed trends. The purpose of this chapter is to summarize the harmful and/or protective risk factors and how the risk factors compare across the literature.

The magnitude of risk factor effect by examining which risk factors demonstrated the strongest (harmful) association with adult hearing loss will be presented. As expected and reported previously, age was the strongest risk factor for adult hearing loss in all studies reviewed. Due to the consistency observed in both the OR and prevalence data (see Chapter 3) we are confident that a true association exists between increasing age (especially at ages ≥ 70) and adult hearing loss. The second strongest (harmful) risk factor was gender. After a thorough analysis of the literature, it was observed that male adults were significantly (statistically) associated with adult hearing loss. Using OR and prevalence results observed above in Chapter 3, we also feel comfortable reporting an association between adult males and hearing loss. The third demographic risk factor that demonstrated an association (harmful) with hearing loss was race/ethnicity. However, this risk factor demonstrated extremely variable results across its participant groups. The white participant group, despite not having ORs (reference group), displayed a significantly higher prevalence of hearing loss than all other races/ethnicities in a majority of the research reviewed. Therefore, in agreement with the literature, an association exists between the white race/ethnicity and adult hearing loss. All other participant groups (e.g. Hispanic, “other”) displayed variable OR and prevalence across the studies, with the exception of the black participant groups, which will be discussed below. The next most harmful risk factor was determined to be smoking cigarettes, which demonstrated harmful but not statistically significant associations with adult hearing loss (see Chapter 3). Therefore, it was deemed that no true association exists between smoking and adult hearing loss. Following smoking, it was determine that level of education displayed a slightly harmful but non-significant association with adult hearing loss. In fact, the “less than high school-completed” participant group explored within this risk factor demonstrated a marginal association with adult hearing loss (see Chapter 3). However, it is difficult to draw firm conclusions, as the results were fairly variable across the literature. The least harmful risk factor examined within this study was the moderate consumption of alcohol. When we analyzed this risk factor, no significant association with adult hearing loss was observed. In fact, the only participant group that could be compared was the “heavy drinkers” (“moderate” drinking was protective – see below) and the OR results were equivocal. Lastly, after rank ordering the harmful risk factors (most to least), it should be noted that the three principal risk factors (age, gender, and race/ethnicity) demonstrated an additive effect; in that white men age ≥ 70 were at the highest risk for adult hearing loss.

The risk factors and/or participant groups that demonstrated a significant protective association with adult hearing loss are now analyzed. In agreement with previous research, the OR analysis demonstrated that moderate consumption of alcoholic beverages (1-4 drinks on a typical drinking day) yielded a protective effect for adult hearing loss. Given these results, this study advocates for the light to moderate consumption of alcohol. In addition to moderate alcohol consumption, a significant protective association was observed in the black racial/ethnic participant group. The consistent agreement across all the literature reviewed demonstrated that black study participants (especially black females) displayed less adult hearing loss than other races/ethnicities. In addition, Lin et al. (2011) observed a statistically significant (univariate – not adjusted) protective effect for study participants that completed “some or more college”. Although Lin et al. (2011) is the only study to report a statistical association, we felt the finding should be mentioned. Furthermore, a majority of research that explored level of education found a marginally protective effect that completing higher levels of education was related with reduced hearing loss as an adult (see Chapter 3). However, we are not willing to report an association with the risk factor, given that only one study found it statistically significant.

CHAPTER 5

Limitations

The presence of limitations and variability across the literature used in this document will now be discussed. Although not commonly reported in a majority of audiologic research, it is commonplace in epidemiologic research to make study limitations explicit. The most commonly reported limitation in the literature reviewed for this document was that a majority of risk factor data was collected via self-report. The method of self-report data collection allows for study participant to control the data provided, thereby introducing possible variability. Furthermore, there is an observed tendency for study participants to deny or minimize the use of a given risk factor (e.g. alcohol consumption, and smoking), which can affect ORs and prevalence data.

The second most common limitation reported was that the risk factor ORs were derived from cross-sectional data. This lack of longitudinal research has limited the amount of long-term data gathered with respect to ORs and/or "rates of change" in hearing sensitivity throughout the adult lifespan. Without longitudinal data, some researchers are much more hesitant to declare a causal relationship or a "true" association between the given risk factor and adult hearing loss.

The next limitation is the comparison of research that used different stratification and/or adjustment methods for the risk factor/participant groups. However, this limitation was essentially unavoidable (in this document) due to the large amount of literature reviewed and the need to compare results. For example, research performed by Li et al. (2006) utilized an "other" racial/ethnic group to assess the relationship between race/ethnicity and adult hearing loss, but did not have a "Hispanic" group. Therefore, when the Li et al. (2006) "other" group was compared with Agrawal et al. (2008), who had both "Hispanic" and "other" participant groups, a fair comparison could not be made because the Li et al. (2006) data included participants of "Hispanic" descent and the Agrawal et al. (2008) "other" group did not. Additionally, it should be pointed out that some of the research reviewed did utilize different methodologies and definitions for "hearing loss/hearing impairment". These differences certainly could have impacted the reported prevalence rates and/or ORs. Lastly, the differences with respect to the adjustment of confounding variables should be made explicit to this document's readers. For example, Agrawal et al. (2008) reported multivariate adjusted (i.e. adjusted for: age, gender, smoking, etc) ORs for all risk factors. In contrast some of the ORs reported by Lin et al. (2011) were univariate adjusted ORs, which allows for confounding variables to skew the OR.

CHAPTER 6

Future Considerations / Risk Factor Prevention

As reported above, adult hearing loss has become a major and ever-increasing public health issue. After considering the ORs and prevalence data reported above, the field of audiology and public health should be working together to: identify adult hearing loss, implement effective health promotion programs, and improve treatment/access strategies.

The future consideration of risk factors and their assessment should be considered an important component of this document. Given the limitations discussed above in Chapter 5, the continued investigation into “how” and “why” risk factors are associated with adult hearing loss is strongly advocated. As mentioned above, the clinical and subclinical utility associated with risk factor analysis could significantly improve treatment/prevention strategies. The ability to know “by how much” and/or “to what degree” a patient’s risk of developing/or having hearing loss could revitalize both the audiologic and medical field’s patient-care models. These clinical/diagnostic improvements may then increase the use and satisfaction levels of: hearing aids, assistive listening devices, cochlear implants, and/or aural rehabilitation (Strawbridge et al., 2000). Consequently, improved treatment options would likely then be able to improve the: psychosocial, cognitive, communicative, and physical aspects of adult life with hearing loss (Sprinzl & Riechelmann, 2010). These future consideration associated with risk-factor related adult hearing loss could greatly improve both the treatment methods and the quality of life for adults with hearing loss.

Next, the process of risk factor prevention and the implementation of strategies to limit and/or decrease adult hearing loss is examined. As discussed above in Chapter 4, some of the risk factors examined are impossible to prevent. For example, this is no program and/or treatment strategy to prevent/alter demographic risk factors such as: the process of aging, gender, and/or race/ethnic heritage. However, the other three risk factors examined within this document are "lifestyle" related, thus making them preventable. Therefore, the effort and financial support from audiologic and public health sources should be invested into effective programs and treatment strategies. Take smoking for example, a majority of the literature indicated a harmful association between smoking and adult hearing loss (ORs > 1). Therefore, the implementation of smoking cessation programs in hopes of improving adult hearing health should be an area of advocacy. Furthermore, the implementation of a large-scale smoking cessation campaign/program could be a cost-effective approach for public health institutions due to the large health care costs (e.g. Veterans Affairs provision of hearing aids) associated with adult hearing loss.

"How" a successful public health based adult hearing loss prevention/treatment program should be established is now presented. First the program organizers must identify "stakeholders" and sponsors that are willing to support the program/cause. The identification of "stakeholders" and/or sponsors on multiple levels should be pursued to ensure appropriate "reach" of the program. Ideally, an adult hearing loss program would want to identify/recruit stakeholders on the federal, state, and local levels to increase program delivery and access. The next step in program implementation is the foundation of clearly defined program goals (short and long-term) and delivery components. For example a long-term goal might be "to reduce self reported hearing loss by 5% in adults ages 30-40 by way of community-based presentations). Additionally, the identification of potential barriers should be discussed. Potential barriers to the implementation of an adult hearing loss prevention/treatment program might be: access to the audience, consistent funding, and/ or acceptance of the program components. Next, the program organizers will need to establish exactly how the program is to be delivered. Some effective methods of program delivery include: informational mailers (e.g. reporting the large prevalence of adult hearing loss in the US or the association between smoking and adult hearing loss), TV commercials, and/or community-based presentations. Following the identification of program goals and components, the individuals delivering the program's message should be trained/coached. Proper training and/or a discussion of the program's goals should help to ensure that the anticipated message/information is delivered. Individuals performing these duties might include: audiologists, public health professionals, teachers, and/or community advocates. Next, the program should incorporate epidemiological and evaluative research to ensure that the program is targeting the correct population (adults in the US) and is has been implemented accurately and effectively. This component of an effective hearing loss prevention/treatment program cannot be understated, as the funding for these programs is usually limited. Therefore, it is essential that the program is operating efficiently and effectively. Additionally, positive results from a program evaluation may facilitate increased funding and/or volunteers. Assuming the program evaluation revealed: the target audience is being reached, the program content is appropriate for the audience, and goals are being met, then the program should be left to function as is. Otherwise, the program organizers, “stakeholders,” and sponsors may want to establish new/adjusted goals or methods of delivery. In conclusion, implementation of a public-health based adult hearing loss prevention/treatment program should be much more effective (both in the short and long-terms) if the aforementioned process is followed.

LIST OF REFERENCES

Agrawal, Y., Platz, E.A., & Niparko, J.K. (2008) Prevalence of hearing loss and differences by demographic characteristics among US adults. *Otology & Neurology*, *30*, 139-145.

Cruickshanks, K.J., Klein, R., Klein, B.E.K., Wiley, T.L., Nondahl, D.M., & Tweed, T.S. (1998a) Cigarette smoking and hearing loss: the epidemiology of hearing loss study. *Journal of the American Medical Association*, *279,* 1715–1719.

Cruickshanks, K.J., Klein, R., Klein, B.E.K., Wiley, T.L., Nondahl, D.M., & Tweed, T.S., Mares-Perlman, J.A. (1998b) Prevalence of hearing loss in older adults in Beaver Dam, Wisconsin. *American Journal of Epidemiology*,148, 1715–1719.

Gates, G.A., Cobb, J.L., D'Agostino, R.B., & Wolfe, P.A. (1993) The relation of hearing in the elderly to the presence of cardiovascular disease and cardiovascular risk factors. *Archives of Otolaryngology Head & Neck Surgery*, *119*, 156-161.

Giovino, G.A. (2007) The tobacco epidemic in the United States. *The American Journal of Preventative Medicine*, *33*, 318-326.

Helzner, E.P., Cauley, J.A., Pratt, S.R., Wisniewski, S.R., Zmuda, J.M, Talbott, E. O., Rekeneire, N., Harris, T.B., Rubin, S.M., Somonsick, E.M., Tylavsky, F.A., & Newman, A.B. (2005) Race and sex differences in age-related hearing loss: The health, aging and body composition study. *Journal of the American Geriatrics Society*, *53*, 2119-2127.

Itoh, A., Nakashima, T., Arao, H., Wakal, K., Tamakoshi, A., Kawamura, T., & Ohno, Y. (2001) Smoking and drinking habits as risk factors for hearing loss in the elderly: epidemiological study of subjects undergoing routine health checks in Aichi, Japan. *Public Health*, *115*, 192-196.

Kochkin, S. (2010) MarkeTrak VIII: Consumer satisfaction with hearing aids is slowely increasing. *The Hearing Journal*, *63*, 19-32

Li, Y., Healy, E.W., Drane, J.W., & Zhang, J. (2006) Comorbidity between and risk factors for severe hearing and memory impairment in older Americans. *Preventive Medicine*, *43*, 416-421.

Lin, F.R., Thorpe, R., Gordon-Salant, S., Ferrucci, L. (2011) Hearing loss prevalence and risk factors among older adults in the United States. *Journal of Gerontology*, *66a*, 582-590.

Pearson, J.D., Morrell, C.H., Gordon-Salant, S., Brant, L.J., Metter, E.J., Klein, L.L., & Fozard, J.L. (1995) Gender differences in a longitudinal study of age-associated hearing loss. *The Journal of the Acoustical Society of America*, *97*, 1196-1205.

Pepe, M.S., Janes, H., Longton, G., Leisenring, W., & Newcomb, P. (2004) Limitations of the odds ratio in gauging the performance of a diagnostic, prognostic, or screening marker. *American Journal of Epidemiology*, *159*, 882-890.

Ries, P.W. (1994) Prevalence and characteristics of persons with hearing trouble: United States, 1990-91, *Vital Health Statistics*, *188*, 94–1516.

Sixt, E., & Rosenhall, U. (1997) Presbycusis related to socioeconomic factors and state of health. *Scandinavian Audiology, 26*, 133–140.

Sprinzl, G.M., & Riechelmann, H. (2010) Current trends in treating hearing loss in Elderly people: a review of the technology and treatment options – a mini review. *Gerontology*, *56*, *351-358*.

Strawbridge, W.J., Wallhagen, M.I., Shema, S.J., & Kaplan, G.A. (2000) Negative consequences of hearing impairment in old age: a longitudinal analysis. *The Gerontologist*, *40*, 320-326.

Viera, A.J. (2008) Odds ratios and risk ratios: What's the difference and why does it matter? *Southern Medical Journal*, *101*, 730-734.

Yueh, B., Shapiro, N., MacLean, C.H., & Shekelle, P.G. (2003) Screening and management of adult hearing loss in primary care. *Journal of the American Medical Association*, *289*, 1976-1985.