SOURCES AND PATTERNS OF NOISE EXPOSURE IN TEENAGERS AND UNDERGRADUATES

by

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ABSTRACT

The present study was undertaken in order to investigate the sources and patterns of noise exposure in teenagers and undergraduates, and also to look for signs of decreased hearing sensitivity, which might be related to noise exposure.

Information was obtained regarding the noise exposure habits of this population through a noise exposure history questionnaire, activity diary, and a 13 hour dosimetry sample. Thresholds were obtained for all subjects using pure tone air and bone conduction audiometry at octave frequencies from 250 to 8000 Hz and inter octave frequencies above 1000 Hz. Middle ear function was checked using immittance audiometry including tympanometry and screening ipsilateral acoustic reflexes at 1000 Hz. The results indicated that the sources and patterns of noise exposure for both teenagers and undergraduates were fairly similiar. The major steady state sources of exposure for all subjects were television and amplified music. The major impulse sources of exposure were firecrackers and rifles.

Mean eight hour equivalent dosimetry levels for teenagers were 84.9 dBA . It was found that 50 % of the teenagers had dosimetry levels exceeding the mean level. Only 4 % of subjects from either group reported regular use of hearing protection in noisy conditions.

Thresholds for all otologically normal subjects were found to be within normal limits (25 dB HL). The poorest mean thresholds for both teenagers and undergraduates were found at 6000 Hz. Correlations between thresholds at 6000 Hz and dosimetry levels, selected steady state sources and selected impulse sources did not indicate a significant relationship between any of these variables.

Dosimetry levels obtained in the current study were higher than those obtained by previous studies and indicate that further investigation in this area is warranted.

The finding of poorer thresholds at 6000 Hz was in agreement with the findings of previous studies but the current study did not show a strong relationship between noise exposure and auditory thresholds for this population.

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CHAPTER ONE

INTRODUCTION

The majority of data relating to noise induced hearing loss (NIHL) has come from research on populations exposed to occupational noise. Only recently has attention been drawn to the possibility of NIHL in the pre-occupational population. This population is composed primarily of children, adolescents and young adults who are exposed to a wide range of noise sources in the course of a day. As a result of this fact it is often difficult to quantify the noise exposure received by this population because the contributing sources are not as continuous or well defined as the noise sources encountered in industry are.

It is important to determine whether this population is exposed to hazardous levels of noise exposure for a number of reasons. In the case of children who are still developing speech and language, NIHL can interfere with both communicative functioning and in the long term, educational success. For adolescents and young adults NIHL has an impact on communicative functioning, educational, and occupational success. The importance of NIHL is that it can be prevented if the parameters of dangerous noise exposure can be defined and then communicated to students through effective hearing conservation programs. In addition, if typical levels of noise exposure are demonstrated to cause hearing impairment in only a small proportion of the pre-occupational population then this will help to identify those individuals who may show increased susceptibility to NIHL. This may then allow for counselling of those individuals in regard to future career choices.

CHAPTER TWO

LITERATURE REVIEW

Effects of Noise on the Structure and Function of the Auditory System

Effects of noise on the structure and function of the auditory system have been well documented . Boehne (1976) discussed a number of possible mechanisms for noise damage in the inner ear as a function of the sound pressure level of a particular exposure. The levels defining each category of exposure were generalized as very intense, intense, and moderate. The appearance of the inner ear epithelium of guinea pigs and chinchillas and the duration of exposure required to produce injury were used to identify these three categories. In the case of very intense, short duration stimuli typical of many impulse noises, the mechanism of damage is usually mechanical since the organ of Corti is often separated from the basilar membrane and found floating in the scala media. Intense and moderate noise exposure usually must be present for several hours or days to produce injury and in these cases it is believed that one or more mechanisms are responsible for cellular damage and degeneration. Boehne postulated that these mechanisms would be metabolic exhaustion of stimulated cells and changes in vascular supply. In addition, progressive degeneration after noise exposure may be due to endolymph entering into the fluid spaces of the organ of Corti.

The mechanisms of damage in the cochlea from noise exposure have been developed more fully in the recent literature. Henderson (1985) noted that the anatomical basis for loss includes changes in all major cellular subsystems. At low levels of exposure, excessively high levels of metabolism are probably responsible for damaging hair cells and afferent dendrites. At higher levels of exposure, it is possible to rupture tight cell junctions allowing the mixture of endolymph and perilymph. At even higher levels of continuous noise exposure, greater than 120 dB SPL, or with impulse noise the cochlea is damaged by mechanical processes.

Not only are changes in sensory elements accomplished by metabolic and mechanical processes, changes in vascular elements of the basilar membrane and the lateral wall of the organ of Corti may also have an effect.

The location of the damage maxima is also of interest. It will be dependent on the frequency of the stimulus, with high frequency sounds producing maximal damage at the base and low frequency sounds producing maximal damage at the apex. Based on our knowledge of the physics of sound wave transmission in the cochlea it is not surprising that the effects of a particular input stimulus are seen at more than one location in the cochlea. For example, damage can appear in the first turn of the cochlea in ears exposed for 9 days to an octave band of noise centered at 500 Hz and 103 dB SPL. In addition, it is possible to destroy 50-60% of the organ of Corti leaving only the third turn uninjured by a 3.5 hour exposure to an octave band of noise centered at 4000 Hz and 108 dB SPL.

The impact of noise on auditory function is equally extensive as its effect on structure. Audiologists are interested in the effects of noise on auditory sensitivity. As a result, the impact of noise on both tonal thresholds and speech discrimination abilities will be of concern, primarily in the case of children and adolescents who are either in the process of developing speech and language or attempting to learn difficult materials in an educational setting.

The effects of noise on hearing as measured by pure tone audiometry indicate certain systematic patterns of loss. A large number of studies have looked at both temporary and permanent threshold shifts due to noise exposure. The focus of this paper is on permanent effects of noise on hearing. As a result only those studies looking at permanent threshold shift will be reviewed in this section.

Taylor et al (1985) examined the hearing of female jute weavers employed for one to 40 years in a factory where noise levels had been constant for 52 years. The spectrum of noise showed maxima at 1000 and 2000 Hz with an impulsive component which corresponded to the motion of the looms. The measured output of the source was 98 dB on the A weighted scale (dBA).

Threshold data indicated that during the first 10 to 15 years of exposure the greatest threshold shift was seen at 4000 or 6000 Hz. After 20 to 25 years the frequencies of 3000, 2000 and 1000 Hz were also affected with the greatest threshold shift being seen at 2000 Hz.

In 1985 the Ministry of Energy, Mines, and Petroleum Resources in British Columbia (Pyplacz, 1986) examined retest audiograms on 19,874 occurrences of hearing loss of 15 dB or more at any frequency. The findings of this study provided valuable information on the permanent effects of noise exposure over time on the miners in this province. The results of analysis indicated that 30% of the hearing losses occurred in the 6000 Hz range, about 25% at 8000 Hz and the rest of the losses varied from 50% at 500 Hz and 1000 Hz to 15% at 4000 Hz. Of hearing losses occurring, 15 dB decreases accounted for 50% and 20 dB decreases for 22%. Of those tested, 73% admitted noise exposure outside of work. Of those admitting exposure outside of work, 68% reported gun use as one of the major sources. The interesting finding was that the breakdown of the number of hearing losses at each frequency by age group showed that hearing loss at 500, 3000 and 4000 Hz occurs consistently across all age groups. Losses of hearing increased with age at 1000 and 2000 Hz and decreased with age at 6000 and 8000 Hz. The results of analysis also indicated that 79% of workers who lost hearing were exposed to work noise of less than 90 dBA. In addition most hearing loss occurred for workers in jobs classified as infrequently exposed, such as supervisors, foremen etc. At six month retest recovery of hearing loss up to 15 dB or more occurred in 47.5% of all losses. The greatest amount of recovery occurred in the first 12 months, with the highest percentage of recovery being at 500 Hz and the least amount of recovery being at 3000 and 4000 Hz. Finally, the analysis indicated that the most hearing loss occurs at 6000 Hz and slightly more in the left than the right ear followed by 8000, 4000, 3000, 2000 and 1000 Hz.

The effects of impulse noise on hearing have been discussed in Ward and Glorig (1961) and Taylor and Williams (1966). Ward and Glorig (1961) looked at the permanent threshold shift produced by a single exposure to firecracker explosion. The results of this study indicated that the greatest loss was seen across time at 6000 Hz with the most recovery being observed between one month and two years at 2000 Hz. The results of Taylor and Williams (1966) for loss of hearing in habitual sport shooters were very similar to that of Ward and Glorig (1961) indicating that permanent threshold shift occurred between 2000 and 6000 Hz with the greatest loss of sensitivity being seen at 6000 Hz.

Current Regulations Pertaining to Noise Exposure

In order to develop regulations for noise exposure it has been important to first define the parameters of noise. Noise is defined as a complex stimulus of varying intensity, frequency, and temporal patterns. The types of noise most often distinguished are steady state and impulse noise. Steady state noise may consist of continuous, fluctuating, or intermittent sources. Recreational noise or leisure noise is most frequently fluctuating or intermittent. Impulse noise consists of one or more transient acoustic events, i.e.: a gunshot, each of which lasts at least 500 milliseconds and has a magnitude (change in SPL) of at least 40 dB in that time. An impulse noise is characterized by its peak SPL, duration, rise and decay time, type of waveform, spectrum, and number of impulses. Impulse noise is associated with many leisure activities as well, eg: firecrackers, gunshots. Since we know the parameters of noise contributing to hazard are amplitude of the source, frequency spectrum of the source, and duration, the schemas we use to evaluate noise exposure need to reflect this.

The most commonly used instrument for measuring noise is the sound level meter. The sound level meter works on the principle of equal loudness relationship for pure tones and bands of noise. This relationship shows at what intensity different frequencies are equal in loudness to a 1000 Hz tone presented at different intensities. The A weighted scale is the most commonly used scale on the sound level meter since it accounts fairly well for man's perception of sound. There are many other scales of rating sound level as well but these will not be discussed here.

Since noise is fluctuating it is valuable to discuss how often it exceeds a certain criterion level. A measure for accounting for both duration and magnitude of all sounds occurring in a given time period is average sound level or Leq-equivalent continuous noise. This value is determined by calculating a noise dosage value for a given sampling period. This noise dosage value which is either less than or greater than 1 can then be converted to an equivalent 8 hour value in dBA. Noise dosage can be measured in a number of ways. The most common method of measuring noise dosage is with a dosimeter which is basically a pocket integrating sound level meter. Noise dosimeters are useful for obtaining accurate estimates of noise exposure when the sources to which an individual is being exposed, change frequently across the period in question.

The damage risk criteria for noise exposure currently in effect has been designed to protect individuals in the industrial workplace where damage to hearing arising from noise is a definite possibility due to high intensity, continuous exposure of long duration. This type of exposure has been shown to cause hearing loss in the absence of protective devices. A number of standards have been devised for use in industry. The first of many attempts to formulate occupational noise standards occurred in the United States with the Walsh Healey Act of 1936. The act as discussed in Feldman (1985) specified the following:

a) measurement based on dBA sound level meter readings;

b) a 90 dBA, 8-hour damage risk criterion;

c) the summing of exposures over time;

d) the specification of need for engineering and administrative controls to reduce worker exposure to 90 dBA for an 8 hour period;

e) halving of exposure-time/intensity trade-off relationship

of 5 dB; and

f) the use of personal hearing protective devices when engineering and/or administrative controls are not feasible. (p.77-78)

Since the formulation of the Walsh Healey Act a number of similar regulations have been enacted. The most commonly referred to is the OSHA or Occupational Health and Safety Administration Act (1983) which is the standard for industry in the United States today. The OSHA regulation continues to use the 90 dBA, 8 hour criteria for maximum exposure with a 5 dB time/intensity trade-off.

In British Columbia, regulations for noise exposure are contained in the Workers Compensation Board Industrial Health and Safety Regulations (1979:13-5 to 13-8) sections 13.21 to 13.35 titled "Noise Control and Hearing Conservation" and are similar to the OSHA act except for the fact that they employ a 3 dB time/intensity trade-off rather than the 5 dB time/intensity trade-off employed by OSHA. The regulation presents guidelines for exposure to steady state and impact noise. In addition, it states a maximum daily dosage of unity which equals one for exposure that is composed of two or more noise levels. The regulation also requires that workers exposed to 85 dBA steady state noise be consistently monitored for changes in hearing status. The B.C. Ministry of Mines, Energy and Petroleum also has the same requirements as the Workers Compensation Board. The choice of 90 dBA, 8 hour criteria in industry is rather arbitrary since demographic data have suggested that damage may begin at 85 dBA (Burns and Robinson,1970) or even as low as 60 dBA (Kryter,1973). However, in terms of economy 90 dBA has stood the test of time.

For both the Workers Compensation Board and the Ministry of Mines action is taken in regard to a worker's hearing status when a drop in sensitivity of 15 dB or greater at any of the frequencies between 500 and 6000 Hz is noted for either ear. When these results are obtained on an audiogram, medical follow up is advised in addition to repeat audiograms at six months. In a paper presented at the CASLPA conference in Halifax (Roberts, 1987) the Workers Compensation Board of B.C. suggested that 6000 Hz be omitted from the criteria for determining loss of sensitivity due to exposure because of test/retest variability.

Maturation of Auditory Function

A number of studies have documented the change in auditory threshold with age in children. Fior (1972) obtained pure tone thresholds from 125 to 8000 Hz for a group of 70 children aged 3 to 13 years . Fior concluded from this data that hearing maturation is gradual reaching a maximum between the ages of 10 and 13. For high frequencies it was noted that improvement in hearing acuity begins at an earlier age with high scores being obtained even at age 4. Threshold variability and auditory fatigue were also examined in this study. The results indicated that threshold variability was very low across the age groups and that threshold variation due to fatigue decreased with age.

This trend toward better thresholds with age is also seen in the data obtained by Roche et al (1983) on boys and girls aged 6 to 18 years. The results of this study indicated that for both boys and girls thresholds improved between the ages of 8 and 13 with a significant decrease in sensitivity noted for both males and females at age 16. This data is in agreement with the observation of Fior (1972) that auditory thresholds are best at age 13 showing a decrease thereafter. The data of Roche et al (1983) also indicates that the mean threshold for boys is better than that of girls until age 13.

A study by Eagles and Doerfler (1961) provides data on auditory thresholds for 5000 children aged 3 to 15 years. These data reinforce the observation that hearing thresholds are significantly better for children than adults with many of the thresholds obtained falling well below audiometric zero.

A study by Waudby (1984) examined the hearing threshold levels of a large sample between the ages of 16 and 64 years. This study, like previous studies discussed indicates that thresholds across frequencies are better for younger age groups than older age groups. Data for males and females were compared and the results indicated a close similarity between the two groups for the age group of 16 to 24.

The results of developmental studies indicate that thresholds improve until about age 13, when a systematic decline in sensitivity is noted for both males and females. This improvement in threshold may be attributed to attentional factors, understanding of the task, or some other developmental parameters. At this time the reasons for improvement are not clear. The decline noted after age 13 is most likely due to environmental factors which include noise. Support for noise as an important variable include the systematic variation noted across sexes and the slightly greater loss noted for boys who may be exposed to more noisy sources than girls.

Animal Studies of Noise Exposure

The effect of noise on the young auditory system has been demonstrated in a number of animal studies. These studies have indicated that the cochlea is most sensitive to damage from noise at a period when structural maturation appears to have just been completed with a lesser effect seen after this time. Recent evidence has also suggested that sensitivity to noise trauma continues to be greater even for the post pubertal animal relative to the adult animal. In this section some of the studies looking at comparisons between adult versus young animals and critical periods for noise trauma will be reviewed.

In a series of experiments involving cats and eight week old kittens, Price (1976) examined the differential effects of increasing intensity of a 5000 Hz, 50-minute pure tone exposure on the cochlear microphonic. The index of measurement was the difference in intensity required to produce a maximum output of the cochlear microphonic (max+0),(max+10) or (max+30) both pre- and post-exposure. In addition there were two post-exposure conditions: 1)Acute-10 minutes recovery before measurement and 2)Chronic-6 weeks recovery before measurement. After the chronic condition was complete all cats and kittens were sacrificed for histology so that differences between the two groups could be determined.

The results of the acute experiments indicated that at low levels of intensity and at (max+0) the cat and kitten ears performed similarly. With increasing intensity, however, the kitten ears showed greater loss of cochlear microphonic than the cat ears. These results were only statistically significant for the (max+10) level, however, where the mean loss for cats was 8.7 dB and for kittens was 15.6 dB. At the highest intensity levels both the cat and kitten ears showed large losses of sensitivity. Therefore, the results indicated that kitten ears show greater susceptibility to loss but this susceptibility is intensity related. From this data the critical intensity level at which increased susceptibility could be inferred to occur for human infants is 110 to 115 dB SPL.

The chronic experiments were carried out to determine whether or not the kitten ears would possess a greater ability to recover from acoustic trauma than the cat ears, despite a greater loss of sensitivity initially. Only the data from the (max+30) condition were suitable for analysis. The results indicated that cat and kitten ears showed the same ability to recover cochlear microphonic sensitivity. For cats, the initial loss of sensitivity of 43 dB recovered to 30 dB. For kittens, the initial loss of sensitivity of 50 dB recovered to 30 dB. The histological data was also equivalent for both groups. Losses of hair cells were related in an orderly fashion to intensity of stimulation and were confined in location to the area occupied by the displacement pattern on the basilar membrane. For the (max+30) condition cats and kittens showed similar patterns of hair cell losses and the correlation between cochlear microphonic sensitivity and hair cell loss was quite good.

The work of Price (1976) illustrated that for at least some exposure conditions the young ear may be more susceptible to damage from noise than the adult ear. The author noted, however, that it would be difficult to say whether with longer, less intense exposures the two groups would show the same patterns of increased susceptibility. The issue was dealt with in a paper by Dodson, Bannister and Douek (1978) in which one week old guinea pigs were exposed to white noise (maxima 500 and 4000 Hz) of 76 dB SPL for 7 days. The animals were then sacrificed at 3, 8, or 16 weeks post exposure. At this time histological examinations were performed. The results indicated that hair cell losses in the 8 week survival group were significantly higher than the 3 week survival group. Degeneration was particularly noticeable in half-turn 3 and to a lesser extent in half-turn 3 1/2. Between the 8 and 16 week survival groups no significant increases were detectable except marginally in half-turns 2 and 1 1/2 where the losses were negligible . The results were deemed to be due to noise as the control group showed an absence of any marked effects. The results of this study led the authors to infer that the threshold for acoustic damage appears to be considerably lower in young animals than adults where 90 dBA is the lower limit. An attempt was made to explain the loss observed to continue beyond 3 weeks. Possible mechanisms put forward to explain the results included general disturbance of homeostasis due to injury of the stria vascularis or weakening of the hair cells due to initial stimulation.

The studies of Price (1976) and Dodson et al (1978) seem to indicate that young animals may be more susceptible to noise damage than adults even when stimuli are of low intensity. In addition, the extent of damage to the cochlea may be related to temporal factors, i.e., the age of the animal at exposure or post exposure.

More recently a number of studies have addressed the issue of critical periods of sensitivity to acoustic trauma. Bock and Saunders (1977) subjected hamsters to an octave band of noise (5000 to 10,000 Hz, 125 dB re 20 u N/M2) for 2.5 minutes at 11, 15, 19, 23, 27, 31, 40, 48, 55, 62 or 75 days after birth. Five days after the noise exposure their cochlear microphonics were measured. The results indicated that the greatest losses of sensitivity were observed between 27 and 55 days of age. The authors inferred this to indicate that further development continues beyond apparent structural maturation of the cochlea at 20 days. This developmental process underlying the critical period for acoustic trauma is in the cochlea and not due to the middle ear cavity or acoustic reflex maturation.

Lenoir and Pujol (1979) confirmed the findings of Bock and Saunders that supranormal periods of sensitivity to acoustic trauma during development do exist. They demonstrated that when exposed to a 120 dB white noise lasting 30 minutes, rats 16 to 40 days of age showed strong permanent threshold shift. This permanent threshold shift was maximal for high frequency tones when animal were exposed at day 22, two days after the reported end of rat cochlear maturation. In 1980 they followed up this study with an examination of six white rats exposed at 22 days of age to 120 dB SPL white noise and showing strong permanent threshold shift (60 to 80 dB for 6000 to 20,000 Hz). The animals were sacrificed at either 7 days or 2 months post-exposure for histological examination. The results obtained confirmed the findings of the previous study indicating progressive degeneration over time. The authors attempted to give explanations for the observed sensitivity at the cochlear level. These included an immaturity of efferent endings of the outer hair cells, poisoning of the organ of Corti by endolymph or a switch from immature to mature state in the cochlear vessels beyond the point of overt structural maturation at day 20.

While the studies of Bock and Saunders (1977) and Lenoir and Pujol (1979) indicate that critical periods of sensitivity exist for acoustic trauma at very early stages of development, a recent paper by Henry (1982) has also drawn attention to the presence of increased sensitivity in the post pubertal age group. In this study 41 mice ranging in age from 60 days (early post puberty) to 360 days (late middle age) were tested for cochlear Action Potential (AP) thresholds at frequencies from 2000 to 64,000 Hz. After this they were subjected to five minutes of 124 dB octave band 12,000 to 24,000 Hz noise. The results at 30 days post exposure indicated that the extent of noise induced AP threshold elevation and the frequencies most severely affected depended on the age of the mice. The 60 day old mice had their greatest threshold elevation at one octave above the center frequency of the noise while the older subjects had the greatest threshold shift two octaves above the noise frequency.

The overall conclusion to be drawn from the animal studies is that the ears of young animals may be more susceptible to noise damage than adult ears. Critical periods have been demonstrated for a wide variety of animals at the cochlear level between 20 and 60 days of age shortly after the structural development of the cochlea is complete. In addition, studies by Henry (1982) have drawn further attention to the fact that increased susceptibility persists beyond the post pubertal age in animals with a continuing tendency for greater susceptibility to noise damage in the younger population.

While animal data appear to be consistent in this regard, extensions of these findings to human beings is often difficult due to a lack of information on comparative development. A paper by Lenoir, Pujol and Bock (1986) has attempted to remedy this problem by constructing a comparative time line of critical periods relating rat and human cochlear development. This time line indicates that while the order of development is similar across the two species the corresponding time periods differ. For rats, cochlear maturation is complete at 20 days of age. For humans this stage is not reached until birth.

Caution needs to be taken when looking at comparative studies because as Saunders and Tilney (1982) pointed out, the delivery of stimulus energy to the hair cell receptors is "a unique frequency, amplitude, and species dependent process" (p.244) which at present is difficult to cross reference because we do not have common procedures for assessing the degree of threshold shift in different species.

Noise and the School Aged Population

A number of studies have drawn relationships between noise exposure and hearing loss in young people. The majority of these studies have examined the effect of single sources of exposure. Very few studies have questioned whether the overall noise exposure from all the possible sources present in an individual environment might contribute to hearing loss. This section will contain a discussion of hearing loss attributed to single sources of exposure .

Hearing Loss Attributed to Single Sources of Exposure

A number of individual noise sources have been examined in detail as potential causes of NIHL. Among these have been firecrackers, guns, amplified music over loudspeakers and under headphones (i.e.: walkmans), and shop noise. The potential hazard of firecracker noise was first studied in Europe where reports from Danish hearing clinics of lesions caused by New Years Eve firecrackers (Bentzen and Hansen, 1961) led to an injunction against Chinese firecrackers and other noisy fireworks in Denmark in 1966. Gjaevenes, Moseng, and Nordahl (1974) looked at a group of Oslo, Norway school children 12 to 15 years old 10 days before and 1 week after Independence Day in May when firecracker usage is high. The children were screened at 10 dB (ISO) at 2000, 3000, 4000 and 6000 Hz. In September this group was reexamined using Closed Space pure tone audiometry. Criteria for permanent hearing loss due to firecrackers was a high frequency dip of at least 30 dB which could not be explained by other causative factors. Of the original 10 identified in May, there were now 5 cases of permanent impairment, all of which were boys who had temporary tinnitus after exposure. For four out of five the impairment was in one ear. The fifth had a bilateral impairment. The dips in the audiogram were rather narrow with a steep low frequency flank slope. The dip maximum was found near 6000 Hz.

The effects of gunfire on hearing have been dealt with extensively in the literature by a number of authors. Kramer and Wood (1982) examined 47 males and 21 females between the ages of 11 and 18 in rural Vermont. These children were questioned regarding use of firearms and heavy machinery, duration of that use and associated tinnitus. Audiometric thresholds were then obtained at octave intervals from 250 to 8000 Hz and at 3000 and 6000 Hz. Subjects were categorized as having NIHL under the following conditions: 1) Thresholds had to be poorer by 30 dB or more at 4000 Hz vs. 3000 Hz or at 6000 Hz vs. 4000 Hz. 2) Thresholds had to improve by at least 10 dB at 8000 Hz compared with the frequency of the greatest hearing loss. These criteria described a notch in the audiogram. NIHL was found in 12 of 47 males. Of these 12, 11 were regular gun users, using them at least four times a month. While 36 of 47 frequent gun users didn't have NIHL configurations, the 11 gun users with NIHL configurations had been firing guns an average of 1.3 years longer. None of the females in the study showed NIHL patterns but they had only reported spending half the time of males in noise.

Fearn (1981) examined a population of 332 children aged 9 to 12 and 490 children aged 13 to 16. In the 9 to 12 year old age group five children reported exposure to gun fire. In the 13 to 16 year old group 58 reported exposure to gun fire. Hearing loss for the 9 to 12 year old age group was noted to be less than 20 dB while the losses for the 13 to 16 year old age group were greater than 20 dB for 10 children. Two children were eliminated and out of the remaining eight, four had losses greater than 30 dB and of these, three had losses greater than 50 dB. No hearing protection was used by 16 of the 58 gun users in the 13 to 16 age group.

The effects of amplified music on hearing have been discussed in a number of papers. Rintleman and Borus (1968) conducted a carefully designed experiment in which they examined the effects of rock music on the hearing of individuals involved with bands. The purpose of their study was to:

1) do an acoustic analysis of the music played by several rock and roll groups both in terms of spectral distribution and overall SPL,

2) to determine whether musicians suffer NIHL as a result of the intensity of the music they play and

3) to obtain a sample of college age listeners' reactions to rock and roll music.(p. 57)

The musicians filled in questionnaires. Most of the groups played hard rock music and the instruments were amplified. All amplifiers were unidirectional with the musicians being 4 to 5 feet from the source. The effects of rock and roll music on hearing were determined by obtaining pure tone air and bone conduction thresholds for two groups of subjects, an experimental group and a control group. The control group consisted of 10 college students who had a negative history of noise exposure with a median age of 19 years. The experimental group consisted of 42 college student musicians with a median age of 19 years. The musicians had played with a rock and roll band from 4 months to 8 years with a mean length of playing time equal to 2.9 years. The average time spent playing rock and roll music was 3.7 hours per week in practice and 7.7 hours per week in performance for an average of 11.4 hours per week. There were no more than two sessions per week usually.

Air conduction thresholds were obtained for octave frequencies from 125 to 8000 Hz plus 3000 Hz. Bone conduction thresholds were obtained for the same frequencies with the exception of 125 and 8000 Hz. Subjects were out of exposure 48 hours before testing. Results indicated no significant differences between the control and experimental groups. Only 2 of 42 subjects had a threshold deviating from the norm and these were not even subjects exposed for the longest time or to the greatest intensity.

Recently a number of studies have examined effects of amplified music under headphones on the hearing of young people. These studies do not document hearing loss due to personal cassette player use but they do offer projections on the nature of hearing loss that might occur with use of these devices over extended periods of time.

Bradley, Fortnum and Coles (1987) examined the exposure patterns to amplified music of 1623 young people 11 to 18 years old in Nottingham, England with reference to stereos and personal cassette players. Their study consisted of two parts. The first part was a 31 item questionnaire which looked at use of personal cassette players, exposure patterns for other amplified music and temporary auditory effects of music exposure. The results of the first part indicated that 37% of students aged 11 to 16 owned personal cassette players with ownership declining to 25% for 17 to 18 year olds. There was no significant difference in ownership patterns across the sexes. The amount of use was found to be modest with the 25th, 50th and 75th percentile values for personal cassette player use at 4.4, 2.7 and 1.4 hours per week. Highest and lowest values were 32 and .04 hours per week. It was found that students listening to non personal cassette player amplified music using headphones reported a higher incidence of hearing difficulty and tinnitus.

In part two of the study the sample was post stratified for personal cassette player use and gender with 11 personal cassette users and 14 non users in the 14 to 18 year age group being randomly sampled. Subjects were asked to take a personal cassette player and set it to the level they would like for 1) listening to background music for reading 2) enjoyment of music in a quiet room and 3) the lowest level they would regard as comfortably loud for listening for 1 hour. Using a method that allowed for conversion between headphone and free field sound level output, a comparison was made for user vs. non user on the above setting selections. The results indicated that there was little difference between users and non users. Older males tended to choose higher levels than females. The mean equivalent free field levels were 65 dBA when listening to background music and 74 dBA when listening as a main interest. For both of these values there was a large range of choice values. For the 11 subjects who were classified as habitual users of personal cassette players there was found to be no significant correlation between levels of use and habitual amounts of exposure. As a result it was found that allowing for modest levels of use and modest number of hours use per week, the annual noise dose from use of personal cassette players is far below the 8 hour equivalent Leq of 90 dBA. The overall finding of this study was that subjects were far more conservative than expected in their use patterns. The authors did not take this to mean that no hazard existed but that it was not as extensive as expected.

The use patterns of personal cassette player owners was further investigated in a paper by Rice, Breslin and Roper (1987). In this paper the results of two studies were reported. In the first study 20 personal cassette users were investigated under lab conditions. Each subject was given a pre-calibrated cassette player and asked to play two pieces of pop music setting the volume to a level at which they would normally listen against a quiet background and in steady traffic noise background of 70 dBA. Subjects then completed a questionnaire on user habits from which information was obtained on average number of hours per week that each reported using a personal cassette recorder. These data were combined with individual listening level information to give estimates of noise exposure. Analysis of variance on listening levels showed no significant difference between listening levels for different pieces of music but a significant increase in mean listening level in the presence of background noise from 80.7 dB to 85.1 dB. In the second study 41 users were examined. Sound level listening was measured with a Leq being obtained over a two minute period. Subjects then filled in a questionnaire similar to study one. Subjects then selected a tape of choice and adjusted a pre-calibrated Sony Walkman to their preferred listening level. This Leq was measured in the same way as the subjects own personal cassette player. Finally subjects were interviewed in different places in order that a wide range of background noises were encompassed. The results of this portion of the study indicated that there was no correlation between listening level with background level confirming the earlier finding that effects of background noise are small. On average, subjects set pre-calibrated personal cassette players 3 dB higher than their own devices.

In the last portion of this study the data points from study one and two were pooled to allow for two analyses: 1) listening level and 2) noise exposure measurement in daily equivalent listening levels averaged over a 40 hour week. The results of the analysis indicated that the mean listening level was close to 85 dBA, with 25% of the sample at 90 dBA and 5% at 100 dBA. In regard to noise exposure, there was no significant correlation between noise level and number of hours of use per week. Of the sample exposed to unobstructed field noise exposure, 5% were at greater than 90 dBA. As a result the authors concluded that there could be a risk to hearing from personal cassette player use if habitually used over long periods of time.

The final paper to be discussed in reference to personal cassette players is that of Rice, Ross and Olina (1987). This paper drew together raw data from a number of sources which had examined user habits, age, sex, patterns of use, listening habits, hearing status, and attitudes to personal cassette player usage. These data were then compared with a new body of data obtained in Turin, Italy on 800 school children. The results of the analysis were numerous. The main findings of the study were that males use personal cassette players on average one hour a week more than females. This finding was statistically significant for pooled data. In addition, 20% of over 750 personal cassette player users reported symptoms of tinnitus or dullness of hearing after using these devices. The authors took this to indicate potential risk to hearing. It was noted that 20% of users listened to sound at Leqs greater than 90 dB. There was also evidence from this study that cassette player levels increased 4 dB in the presence of background noise. In determining damage risk from personal cassette player use the results of analysis indicated that the mean population risk of hearing performance decrement from listening habitually through headphones of personal cassette player devices over 10 years could be estimated as follows: With 5% of users listening at levels greater than 90 dBA, 1.3% were seen to be at risk for damage with .065% actually experiencing damage to their hearing. This risk was seen to be greatest for males. In conclusion, this study predicted that 1 out of 1,500 personal cassette player users would experience hearing loss over a 10 year period that would be permanent, i.e.: mean hearing level at 1000, 2000 and 3000 Hz equal to or greater than 30 dB HL. As was the case with the other studies discussed here in regard to personal cassette players no audiometric data was presented.

Shop noise has been investigated in a paper by Chung et al (1981). The objectives of this study were to 1) obtain baseline data on auditory thresholds of children from an industrial program, 2) determine the noise levels of wood working shops, metal shops and auto shops in a high school and 3) study the possible effects of shop noise on the hearing of high school students. A total of 89 male students in the industrial program of Templeton High School participated in the study. Their age range was from 15 to 20 with a mean of 17.06 years. Eighty of the students were included in the study. Shop exposure and off time exposure were assessed using the questionnaire format of Roche et al (1977). The sum of individual questions were pooled to yield a total noise score. Subjects were grouped into four cells: 1) high shop exposure and off school exposure, 2) high off school exposure and low shop exposure, 3) low off school exposure and high shop exposure and 4) low off school exposure and low shop exposure. Noise levels were measured for various power tools located in different shops. In addition three instructors wore noise dosimeters for a period of 1 hour and 35 minutes to 2 hours and 10 minutes. The hearing thresholds of the four subject groups were presented as low frequency average and high frequency average. Low frequency average consisted of 500, 1000 and 2000 Hz and high frequency average consisted of 3000, 4000, and 6000 Hz. T tests were performed on low and high frequency averages for HH vs.LL, HH vs.HL, LH vs.LL and HH+LL vs. HL+LL. The results indicated that there was little difference between the HH+HL vs. LH+LL groups. This suggests that off school noise exposure doesn't have a significant impact on the hearing threshold of an individual. The conclusions of this study were that:

1) Off school noise exposure was not a significant factor in reducing hearing sensitivity;

2) Most of the power tools have intensity levels over 90 dBA with planer and air impact chisels registering over 105 dBA;

3) Dosimetry readings in Leq for instructors teaching intermediate woodwork, senior woodwork and senior metalwork were 78, 96 and 79 dBA;

4) Finally, the statistical tests noted that shop noise has probably increased the hearing threshold level of students by a significant amount. (Chung et al 1981, p. 4-5)

Sources and Patterns of Noise Exposure in Children and Adolescents

There have been very few quantitative examinations of the sources and patterns of noise exposure in children and adolescents. Those studies which have been published indicate that the possibility of permanent hearing damage from noise exposure in this population is very real. A survey of the literature reveals a number of studies looking at isolated cases of trauma attributed to individual noise sources, i.e.: firecrackers, amplified music. These studies, although providing useful information are limited in the sense that they do not provide us with a complete picture of the demographics of noise exposure in this population. To determine if children and adolescents are at risk for hearing damage from noise exposure we need to: a) establish what all the potential sources of damage are and their measured outputs, b) how often they are encountered and c) what the total dosage is that can be expected in a typical day for this population.

A number of studies have attempted to determine what the noise sources are that children and adolescents are exposed to. Axellson, Jerson and Lindgren (1981) surveyed 538 teenage boys 17 to 20 years of age from technical schools in Sweden during the first 3 months of their 2 year education. The boys were interviewed in regard to their leisure activities in regard to their actual sources and patterns of exposure to those sources. The most common activity in which this group of subjects engaged was listening to pop music over loudspeakers with 95% of the boys reporting exposures several times weekly or daily.

Lees, Roberts and Wald (1985) looked at a group of young persons aged 16 to 25 selected from students attending two Kingston, Ontario high schools and Queens University. These students were also interviewed with regard to leisure noise exposure to the following sources: listening to stereo and band music, playing in bands, attending video arcades, participating in hunting and shooting, using snowmobiles, motorbikes and chainsaws. The exposure evaluation for these sources was both quantitative, with an examination of duration and frequency of exposure to each source, and qualitative, involving a rating of the noise level for each source in one of five categories between very quiet and very loud. The goal of this study was to determine whether a correlation existed between a particular leisure noise activity and decreased hearing sensitivity. As a result the findings related to the questionnaire portion of the study were not reported. The authors did note, however, that the highest correlation between their criterion for damage (10 dB notch) and leisure activity was found for band playing, (r=.60). This was followed by video arcade (r=.43) and listening to bands (r=.42). The validity of these values are in question as the probability criteria varied across activities.

Lass et al (1987) surveyed a group of 236 students between the ages of 11 and 15 with regard to knowledge of the normal hearing mechanism, causes of hearing loss and in particular the effects of noise on hearing. Of the group surveyed, 69% of the children indicated that they had used walkmans with earphones, 93% indicated that they had listened to a stereo system and only 41.6% of these children listened to the latter with headphones.

The most commonly used item was the power lawnmower, reported by 60.2% of the sample. One interesting, but not unexpected finding of the study was that only 13% of the children reported using earplugs when exposed to noise.

By far the most extensive and well designed study of noise exposure and children has been conducted by Roche et al (1978, 1982 and 1983). This was a longitudinal study which began in 1977 and ended in 1983. The study included a total of 270 children from both the Fels Research Group and a cross section of children from schools in Yellow Springs, Ohio. At the beginning of the study reported in Roche, Siervogel and Himes (1978) all the participants were given an initial noise exposure questionnaire on their first visit and interval noise exposure questionnaires on subsequent six month visits. From the data collected on the interval noise exposure questionnaire both a total noise score and event score were calculated. To obtain a total noise score intensity and duration values for individual scores were summed across sources. For example, in response to a question asking a child to rate intensity of television volume during viewing and duration of observation, a weighting for intensity of 0.1 quiet, 0.25 average, or 1.0 for loud would be assigned. If a child reported viewing five quiet hours then the assigned weighting given would be a score of 0.5 for this item. Event scores were obtained by coding exposure as 1 and no exposure as 0 regardless of intensity of duration. Total event scores were then summed across sources.

The results of the noise exposure survey were analysed across age and gender. They indicated that the median total interval noise scores increase with age in each sex. At most ages the median total interval score for boys exceeded that for girls with a maximum sex difference in interval scores at 16 years of age. An observed increase in noise exposure with age was statistically significant. The total event score results obtained indicated no apparent sex differences or age trends. In addition, systematic sex differences and age trends in median event scores from the interval noise exposure histories in pre-adolescent years were absent. A definite increase was noted in median event scores for teenage boys. These medians increased from 2.0 at 13 and 14 to 4.0 at 16 and 17 years. These same trends were not seen for girls. The results of the event score analysis were used to group subjects into exposed or not exposed for each of nine categories of noise exposure selected for the experiment. These were flight patterns, amplified instruments, firearms, loud stereo, loud T.V., farm machinery, fireworks, loud vehicles and power tools. The data indicated that less than 5% of the children were exposed to flight patterns and amplified instruments, 50% were exposed to fireworks and loud vehicles and 75% were exposed to power tools. A slightly larger proportion of children in the 12 to 17 year old age group reported exposure to these noise categories than the younger age group. The exception was loud T.V. where younger children reported greater exposure than the older group.

The main finding of this study which utilized only questionnaires to determine noise exposure was that noise exposure increases with age for both males and females with a marked sex difference being noted only for the 16 and over age group with boys having higher total noise exposure. In addition, it was noted that older boys reported higher noise exposure values than younger boys but the same trends were not evident for girls.

Siervogel and Roche (1982) collected dosimetry data on a subgroup of participants from the Fels longitudinal study to determine if the typical noise levels experienced by children were such that they would constitute a serious risk for hearing loss. These dosimetry readings represented an improvement over the questionnaire methods of obtaining data relating to patterns of noise exposure used in the previous report of Roche et al (1978). The reason for this being that the dosimetry readings provided an objective measure of noise exposure. At the time of publication of this study 127 children had been monitored by dosimetry. The children were equipped with four types of portable dosimeters, two of which were proven to be satisfactory: the General Radio (model 1954-9180) and the Metrosonics (model dB:301). Subjects wore the dosimeters for a 24 hour period beginning in late afternoon. In addition to wearing the dosimeters subjects kept a diary for the 24 hour period in which the dosimeter was worn. The measurements were taken on weekdays only from Monday to Friday throughout the year so that in school vs. out of school exposure could be viewed.

The Leq (24) values obtained in the study included energy from the total acoustic environment of the children involved. The primary noise sources reported by the children are the same as those reported in Roche (1978). The results obtained by dosimetry were compared to those obtained by questionnaire in the previous study. While the questionnaire data indicated that boys older than 9 were exposed to more noise than girls of the corresponding age, results of the dosimetry readings indicated only a 2 dB difference in Leq (24) between the two sexes. This difference was found only to be of minimal significance (.04 level). In addition the questionnaire summarized all noise exposure during a six month period while dosimetry recorded exposure during a 24 hour period. The questionnaires indicated a positive age effect which was not identified by dosimetry. The authors were confident that a one day, 24 hour sample of noise is representative of typical noise exposure for an individual. The average Leq (24) yielded using dosimetry obtained by Metrosonics Metrologgers was 77.6 dBA for boys and 75.8 dBA for girls. The authors felt fairly confident about the values obtained since they corresponded to the EPA estimate (1974) for school children of 77 dBA and the estimates of Schori and McGatha (1978) who obtained Leq (24) readings via dosimetry for a sample which included 10 children aged 5 to 16. The average Leq (24) reading for this group was 76.2 dBA. Siervogel and Roche (1982) suggest that due to measurement variability in the dosimeters, actual true average daily dose for children is higher than that obtained in their study and the studies of others. They suggest that the true average value may be somewhere between 77 and 84 dBA.

Roche et al (1983) provided an overall summary of the findings of the six year longitudinal study which in total involved 270 children aged 6 to 18 by its completion. This paper discusses in more detail the findings regarding noise exposure patterns obtained via dosimetry. As mentioned in the previous study by Siervogel and Roche (1982), during the dosimetry recording period the subjects kept a diary of timed activities during noise recording that were coded into 189 activity categories with the allocation of one category to each three minute period. For the purpose of analysis these activities were then grouped into 20 categories of noise sources. For each child an Leq (t) was computed for each activity category. This provides a measure of the noise level associated with a specific activity averaged over individuals with respect to time. Also an Leq (8) was calculated to represent the noise level that given over an 8 hour period would have the same sound energy as that to which the children were exposed. The least common activities reported by the subjects involved lawnmowers, combustion engines and small power tools. In addition, few girls participated in school gymnastics classes. The ranking of activities is similar by Leq (t) or Leq (8). Within four groupings of categories (A, B, C, and D) the Leqs were similar but the means differed from one group to the next. Girls had lower mean Leqs than boys for almost every activity with significant differences $p<.05$ only for walking to and from school, normal school classes, home radio/T.V., and sleep. For boys, lawnmowers/combustion engines, live music, school bus, school assembly and recess were major noise sources. Each of these sources had an Leq (t) greater than 80 dB and an average duration from .5 to 2.1 hours per day in those exposed. These noise exposure data tended to decrease with age except in the case of live music for which duration and noise level tended to increase with age. The Leq (8) values were converted to kilo pascal squared persons (Kpa 2) and multiplied by the number of boys and girls reporting exposure. The results of this type of analysis indicated school assembly and recess as the most important source of noise for boys accounting for 16% of the total sound energy. For girls, loud music was noted as the most important source accounting for 24% of the total sound energy. The largest sex difference involved lawnmowers/combustion engines for which boys are exposed to 60% more energy than girls.

Other Variables

When attributing hearing loss to noise exposure it is important to keep in mind the host of additional variables which could also account for the same data either separately or in combination with noise. Additional variables which have been documented to influence the effects of noise on hearing include ototraumatic agents, genetics, eye colour, disease, sex of an individual and presbycusis.

Henderson et al (1987) reviewed the data on interactions between drugs, vibration, and noise. Drugs which were noted to increase the damage to the auditory system when combined with noise were Aminoglycerides, antibiotics, Cisplatinum, and possibly aspirin. Vibration was seen to have an impact on hearing only when combined with noise. The authors concluded that vibration combined with noise accelerates the rate of hearing loss at frequencies of 5000 Hz and above. The interaction of vibration and noise is further noted to increase in cases of White Finger or Raynaud's disease.

A number of studies have looked at the contribution of genetic variables to NIHL data. Barr, Anderson and Wedenberg (1973) analysed the results of 1/2 million screening exams for 4 to 16 year olds and 18 year old males entering military service. A sensorineural hearing impairment was found in 237 of those examined. The authors asked how much of this hearing impairment was due to noise, genetics, birth trauma or a combination of these variables. After ruling out noise and birth trauma, they postulated genes for hearing loss must be present due to the large number of children with parental hearing defects, the large number of boys affected, increases in progressive hearing loss, high frequency loss, a dip in the mid frequency range below 3000 Hz, and a pathological elevation of reflex threshold for both ears.

Klockhoff and Lyttkens (1982) looked at 55 children with a high frequency loss at 4000 Hz who had a negative history of noise exposure, complications during pregnancy or delivery, head injury, ototoxic antibiotic use and disease. The audiograms of these children looked very similar to NIHL with a median loss of 50 dB at 4000 Hz with a lower frequency limit at 2000 Hz and an upper frequency limit at 8000 Hz. These children all displayed the same patterns postulated to be genetic in the Barr, Anderson, and Wedenberg (1973) study, namely elevated stapedial reflex in 83%, history of family hearing loss in 76%, and progressive hearing loss in 10% of the children. Klockhoff and Lyttkens (1982) concluded that the defects were either totally congenital or that NIHL causes damage only in ears with this type of genetic weakness.

The relationship between eye colour and permanent threshold shift was examined in a paper by Carter (1980). Threshold data were obtained for a group of first year and third year industrial apprentices . These apprentices were grouped according to a recognized eye colour rating scheme based on presence or absence of melanin pigmentation in the iris. The eye colours identified were blue, grey, green, hazel and brown. Each eye colour was assigned a numerical code from 1 to 5 to represent the continuum from least pigmentation, blue, to the colour with the greatest pigmentation, brown. The results of this study indicated that absence of melanin pigmentation was related to susceptibility to noise induced permanent threshold shift. This finding was only significant at 4000 Hz in the left ear.

Disease has been noted to influence the effects that noise has on hearing. Drescher (1974) noted that animals with higher than normal body temperature, as would be the case with high fevers, experienced a greater temporary threshold shift than animals with normal or lower body temperatures.

Presbycusis or aging is known to greatly confound the effects attributed to noise. The reason for this is the fact that with age deterioration of the cochlea occurs resulting in a hearing loss that first shows its signs in the higher frequency range of 2000 to 8000 Hz. This is also the region affected by noise. As a result it is often difficult to separate the two variables. In the case of the pre-occupational population which includes both children and adolescents it was noted that hearing thresholds improved to age 13 after which time they show a decline. This decline is usually attributable to noise but it could also be due in part to the natural aging process. This is difficult to determine as the point at which presbycusis begins is not clearly defined.

CHAPTER THREE

OBJECTIVES

The MRC Report on Damage to Hearing Arising from Leisure Noise (1985) suggested several areas in which further research in the area of noise exposure and young people needed to be conducted. The most noticeable finding of their report was the lack of systematic estimates of the number of people of any age undertaking activities where they might be exposed to social noise that was not limited just to lists of noisy activities, but rather, included immission ratings derived from accurately specified noise levels and exposure patterns. In addition, they noted a difficulty in deciding how to proceed from descriptive measurements of sound levels to actual noise dosages received by individuals. Finally, they suggested that better information on the impact of leisure noise might be obtained from double sample studies where school leavers were screened in regard to leisure noise specifically. This would include detailed exposure assessment, elaborate data on control variables, socioeconomic status, otological status, genetic factors as well as audiograms at 3000 and 6000 Hz.

While the data discussed in the literature review seems to indicate that researchers are looking more closely at their measurement schemes for leisure noise exposure through controlled measurement of the output of sources under a variety of use settings and background conditions in addition to more careful assessment of actual use patterns of young people for these different sources, there are still very few studies that have combined objective measurement of noise exposure, i.e.: dosimetry with actual diaries of exposure outside of Roche et al (1978, 1982 and 1983). As identified in the MRC report it is necessary that data be available on a number of different sampling populations in order to better understand the demographics of leisure noise exposure and its actual impact on hearing sensitivity. It is difficult to determine with any degree of confidence the effects of leisure noise exposure on hearing sensitivity in the absence of a) proper interview techniques, b) adequate methods to determine the interaction between noise and a number of variables such as genetics, aging, drugs, otological status and c) the lack of thorough test procedures. An observation made regarding the present studies is that very few of them actually measured 6000 Hz, a frequency which has been shown to be affected by noise in the early stages of prolonged exposure. In addition, no studies used both bone and air conduction pure tone audiometry in their assessment of hearing sensitivity. This leaves one wondering how many of the reported decreases in sensitivity attributed to noise exposure may have had other etiologies.

The objectives of the current study are two fold:

1) To obtain additional information on the sources and patterns of noise exposure in young people through both objective and subjective measurement techniques.

2) To look for correlations between both amount and history of leisure noise exposure in this population and permanent decreases in hearing sensitivity between 2000 and 6000 Hz utilizing pure tone air/bone audiometry and immittance measurements.

CHAPTER FOUR

METHOD AND PROCEDURES

Subjects

The initial goal in this study was to sample from grade 12 students in two Vancouver Schools: one on the west side and one on the east side. This would have enabled us to look at any regional differences in our target population. Unfortunately this was not possible due to lack of accessibility to this population. As a result the data had to be obtained from a number of individual populations as they became available to us.

Two groups of pre-occupational subjects were found to participate in this study. One group was a sample of 30 undergraduate students from a Toronto area college, 15 males and 15 females, between the ages of 22 and 25. This sample consisted totally of volunteers. The second group of subjects were 22 teenagers, 11 males and 11 females, between the ages of 13 and 18 from a number of high schools in the Greater Vancouver area. It was not possible to randomly select the sample due to a limited number of available subjects willing to participate in the project.

Apparatus

Two separate sets of equipment were utilized for the standard audiometry portion of this study. For the Toronto subjects a GS Diagnostic Audiometer model AD12 and a Madsen Impedance Audiometer Model ZS331 were utilized. For the Vancouver subjects a Maico Hearing Instruments Model Ma-22 Diagnostic Audiometer and a Madsen Impedance Audiometer Model ZS76-I were utilized. The calibration for the Ma-22 was checked with a Bruel and Kjaer precision sound level meter and was found to meet ANSI standard S3.6-1969 (1972) . For all the subjects participating pure tone audiometry was carried out in an IAC booth utilizing TDH-39 headphones.

The dosimetry portion of the study which involved only the Vancouver subjects was conducted using Quest Electronics M-8B portable noise dosimeters obtained from the Workers Compensation Board in Richmond, B.C. The M-8B measures cumulative noise exposure in accord with the ISO standard R1999 which utilizes a 3 dB doubling rule whereby every 3 dB increase in sound level results in a halving of allowable exposure time. The M-8B measures sound level with an "A" weighting scale yielding a Leq noise dosage based on the formula D= C1/T1 + C2/T2+.....CN/TN where D= noise dose, C= duration of time at a given level and T= the noise exposure time limit per day given in ISO standard R1999. The dosage value produced by the M-8B is given in percent maximum exposure which is based on a percent maximum exposure of 90 dBA for 8 hours. The M-8B indicates instances of peak exposure levels exceeding 120 dBA by triggering an overload light. The M-8B has a noise level range of 80 to 120 dBA with a 30 dB crest factor referenced to 20 u N/M2 with a criteria level of 90 dBA for 8 hours producing 100% readout.

The M-8B has a ceramic microphone, 1/2 inch in diameter. The sensitivity of the microphone is 70 dB below one volt per microbar measured at 1,000 Hz. The microphone comes equipped with a 30 inch cable and spring clip for attachment to the shirt collar just below the ear. In addition all microphones are equipped with a protective reticulated polyurethane foam windscreen which produces negligible attenuation effects.

Calibration of the M-8B is done before each use with a CA 32 single level, single frequency precision timed calibrator. This calibrator delivers a 32 second pure tone at 1,000 Hz, 110 dB SPL. Using the 90 dBA, 8 hour criterion level a properly functioning dosimeter should read out in response to this tone a value between 008.97 and 014.25 based on a +/- 1 dB tolerance, with 011.30 being exact.

Materials

There were two written components to this study. The first was a questionnaire and the second was a 5 day diary corresponding to Monday to Friday of a regular school week. Copies of these have been included in Appendix A. The contents of the questionnaire and diary are partially based on the studies by Axellson et al (1981) and Roche et al (1978).

Procedure

There were two to three meetings with the subjects. These meetings were conducted by two individuals: C.Ruckle in B.C., and K.Fuller, M.Sc, Audiologist, in Ontario. Subjects were presented with questionnaires and diaries on their first meeting and they were instructed on how to complete the forms. All Vancouver subjects participated in the dosimetry portion of the study and were scheduled for a 13 hour wearing period from 8 a.m. to 9 p.m. corresponding to one of the days in which they were completing the diary. All dosimeters were calibrated before being placed on the subject. Dosimeters were worn with the box portion on the left hip and the microphone portion clipped to the left shirt collar in line with and just below the ear. All microphones were equipped with windscreens. Subjects wearing the dosimeters were instructed not to remove them during the sampling period. In addition they were instructed not to yell into the microphones or remove the windscreens. Finally, all subjects who participated in the study were brought into contact with the investigator one more time for hearing evaluation at one of the two locations. This evaluation included tympanometry, screening ipsilateral acoustic reflexes at 1000 Hz at 100 dB SPL, and pure tone air/bone conduction audiometry which included thresholds at 3000 and 6000 Hz in addition to the standard test frequencies from 250 to 8000 Hz.

CHAPTER FIVE

RESULTS

The results to be presented in this chapter were obtained from the noise exposure history questionnaires, dosimetry readings, and threshold data . The data from the noise exposure diaries will not be included in the results section of this thesis.

Subjective Reports of Noise Exposure- Noise Exposure History Questionnaire

Sources of Exposure

Figure 1 displays the number of teenagers and undergraduates reporting exposure at any time during the past 12 months to each of the 35 sources listed in Table I. In general, the number of subjects reporting exposure to each source are fairly similar for both age groups. Television and amplified music over loudspeakers are the primary sources of exposure reported by teenagers and undergraduates. The greatest difference between the two groups occurred for the number of subjects reporting exposure to pop music in the car and firecrackers. More undergraduates reported exposure to pop music in the car than teenagers. There were 90 % of the undergraduates reporting exposure to this source in the last year in comparison to only 59 % of teenagers. This is most likely due to the fact that a greater number of undergraduates own cars than teenagers. Firecracker use was reported by a larger number of teenagers than undergraduates. There were 79 % of teenagers reporting firecracker use in the last year in comparison to only 29 % of undergraduates.

For both subject samples certain sources were not reported as contributing to exposure at all during the past year. For teenagers, these were: air guns, pistols, mopeds, and model airplanes. For undergraduates, these were pistols, air guns, mopeds, car racing, model airplanes and trains.

Patterns of Exposure

Teenagers and undergraduates reported their exposure to each source in terms of its pattern of occurrence during the last 12 months, i.e. daily, weekly, monthly or yearly. The sources most frequently encountered by subjects were those reported as occurring daily. The sources least frequently encountered by subjects were those reported occurring on a yearly basis. Table II presents the distribution of exposure patterns for teenagers (Table IIa) and undergraduates (Table IIb). From the table it can be seen that the patterns of exposure for both subject samples were fairly similar. Exposure to television and amplified music was reported to occur on a daily basis for the majority of subjects in each group. There were more teenagers than undergraduates reporting exposure to walkmans for intentional listening on a daily basis (86 % as compared to 56 %). In addition, 50 % of the undergraduates reporting involvement as studio musicians did so on a daily basis while 100 % of the teenagers reporting involvement in this activity did so on a weekly basis. For both samples, the most infrequently encountered sources included firecrackers, rifles, snowmobiles and chainsaws with the majority of subjects reporting exposure to these on a yearly basis.

In addition to identifying the sources to which they were exposed by period, subjects were required to estimate the number of episodes of exposure and their approximate duration. Of interest in the present investigation was the reported duration of exposure to those sources reported by the subjects on a daily basis and the number of episodes of exposure reported by subjects during the year for impulse sources. In displaying the data, duration of exposure was reported for steady state sources while number of episodes only was reported for impulse sources. These results are displayed in Figures 2 and 3 for each group. Table III lists the mean duration of exposure for those sources which have their highest frequency of occurrence on a daily basis and Table IV lists the mean number of episodes for impulse sources on a yearly basis. Two mean values have been provided for the teenage data because it was noted that for each source one report was significantly different from the rest. One male subject reported 1000 episodes of firecracker use in a year in comparison to a range of 1-20 episodes for the other subjects reporting exposure to firecrackers. In addition, one male subject reported 30 episodes of rifle use in the past year in comparison to a range of 1-4 episodes for the other subjects reporting exposure.

Sources and Patterns of Exposure- Objective Measurement

Dosimetry

Table V shows the dosimetry data for each of the 22 teenagers. The mean 8 hour equivalent dosage for the group as a whole was 84.9 dBA with a standard deviation of 5.1. The results indicated that 11 of the subjects exceeded 85 dBA for the 13 hour sampling period. The dosage for each subject was plotted in Figure 4 which illustrates a fairly clear division into three groups: those with levels less than 80 dBA, 80-85 dBA and greater than 85 dBA. The mean and standard deviation for each of these groups was computed and is shown in Table VI. For those subjects exceeding 85 dBA during a sampling period class schedules were checked to see how many of those subjects had either band, p.e.,or industrial education during that time. The results indicated that 10 of the subjects exceeding this level had engaged in one of the above activities. At the same time it was noted that three of the subjects not exceeding that level had also engaged in these activities.

The male and female dosimetry results were plotted in Figure 5 to show any differences between the two groups. Visual inspection of the data did not reveal any significant differences. A two tailed t- test was computed which confirmed that there was no significant difference between the two groups ($p=.01, t=1.64, df=20$).

Threshold Data

Thresholds for all subjects included in the analysis were within normal limits. The two subjects excluded from analysis were a male (subject 3) from the teenage group with an active middle ear infection and a female from the undergraduate group with a moderate mixed hearing loss. The focus of the analysis was on the teenage population since it was the only group on which a complete data set i.e. of dosimetry, questionnaire and thresholds, was available. Table VII displays the results from 1000-8000 Hz, right and left ears, for the teenage sample. Figure 6 shows the mean thresholds for the better ear of teenagers in this study plotted against the same data from Roche et al 1978 and the U.S. Department of Health, Education and Welfare Study of 12 and 17 year olds (1975). The mean thresholds for the present sample are better at all frequencies than those obtained in the DHEW study. The mean thresholds obtained by Roche and his associates for 12-17 year olds were better than those obtained in the current study. The thresholds for teenagers in the current study were poorest at 6000 Hz. This finding is in agreement with the results from the DHEW study. Mean threshold for the better ear at 6000 Hz was 3.33 dB in the current study and 11.4 dB in the DHEW study.

Threshold data from the current study was examined for differences between the two ears. These results are shown in Figure 7. From this figure it can be seen that the mean thresholds for each ear were within 2.5 dB of each other at every frequency except 2000 Hz where it was 3.5 dB. For both the right and left ears, the poorest mean threshold was obtained at 6000 Hz. The greatest threshold variability was also seen at 6000 Hz in the right ear.

Male vs female mean thresholds for 1000-8000 Hz obtained in the current study were plotted against each other in Figure 8. Right ear mean thresholds were better for males at all frequencies except 1000 Hz. Left ear mean thresholds were better for females at all frequencies except 3000 and 8000 Hz. The mean thresholds for males and females differed most at 3000 and 6000 Hz in the right ear and 2000 Hz in the left ear. For both males and females the poorest thresholds were found at 6000 Hz for right and left ears.

As a final examination of the data, the mean thresholds for the teenage sample were plotted against those obtained for the undergraduate sample in Figure 9. The mean thresholds for the undergraduate sample were poorer than those obtained for the teenage sample at every frequency except 6000 Hz in the right ear where the teenage thresholds were slightly poorer. For both samples, the poorest thresholds were found at 6000 Hz in both ears.

Observed Notches at 6000 Hz

The thresholds at 6000 Hz were more closely examined for the teenage sample. The goal of this analysis was to identify the presence of notch configurations at 6000 Hz. A notch was defined as a decrease in sensitivity at 6000 Hz of 10 dB or greater relative to the surrounding frequencies within one octave. The results indicated that 50 % of the teenagers had notches at 6000 Hz. Of those subjects displaying notches at 6000 Hz, 36 % were females and 64 % were males.

Of those notches observed, 55 % were in the right ear exclusively, 36 % were in the left ear and 9 % were in both ears. For those subjects displaying notches, health histories were examined to determine whether or not there were contributing medical or genetic variables which might explain the observed results. For those subjects with notches in only one ear, two out of a total of nine had a positive medical history and none had a genetic history. The only subject with a genetic history of hearing loss was a female who displayed a double notch at 3000 and 6000 Hz in the right ear. After taking into account medical and genetic variables, there still remained eight subjects with notches which could possibly be attributed to noise. Of the remaining eight subjects with notches it was noted that of those displaying single notches, two were frequent gun users and one was a regular band participant. The only subject displaying a notch at 6000 Hz in both ears was also a frequent gun user . After accounting for the remaining notches with additional exposure to gun fire and band there still remained five of the subjects with notches who did not report gun fire use or frequent band participation.

Correlation Between Thresholds at 6000 Hz and Dosimetry Levels

The mean thresholds obtained at 6000 Hz for both the right and left ears were correlated with the observed dosimetry levels using a Pearson Product Moment Correlation. The results indicated a weak negative correlation between dosimetry and thresholds at 6000 Hz in both the left (r=-.39) and right ears (r=-.36).

Correlation Between Thresholds at 6000 Hz and Exposure to Steady State Sources- Teenage Data

The mean thresholds obtained at 6000 Hz for both the right and left ears were correlated using a Pearson Product Moment Correlation with the mean observed daily duration of exposure to the following steady state sources: amplified music over speakers, music under headphones- intentional listening and background listening, music in the car - pop and rock, television and participant sports. These results are shown in Table VIII. In general the correlation between any of these activities and thresholds at 6000 Hz in either the right or left ears was weak or non existent.

Correlation Between Thresholds at 6000 Hz and Episodes of Exposure to Impulse Sources in One Year- Teenage Data

The mean thresholds obtained at 6000 Hz were correlated with the mean number of episodes of exposure reported in one year to the following impulse sources: firecrackers and rifles. These results are shown in Table IX. The results indicated a weak correlation between the number of episodes of exposure to these impulse sources and mean thresholds at 6000 Hz in either the right or left ears.

Use of Hearing Protection

Subjects were asked to report their use of hearing protection in noise. They were given the option of reporting use as always, occasional, or never. The results indicated that 86 % of teenagers never used hearing protection , 9 % used it occasionally, and 4 % used it regularly when exposed to noise. The results for undergraduates were slightly better: 72 % of undergraduates never used hearing protection, 24 % used it occasionally, and 4 % used it regularly when exposed to noise. Of those reporting no use of hearing protection in the teenage sample, two were frequent rifle users. For the undergraduate sample the two regular rifle users reported occasional use of hearing protection only.

Table I

List of 35 Sources of Noise Exposure

1) firecrackers*
2) air gun*
3) pistol*
4) rifle*
5) moped
6) motorcycle
7) motocross
8) snowmobile
9) lawn mower
10) chain saw
11) car racing
12) model car
13) model airplane
14) model train
15) outboard motor
16) spectator- rock concert
17) spectator- pop concert
18) spectator- classical music
19) dances: taped music
20) music over speakers-portable or stationary
21) music under headphones (walkman style)- intentional listening
22) music under headphones (walkman style)- background music
23) music in car-rock
24) music in car-pop
25) music in car-classical
26) musician-band
27) musician-studio
28) noisy tools-home shop
29) noisy household appliances
30) television
31) computer printer
32) video games
33) portable telephones
34) spectator sports
35) participant sports

* Impulse Sources

Table II

Number of Subjects Reporting Exposure to Sources by Period

II a) Teenagers Total n=22

Source	Day	Week	Month	Year
1	0	0	1	15
2	0	0	0	0
3	0	0	0	0
4	0	0	0	5
5	0	0	0	0
6	2	0	2	1
7	0	0	0	0
8	0	0	0	1
9	0	6	1	4
10	0	0	0	2
11	1	0	0	0
12	0	0	1	1
13	0	0	0	0
14	0	0	1	0
15	1	0	0	2
16	0	0	0	5
17	0	0	0	2
18	0	0	1	0
19	1	0	2	8
20	20	0	0	0
21	6	1	0	0
22	4	4	0	0
23	6	7	0	0
24	6	0	0	0
25	1	2	0	0
26	0	2	0	1
27	0	3	0	0
28	0	0	7	1
29	4	8	2	0
30	18	2	0	0
31	1	8	2	1
32	2	8	1	0
33	0	1	1	0
34	0	3	2	3
35	6	0	2	1

II b) Undergraduates Total n=30

Source	Day	Week	Month	Year
1	0	1	2	4
2	0	0	0	0
3	0	0	0	0
4	0	0	0	1
5	0	0	0	0
6	0	0	3	0
7	0	0	1	0
8	0	0	0	2
9	0	8	5	0
10	0	1	0	0
11	0	0	0	0
12	0	0	0	1
13	0	0	0	0
14	0	0	0	0
15	0	0	2	4
16	0	0	11	6
17	0	0	2	3
18	0	1	2	1
19	0	5	8	1
20	24	2	3	0
21	8	7	1	0
22	8	3	1	1
23	18	8	1	0
24	4	5	2	0
25	0	4	3	0
26	0	1	0	0
27	1	1	0	0
28	0	2	9	0
29	7	13	3	0
30	26	0	2	0
31	6	10	2	1
32	0	0	3	1
33	4	0	7	0
34	0	0	10	2
35	2	0	4	0

Table III

Mean Duration of Exposure on a Daily Basis for Steady State Sources With Greatest Frequency of Occurrence Reported on a Daily Basis

Teenagers

Source	Mean Number of Hours
20	3.20
30	2.54
21	1.08
24	.66
35	1.46
11	1.75

Undergraduates

Source	Mean Number of Hours
30	2.52
20	1.89
23	1.19
21	2.45
22	1.75

Table IV

Mean Number of Episodes of Exposure to Impulse Sources on a Yearly Basis

Teenagers

Source	Mean Number of Episodes	
1	Outlying value included:	66.0
	Outlying value excluded:	3.67
4	Outlying value included:	8.2
	Outlying value excluded:	2.75

Undergraduates

Source	Mean Number of Episodes
1	7.7
4	2.0

Table V

Dosimetry Data by Subject

Subject	Sex	Dose in dBA
1	f	82.20
2	f	85.25
3	m	78.00
4	m	84.50
5	m	87.00
6	f	91.10
7	f	83.30
8	m	88.10
9	m	78.00
10	m	90.00
11	f	88.00
12	f	78.00
13	f	83.20
14	m	83.00
15	f	78.00
16	m	81.80
17	m	82.40
18	m	92.90
19	f	86.40
20	f	82.20
21	f	97.50
22	m	87.90

Table VI

Summary Statistics for Grouped Dosimetry Data

$\leq$80 dBA	80-85 dBA	$\geq$85 dBA
n=4	n=8	n=9
μ=78	μ=82.83	μ=89.42
σ=0	σ=.75	σ=14.51

Table VII

Thresholds by Subject-Teenagers

* --------- Right Ear Data --------- * ---------- Left Ear Data ------------ *

Frequency in KHz

n	sex	1K	2K	3K	4K	6K	8K	1K	2K	3K	4K	6K	8K
1	f	5	0	5	0	10	5	0	-10	-5	0	5	-5
2	f	-5	-10	10	0	10	5	-5	-10	10	-5	5	-5
3	m	5	0	10	5	20	15	-5	0	5	20	15	15
4	m	-5	-5	-5	-10	5	-5	0	5	0	-10	0	5
5	m	5	15	10	-5	0	15	5	10	5	10	0	0
6	f	-5	5	-5	-10	5	5	5	-5	0	5	5	10
7	f	5	5	5	-5	15	5	5	0	5	5	5	10
8	m	5	5	0	-5	0	-5	-5	0	-5	-10	5	-10
9	m	0	-5	5	10	15	5	5	-5	0	5	15	5
10	m	5	-10	-10	0	-10	-10	-5	-5	-10	-5	-5	-5
11	f	5	0	5	5	10	0	-5	-10	0	-5	5	10
12	f	5	5	5	0	0	5	-5	-5	-5	-5	0	5
13	f	10	5	0	0	5	0	5	0	0	0	15	5
14	m	5	5	5	5	20	20	5	5	5	5	15	10
15	f	5	5	0	5	10	10	-5	-5	-5	-5	0	5
16	m	0	0	-5	-10	15	0	5	5	0	-10	15	10
17	m	0	5	0	5	5	5	0	5	5	5	10	5
18	m	5	-5	5	5	-10	5	5	0	5	-5	0	5
19	f	-5	-5	15	5	5	0	-10	-10	-5	-5	0	-5
20	f	5	5	5	10	20	0	5	5	5	5	5	5
21	f	0	15	10	5	15	10	5	5	5	-5	0	5
22	m	5	5	-5	5	0	5	-5	0	-5	5	10	-10
μ		2.38	1.90	2.62	.71	6.90	3.81	.24	-1.67	.24	-1.19	5.24	2.14
σ		4.36	6.80	6.25	6.18	8.44	6.69	5.12	5.99	5.12	6.10	6.02	6.81

Note: Frequency reported in KHz

Table VIII

Correlation Between Mean Daily Duration of Exposure to Steady State Sources and Mean Thresholds at 6000 Hz

Correlation Matrix

Source #	Right Ear Threshold	Left Ear Threshold
20	-.10	.00
21	-.05	-.06
22	-.18	-.20
23	.11	.35
24	-.10	.09
30	.08	-.25
35	-.08	.19

Table IX

Correlation Between Mean Number of Episodes of Exposure to Impulse Noise in One Year and Thresholds at 6000 Hz

Correlation Matrix

Source #	Right Ear Threshold	Left Ear Threshold
1	.21	37.0
4	-.05	-.17

Figure 1
Number of Subjects Reporting Exposure
To Sources During the Last 12 Months
Teenage and Undergraduate Data

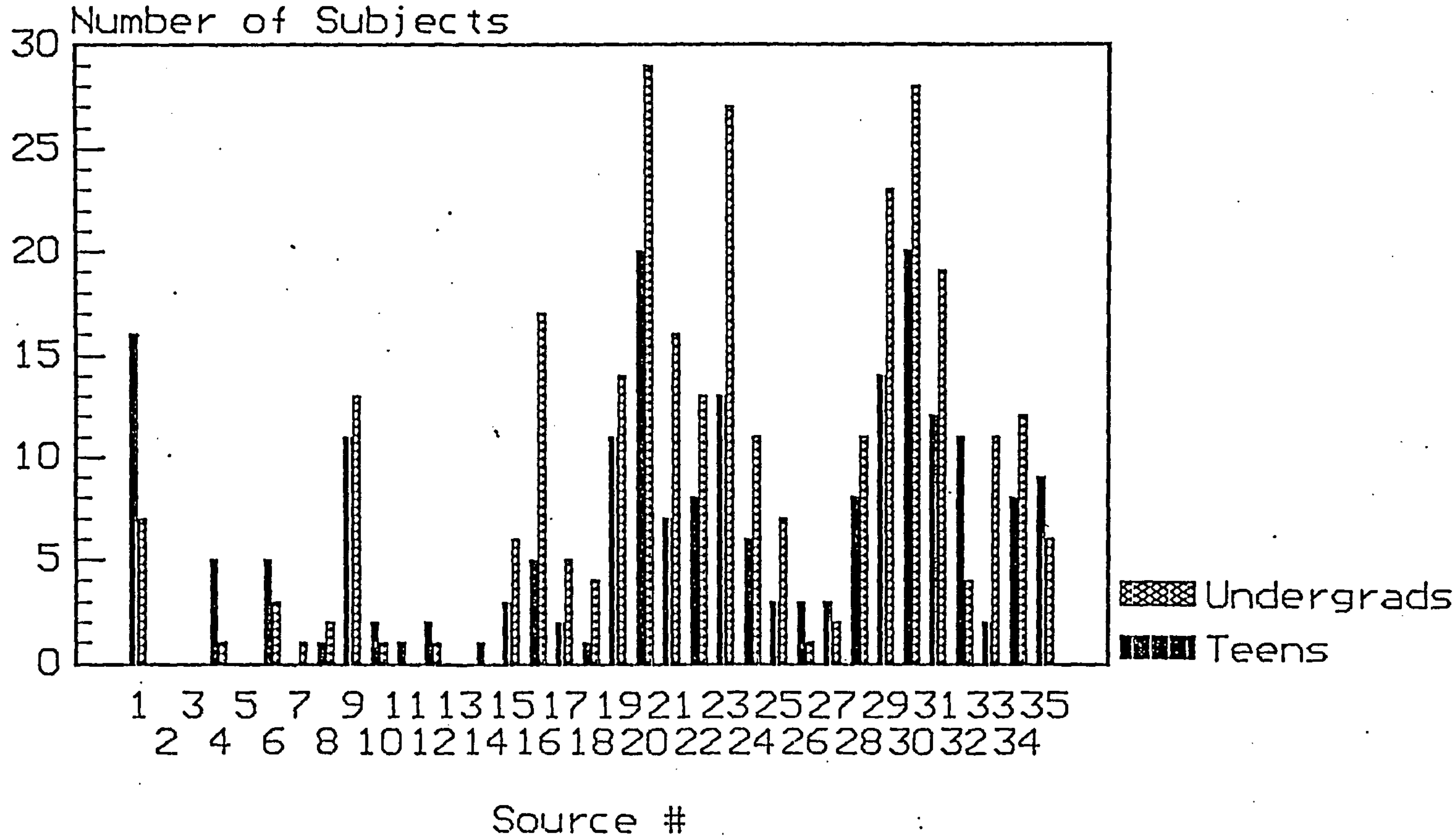
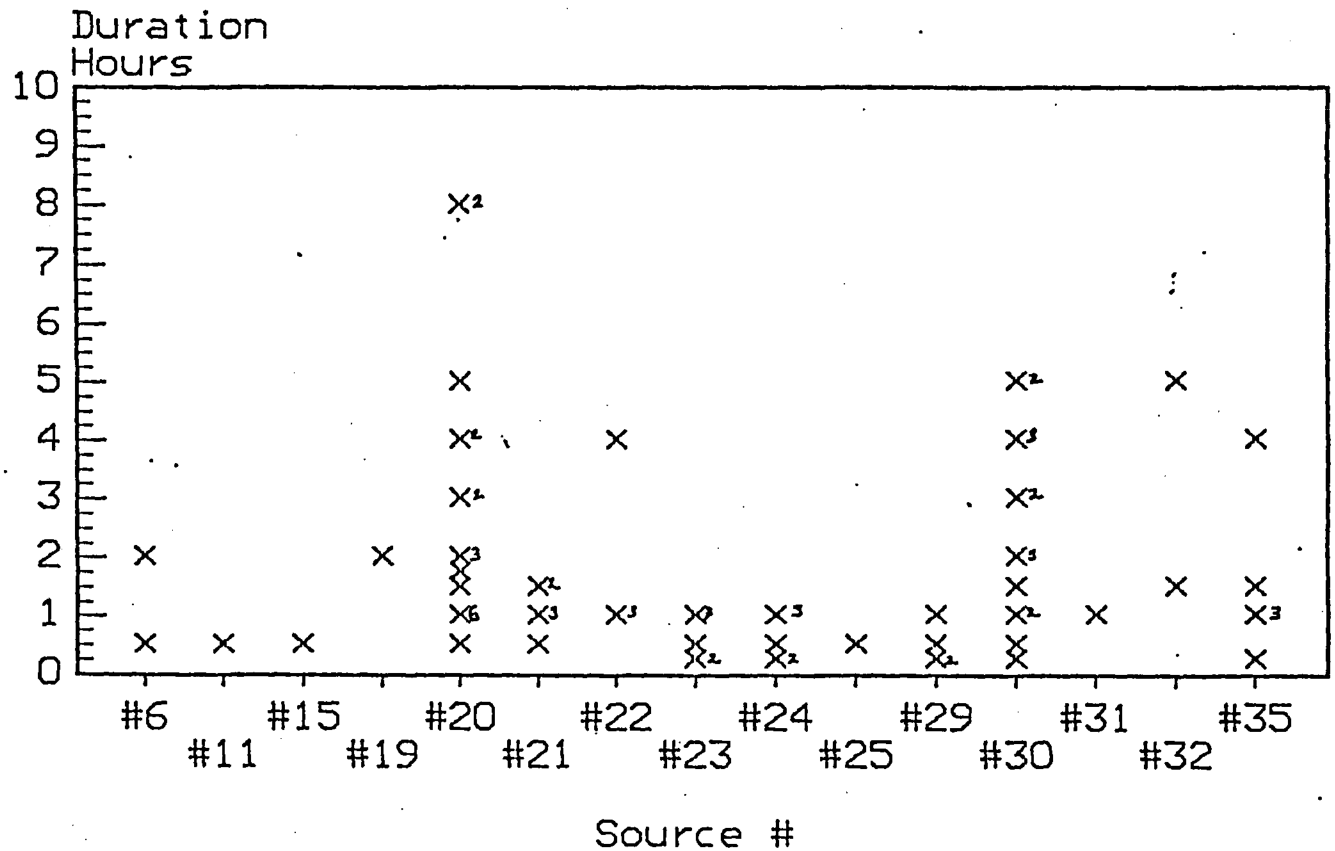
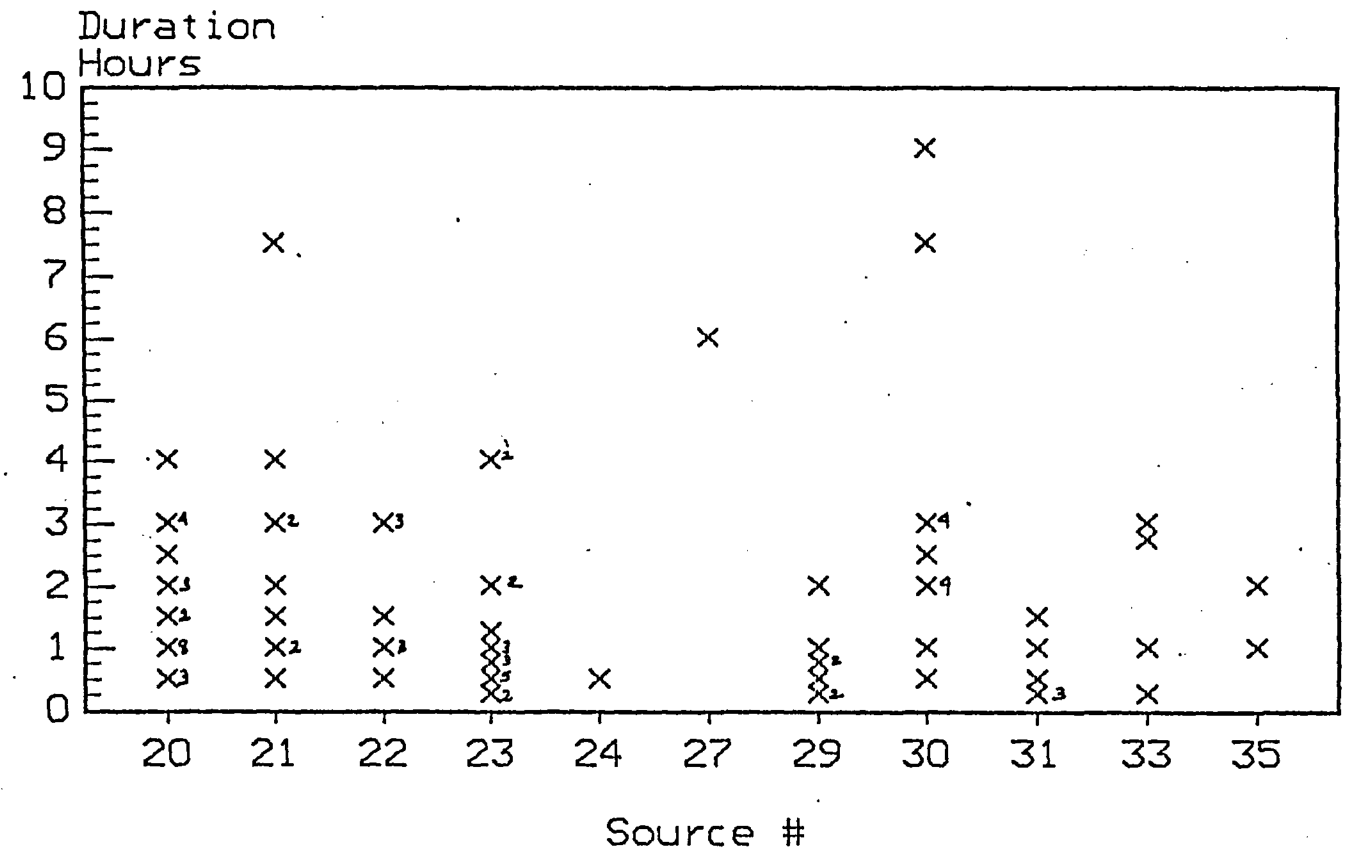


Figure 2
Overall Daily Duration of Exposure
Plotted by Source
2a) Teenage Data



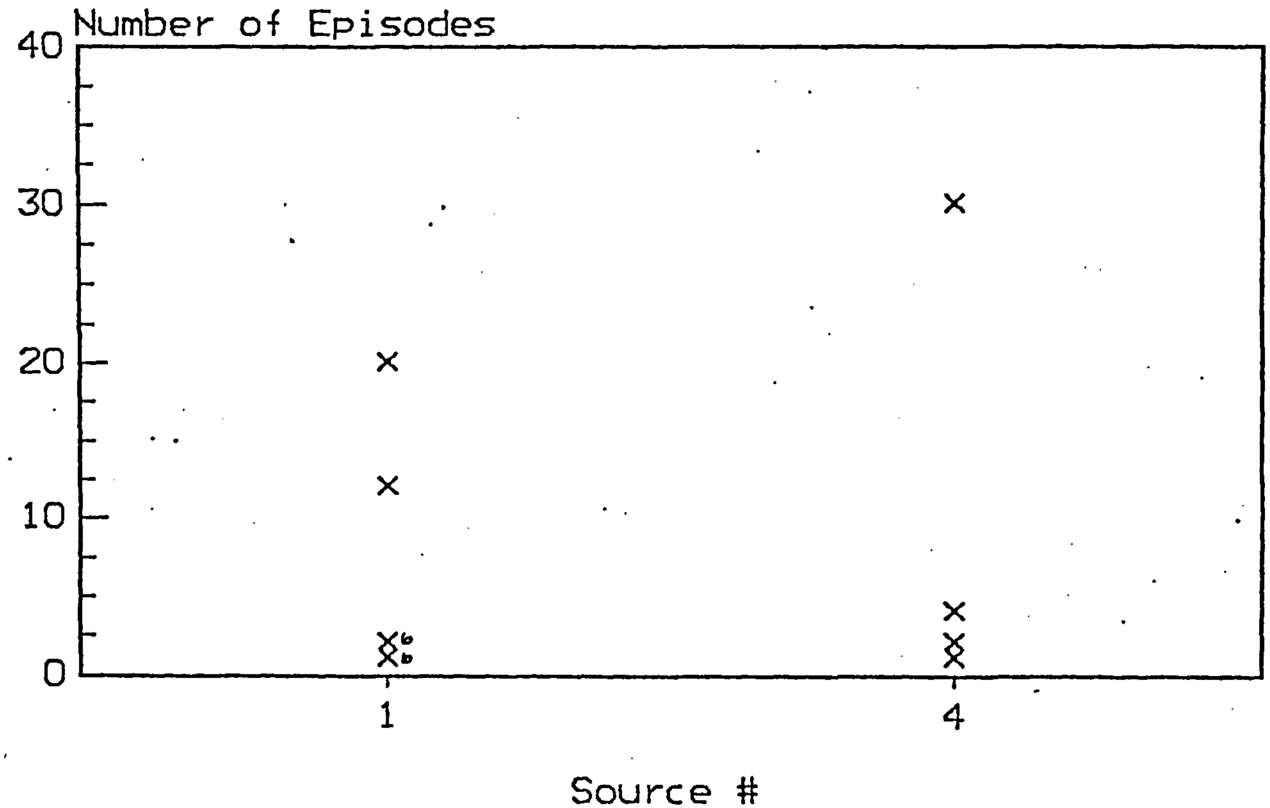
X= Number of Subjects Reporting at That Level

Figure 2
Overall Daily Duration of Exposure
Plotted by Source
2b) Undergraduate Data



X= Number of Subjects Reporting at That Level

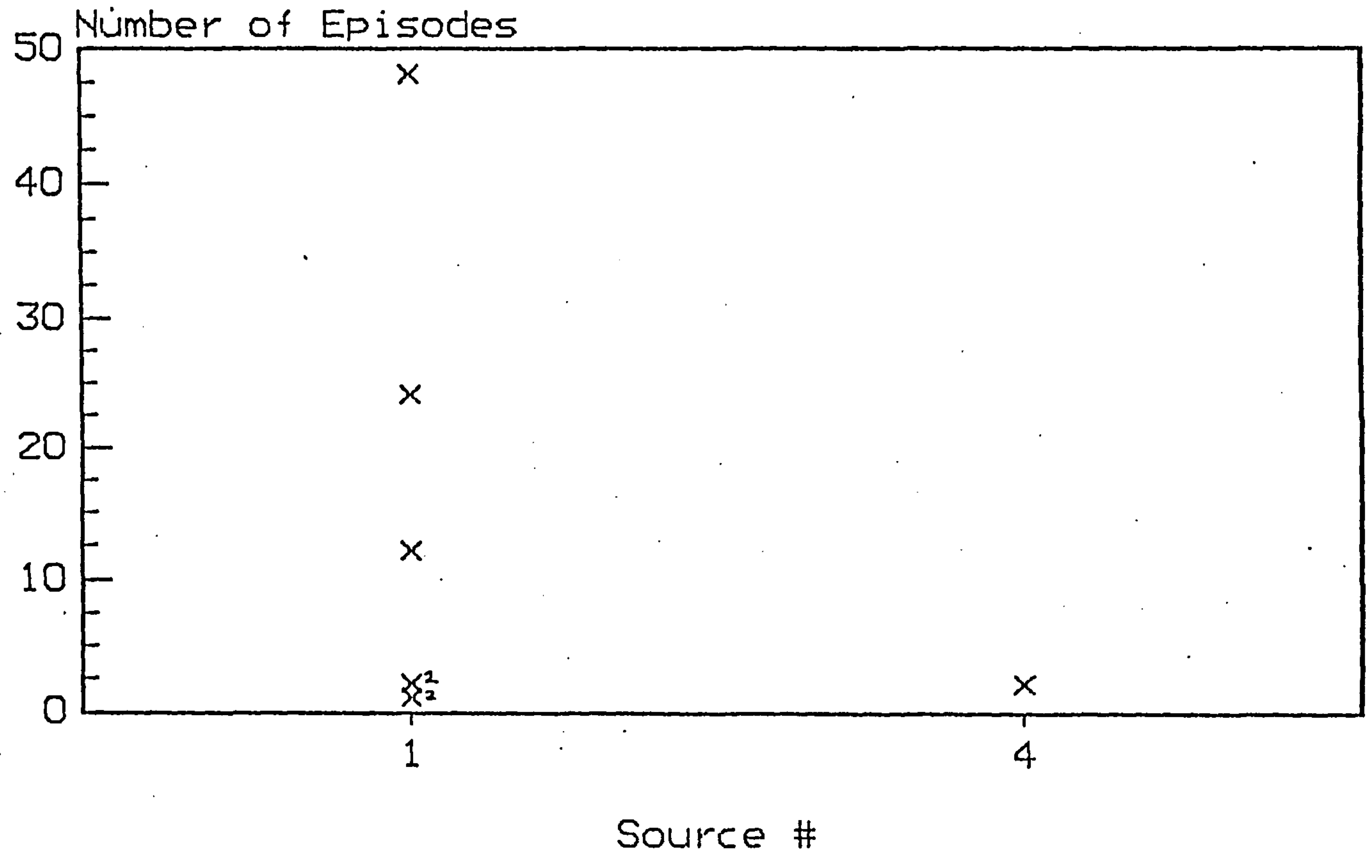
Figure 3
Reported Number of Episodes of Exposure
to Impulse Sources in One Year
3a) Teenage Data



X= Number of Subjects Reporting at That Level

Note: One Subject reported 1000 episodes for source #1 in one year

Figure 3
Reported Number of Episodes of Exposure
to Impulse Sources in One Year
3b) Undergraduate Data



X= Number of Subjects Reporting at That Level

Figure 4.
Dosimetry Results Plotted By Subject

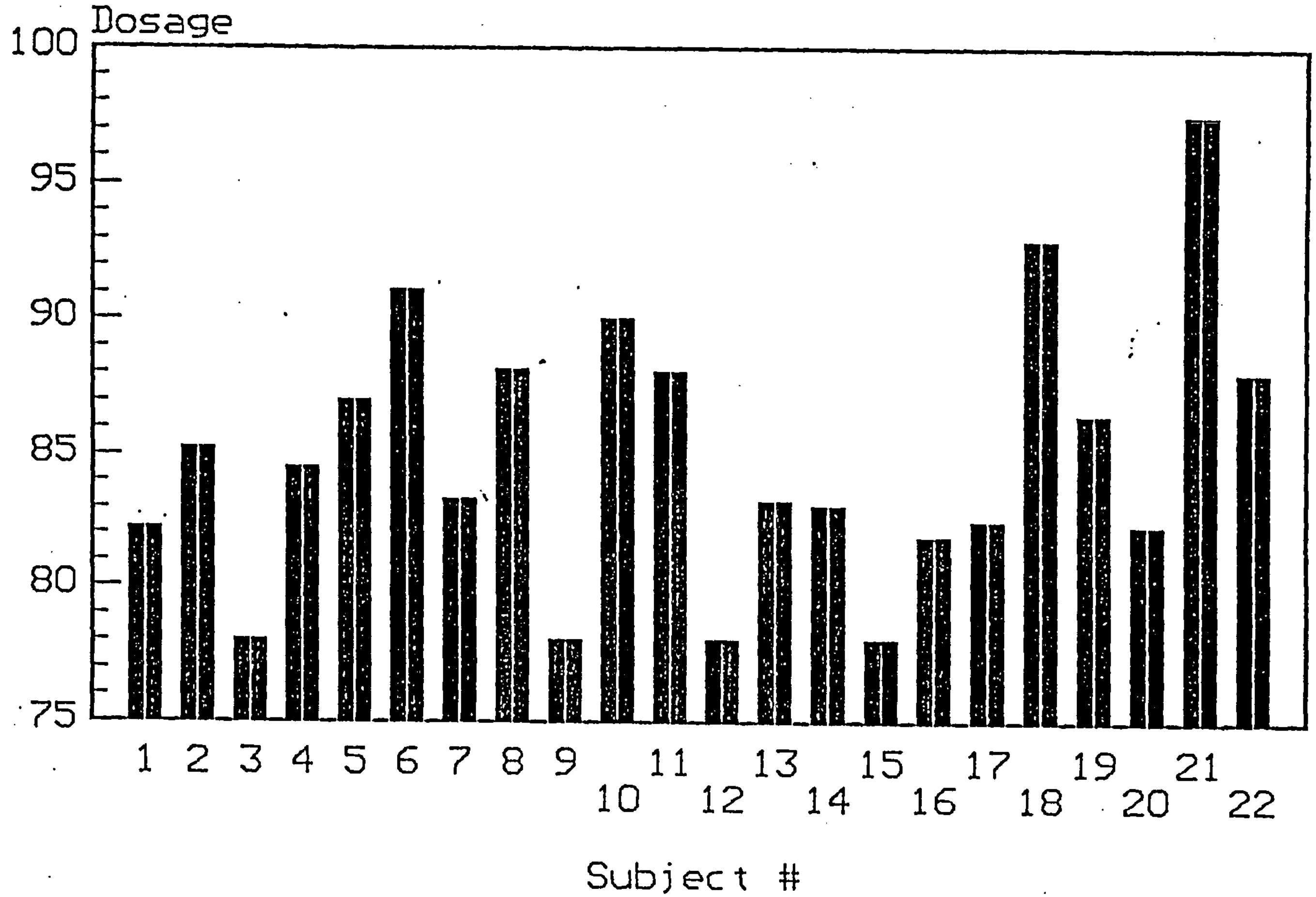


Figure 5
Dosimetry Data Plotted By Sex
5a) Females

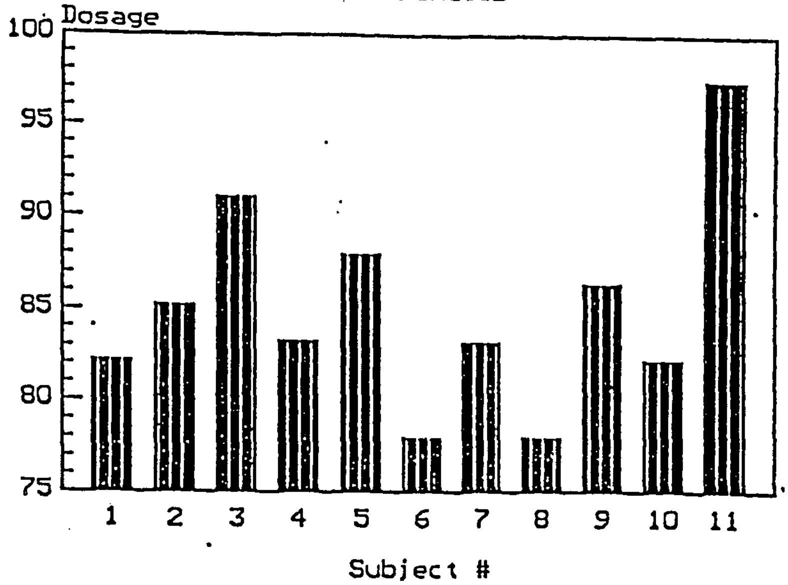


Figure 5
Dosimetry Data Plotted By Sex
5b) Males

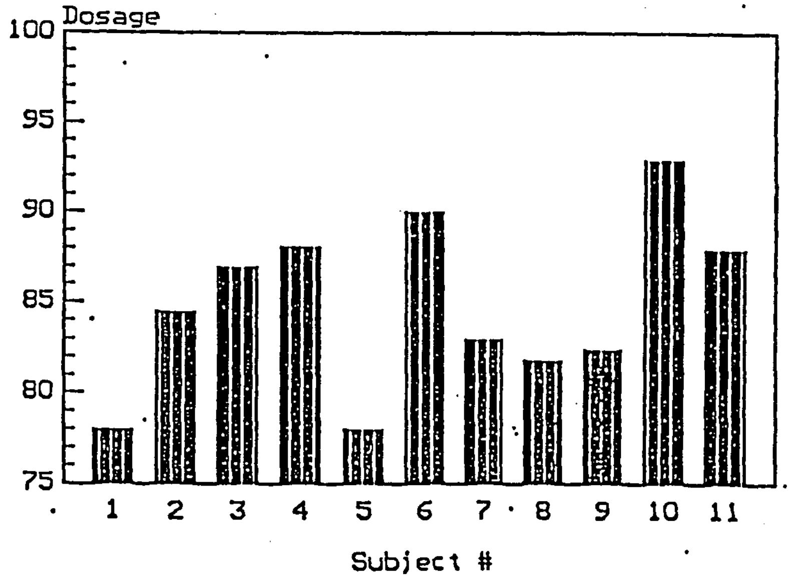


Figure 6
Mean Thresholds for Better Ear of
Teenagers Plotted Against Same Data
from Roche 1978 and DHEW 1975

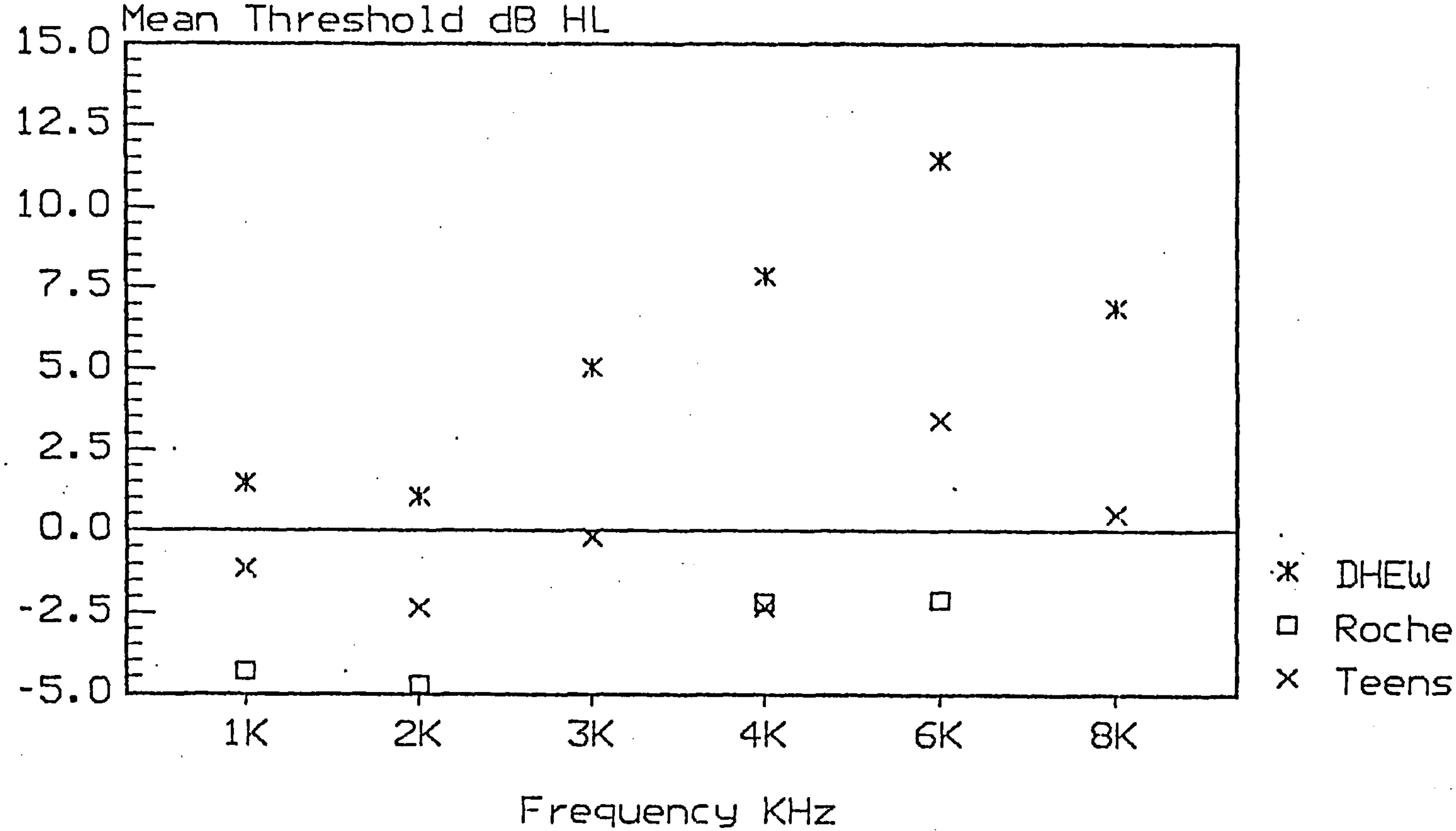


Figure 7
Mean Thresholds 1000-8000 Hz
Right vs. Left Ears
Teenage Data

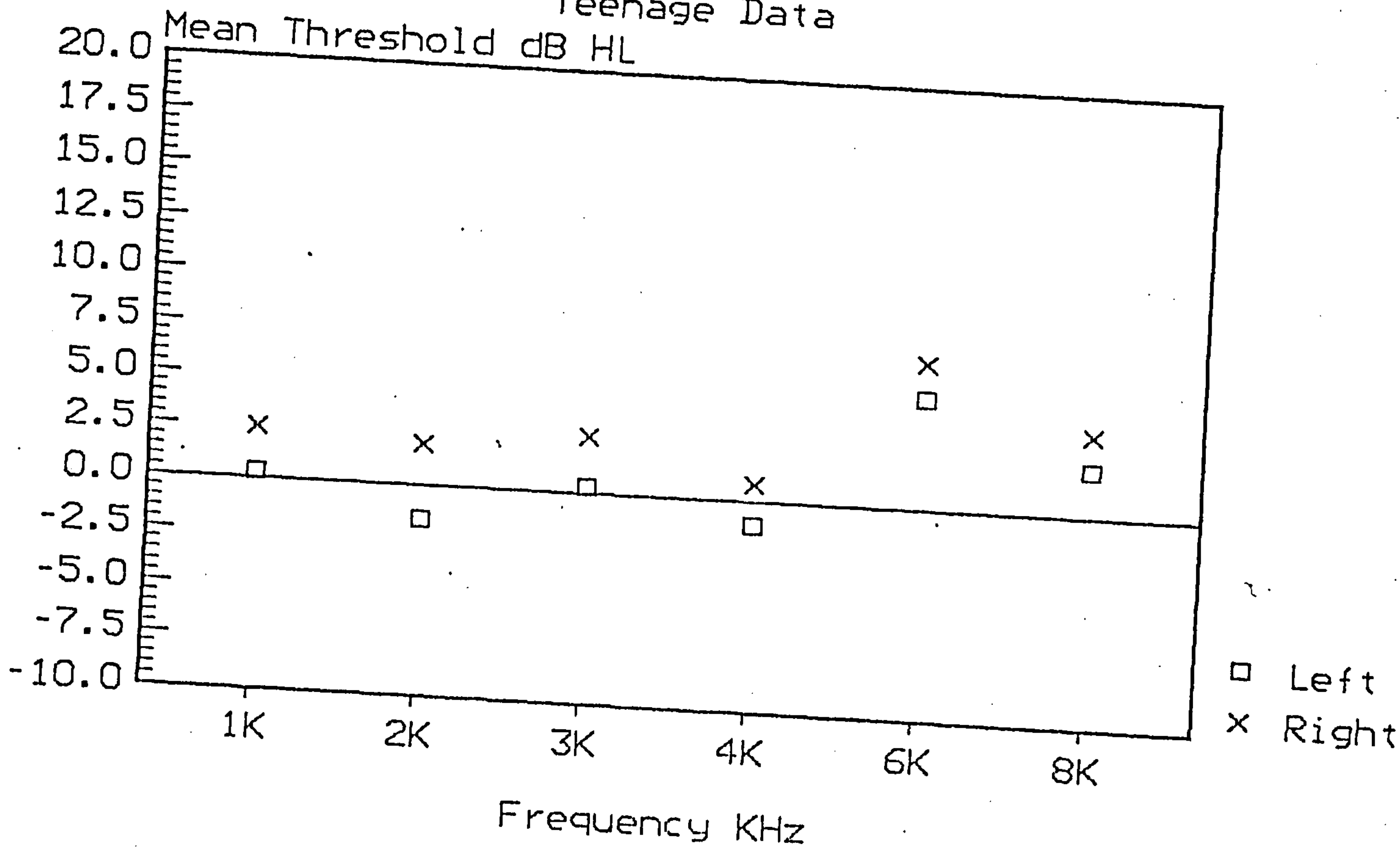


Figure 8
Mean Thresholds 1000-8000 Hz
Plotted by Sex
8a) Right Ear Teenage data

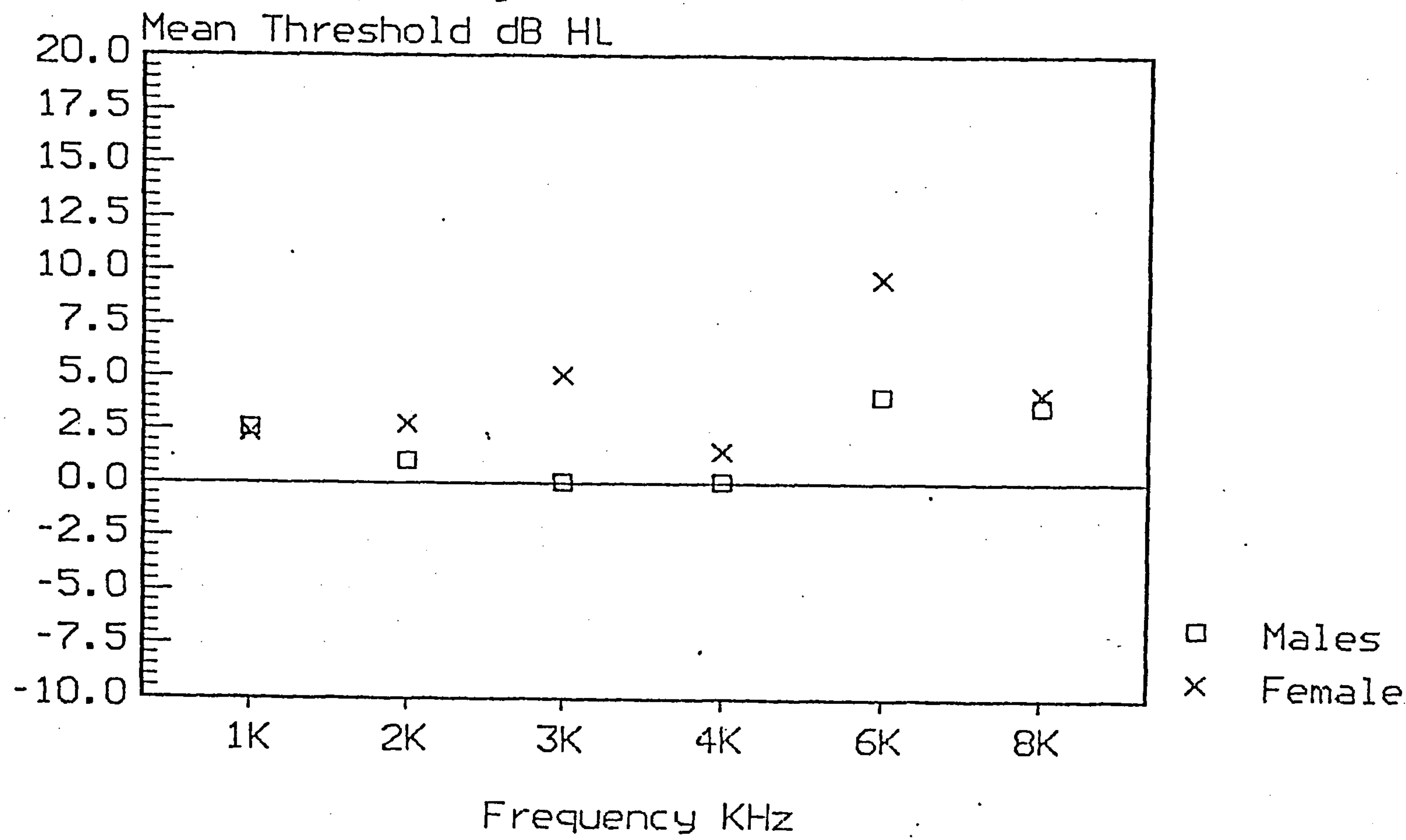


Figure 8
Mean Thresholds 1000-8000 Hz
Plotted by Sex
8b) Left Ear Teenage data

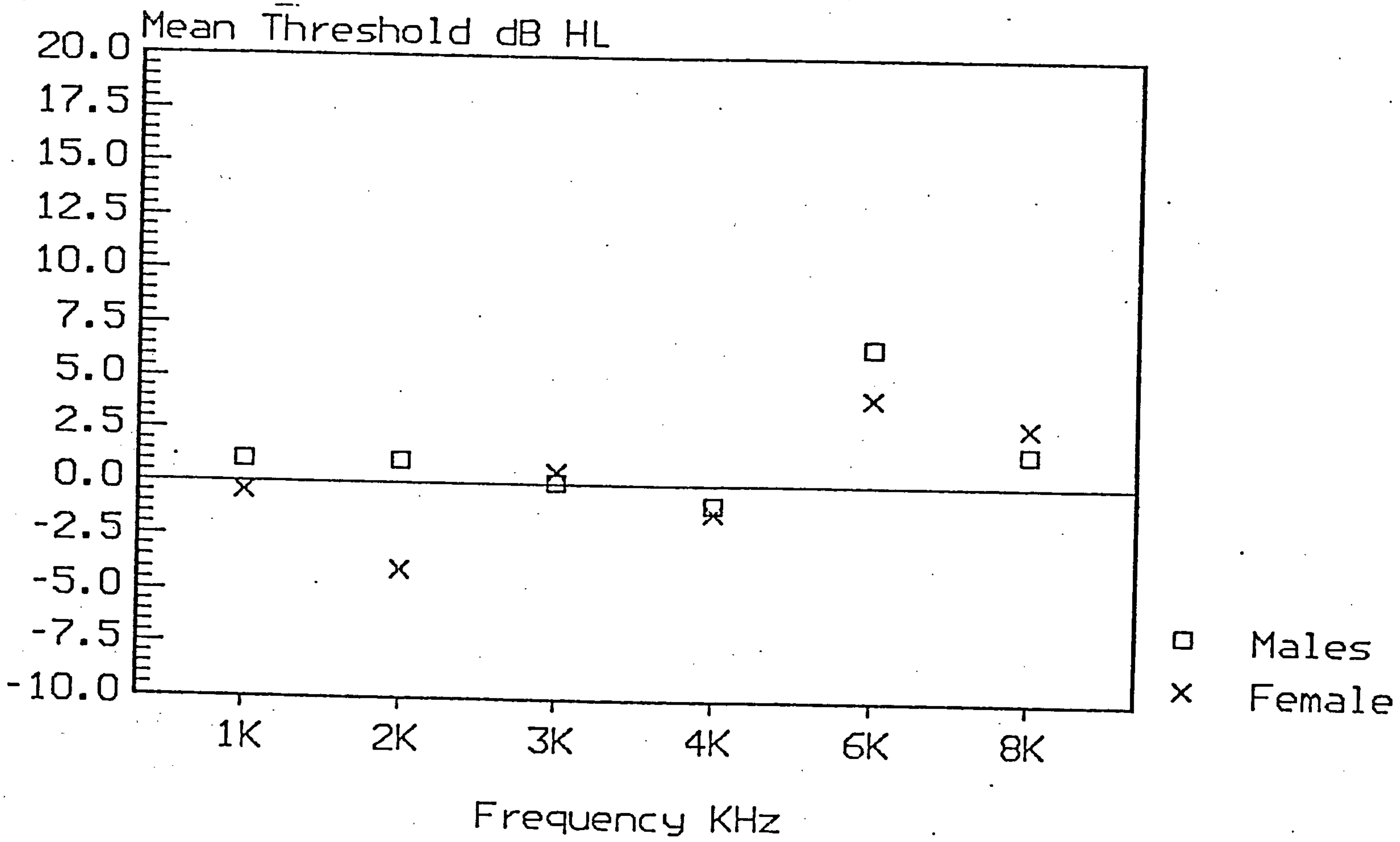


Figure 9
Mean Thresholds 1000-8000 Hz
Teenagers vs. Undergraduates
9a) Right Ear Data

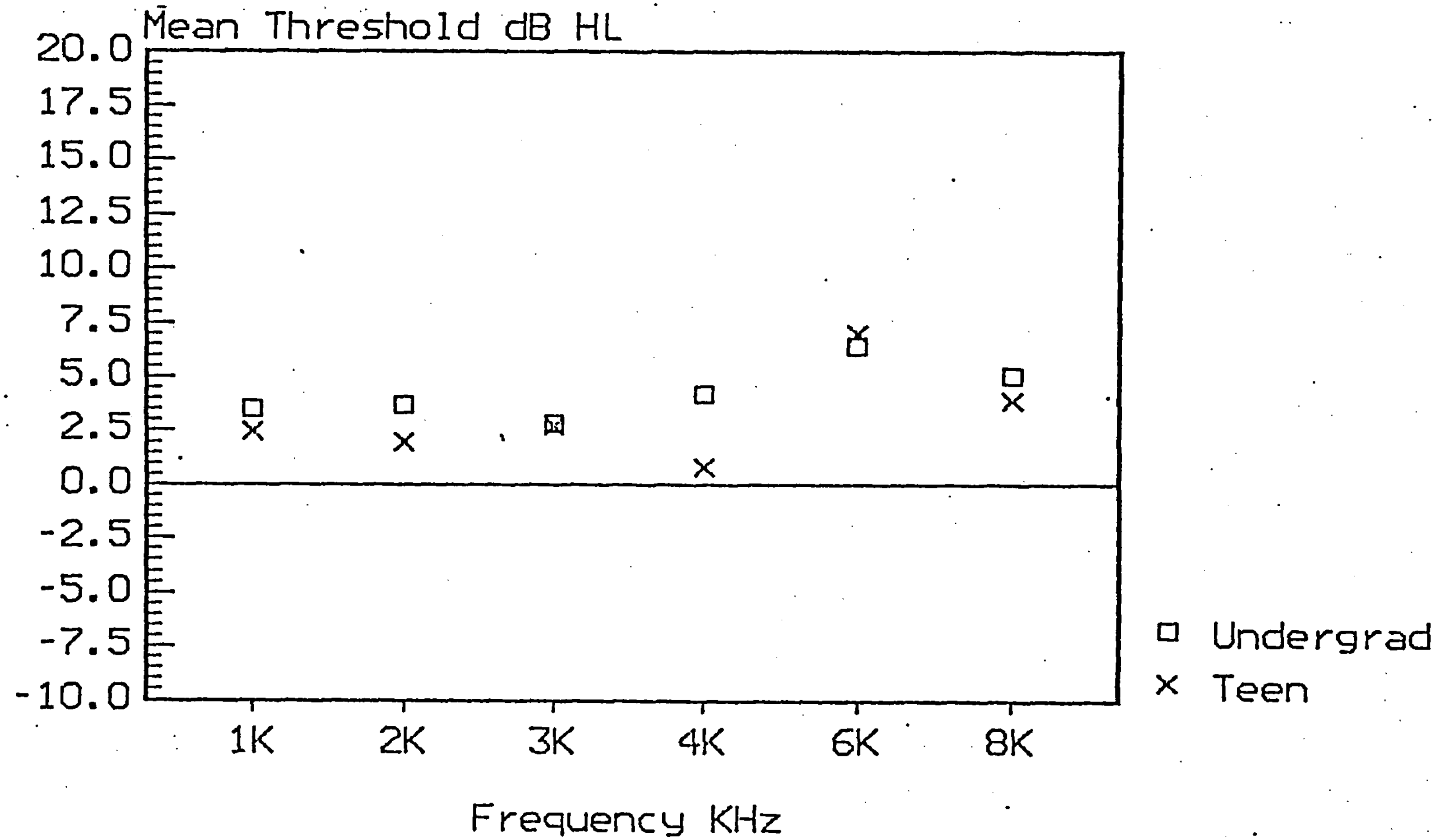
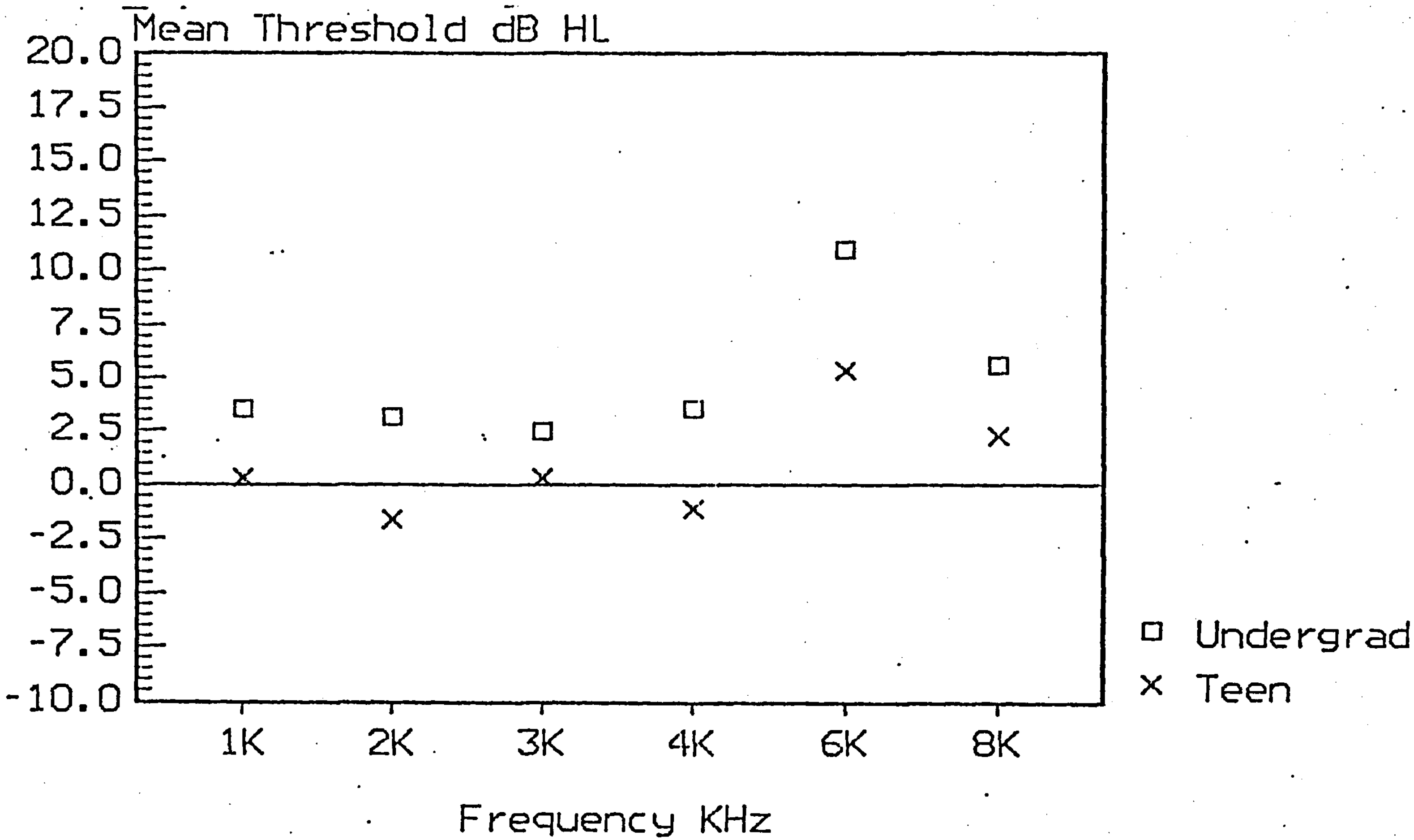


Figure 9
Mean Thresholds 1000-8000 Hz
Teenagers vs. Undergraduates
9b) Left Ear Data



CHAPTER SIX

DISCUSSION

The purpose of this study was twofold: 1) to identify the sources and patterns of noise exposure in teenagers and undergraduates and 2) to look for signs of decreased sensitivity that could possibly be attributed to noise exposure.

Summary of Results

The main findings of this study were:

1) Sources and patterns of noise exposure were similar for teenagers and undergraduates.

2) Television and amplified music were the major sources of noise exposure reported for both teenagers and undergraduates.

3) The primary impulse noise sources reported by each sample were rifles and firecrackers.

4) 50% of teenagers were exposed to greater than 85 dBA, 8 hour equivalent levels for a 13 hour sampling period.

5) Mean thresholds for teenagers and undergraduates were better than 25 dB HL at all frequencies for otologically normal subjects.

6) The poorest thresholds were obtained at 6000 Hz for teenagers in both ears.

7) Thresholds at 6000 Hz were poorer for males than females.

8) Thresholds for teenagers were better than those obtained for undergraduates.

9) The majority of subjects in either the undergraduate or teenage samples did not report use of hearing protection in noisy conditions.

10) There was very little correlation found between either duration of exposure to steady state sources or number of episodes of exposure to impulse sources and thresholds at 6000 Hz in either the right or left ear.

Of primary interest to the issue of hearing conservation in the pre- occupational population are the findings related to dosimetry levels, hearing sensitivity at 6000 Hz and the number of subjects reporting use of hearing protection in noisy conditions.

Dosimetry Levels

The current study found that the mean 8 hour equivalent dosimetry level for a 13 hour sampling period was 84.9 dBA. This finding is in agreement with the postulated corrected levels given by Roche et al (1982). This study obtained values of 77.2 dBA for boys and 75.8 dBA for girls but suggested that true values would be somewhere between 77 and 84 dBA due to measurement variability. The levels obtained in the current study are higher than the EPA (1974) level of 77 dBA and higher than the Schori and McGatha (1978) average Leq (24) of 76.2 dBA. None of these studies provided the individual dosimetry levels for each subject so it is difficult to relate them to the current study which found that 50 % of teenagers sampled exceeded the level of 85 dBA .

This finding may be cause for concern since workers in industry exposed to 85 dBA for 8 hours need to wear hearing protection and have their hearing monitored annually (WCB,1979) . The reported levels are also of concern since a large portion of the sampling period included time in which students were in school. It is possible that if levels are this high there could be implications for not only hearing but effective learning in the classroom since we know that signal to noise ratio is an important factor in effective processing of information.

A closer examination of those subjects exceeding 85 dBA indicated that 95 % had engaged in either p.e., industrial education or band during the sampling period . This might lead one to suspect that the added exposure from these activities may have contributed to the higher levels but without further investigation this can not be substantiated.

It is unfortunate that dosimetry could not be obtained for the undergraduate sample as there appeared to be a trend in the individual dosimetry results towards lower dosimetry levels for the older teenage subjects than the younger ones. Several additional factors may have accounted for this finding. From observation, it can be seen that younger teenagers tend to be somewhat louder in their vocalizations than the older teenagers. This may have somehow contributed to the higher levels obtained for younger subjects.

Hearing Sensitivity at 6000 Hz

The current study found that in general the poorest thresholds for both teenagers and undergraduates were obtained at 6000 Hz. This finding is in agreement with a number of other studies : Taylor et al (1965) who noted the greatest threshold shifts are seen at 4000 or 6000 Hz during the first 10 to 15 years of exposure to noise, Gjaevenes, Mosang and Nordahl (1974) who reported that a dip at 6000 Hz was noted in children exposed to firecrackers and Axellson and Jerson (1981) who noted that the worst thresholds were at 6000 Hz in both ears for teenage boys 17 to 20 years old.

These results are also consistent with the findings of Pyplacz (1986), who reported that for 19,874 occurrences of hearing loss in miners there was a greater proportion of hearing loss at 6000 Hz among younger subjects but a greater proportion of hearing loss at 1000 and 2000 Hz among older subjects.

The number of subjects displaying notches at 6000 Hz was interesting. The results indicated that 50 % of subjects in the teenage sample had a notch greater than or equal to 10 dB relative to the surrounding frequencies. These results are consistent with the findings of Axellson and Jerson (1981) and Lees et al (1987).

The interesting characteristic of thresholds in the younger populations which may or may not be significant is the fact that since our criteria for normal hearing is 25 dB HL we tend to overlook relative decreases in sensitivity across the frequency range unless they exceed this level. We may wish to consider the fact that since 6000 Hz seems to consistently have poorer thresholds than other frequencies it may be an earlier indicator of damage due to noise exposure. As a result we may wish to take a closer note of decreased sensitivity at this frequency even if it is within normal limits . While the suggestion by Roberts (1987) sheds doubt on the validity of including 6000 Hz in the criteria for determining NIHL due to poor test/ retest reliability, the consistency of decreases in sensitivity at this frequency can not be overlooked and, therefore, requires further investigation.

Hearing Protection

In view of the obtained dosimetry readings and decreases in hearing sensitivity at 6000 Hz some concern needs to be taken regarding the fact that a large number of teenagers and undergraduates did not report regular use of hearing protection in noisy conditions. The results indicated that 86 % of teenagers and 72 % of undergraduates did not report regular use of hearing protection. Of those teenagers who did not report use of hearing protection , two were regular rifle users. Undergraduates appeared to be somewhat better in this respect, since the two undergraduates reporting gun use did use hearing protection on an occasional basis.

This finding of limited use of hearing protection in young people is consistent with the findings of Lass et al (1987) which found that only 13 % of students between the ages of 11 and 15 reported use of earplugs when exposed to noise.

When informally questioned about conditions requiring hearing protection, the majority of subjects did not consider it to be an issue of importance since most of them did not have any idea about the connection between noise and their hearing.

Summary

The results of the current study indicate that levels of noise exposure experienced by teenagers may be higher than acceptable standards. The thresholds obtained from subjects at 6000 Hz did not indicate any significant decreases in sensitivity that would be considered outside the limits of normal but thresholds at this frequency were appreciably different from those obtained at the surrounding frequencies. The current study did not indicate that exposure to noise was responsible for decreases in hearing sensitivity at 6000 Hz nor did it rule this possibility out.

Future Considerations

To this writer's knowledge there is a limited amount of time spent on hearing conservation with teenagers and undergraduates in this province. If indeed the levels of noise exposure are as high as reported in this study or higher and if 6000 Hz is any indicator of decreased sensitivity due to noise exposure then more attention to hearing conservation appears to be warranted. It is evident that teenagers and undergraduates are not sufficiently aware of the possibility of damage to their hearing from noise exposure or else a larger number of them would be wearing hearing protection when exposed to noisy conditions.

In conclusion, the findings of this study indicate that there is evidence of possible significant noise exposure by teenagers. As a result further study of this issue is strongly recommended to clarify the risks.

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b) Do you take any medication for them?

7a) Do you have any serious illnesses or disorders requiring ongoing medical treatment (i.e. kidney disease)?

8) Have you had a high fever (greater than 104 farenheit)?

9) Have you ever had a head injury?

10a)Do you have a history of ear infections?
b)right, left or both ears?

c)When did it first start?

d)When was the most recent infection?

e)Type of medication prescribed if treated by a doctor?

11) Have you ever had ear surgery?

12a)Do you still have your tonsils and adenoids?
b)If yes, have you had tonsilitis?

c)Type of medication prescribed if treated by a doctor?

13)Do you have any problems with dizziness?

14)Does anyone in your family have Raynaud's Disease?

15)Do you have a history of thyroid problems treated medically?

16)Do you smoke?

Noise Exposure History

In this section you will need to estimate the number of times that you have been exposed to a particular noise source. In addition, you will need to estimate the number of hours that the total number of exposures represents, ie:one exposure daily to your walkman for three and a half hours would be recorded as 1/3.5 under the daily exposure column. There is no need for you to fill in the boxes for weeks, months and years if you do something on a daily basis. The same is true for activities that only occur on a yearly basis. With these you don't need to fill in the day, week or month columns. If you never engage in a particular activity mark N/A. Round off estimates to the nearest 15 minutes, except for those activities which are marked by a star. For those activities, estimate as closely as possible to the actual time values per exposure. For example, five exposures to firecracker explosions lasting 30 seconds each would represent two and a half minutes of exposure time. You will need to fill in 5/2.5minutes under the daily exposure box in this case.

Activities	day	week	month	year
firecrackers*				
target practice: -air guns*				
-pistols*				
hunting:rifle*				
moped				
motorcycle				
motocross				
snowmobile				
lawn mower				
chain saw				
car racing				
models: -cars				
-airplanes				
-trains				
outboard motor				
spectator: -rock concert				
-pop concert				
-classical music				
dances:taped music				
music over speakers (portable or stationary stereo)				
music under headphones (walkman style): -intentional listening				
-background music				
music in car: -rock				
-pop				
-classical				
musician: -band				
-studio				
noisy tools(home shop)				
noisy household appliances				
television				
computer printer				
video games				
portable telephones				
spectator sports				
participant sports				

Additional Questions (please explain your answers)

1)At what level do you normally set your walkman style devices for a)intentional listening- low medium high
b)background music-low medium high

2a) Do you work after school?
b) What type of work is it?

c) How many hours a week do you work there?
d) How long have you worked there?

3) Do either/both of your parents have industrial or noisy occupations?

4) If you drive a car what make is it?

5) Do you live near a noisy road, highway, or airport?

6a) Do you wear hearing protection when exposed to noise?
b) occasionally or all of the time?

7) What are the spectator sports you normally attend?

8) What sports do you participate in?

9a) Do you ever have ringing or buzzing in your ears?
b) Is it constant or intermittent?
c) Do you associate the ringing or buzzing with any particular situation/s?

10) Do you ever find that you have difficulty hearing people standing within 10 feet of you, after being exposed to loud noise?

11a) If you hunt what kind of firearm do you use?

b) Which hand do you use to hold the gun?

12a) If you play in a band ,what type of band is it?

b) What instruments do you play?

DAY ONE

Date:

Activity	Before 9am	9am-3pm	3pm-9pm
firecrackers*			
target practice:			
-air guns*			
-pistols*			
hunting:rifle*			
moped			
motorcycle			
motocross			
snowmobile			
lawnmower			
chainsaw			
car racing			
models:			
-cars			
-airplanes			
-trains			
outboard motors			
spectator:			
-rock concert			
-pop concert			
-classical music			
dances:taped music			
music over speakers (portable or stationary stereo)			
music under headphones (walkman style)			
-intentional listening			
-background music			
music in car:			
-rock			
-pop			
-classical			
musician:			
-band			
-studio			
noisy tools(home shop)			
noisy household appliances			
television			
computer printer			
video games			
portable telephones			
spectator sports			
participant sports			

DAY TWO

Date:

Activity	Before 9am	9am-3pm	3pm-9pm
firecrackers*			
target practice:			
-air guns*			
-pistols*			
hunting:rifle*			
moped			
motorcycle			
motocross			
snowmobile			
lawnmower			
chainsaw			
car racing			
models:			
-cars			
-airplanes			
-trains			
outboard motors			
spectator:			
-rock concert			
-pop concert			
-classical music			
dances:taped music			
music over speakers (portable or stationary stereo)			
music under headphones (walkman style)			
-intentional listening			
-background music			
music in car:			
-rock			
-pop			
-classical			
musician:			
-band			
-studio			
noisy tools(home shop)			
noisy household appliances			
television			
computer printer			
video games			
portable telephones			
spectator sports			
participant sports			

DAY THREE

Date:

Activity	Before 9am	9am-3pm	3pm-9pm
firecrackers*			
target practice:			
-air guns*			
-pistols*			
hunting:rifle*			
moped			
motorcycle			
motocross			
snowmobile			
lawnmower			
chainsaw			
car racing			
models:			
-cars			
-airplanes			
-trains			
outboard motors			
spectator:			
-rock concert			
-pop concert			
-classical music			
dances:taped music			
music over speakers (portable or stationary stereo)			
music under headphones (walkman style)			
-intentional listening			
-background music			
music in car:			
-rock			
-pop			
-classical			
musician:			
-band			
-studio			
noisy tools(home shop)			
noisy household appliances			
television			
computer printer			
video games			
portable telephones			
spectator sports			
participant sports			

DAY FOUR

Date:

Activity	Before 9am	9am-3pm	3pm-9pm
firecrackers*			
target practice:			
-air guns*			
-pistols*			
hunting:rifle*			
moped			
motorcycle			
motocross			
snowmobile			
lawnmower			
chainsaw			
car racing			
models:			
-cars			
-airplanes			
-trains			
outboard motors			
spectator:			
-rock concert			
-pop concert			
-classical music			
dances:taped music			
music over speakers (portable or stationary stereo)			
music under headphones (walkman style)			
-intentional listening			
-background music			
music in car:			
-rock			
-pop			
-classical			
musician:			
-band			
-studio			
noisy tools(home shop)			
noisy household appliances			
television			
computer printer			
video games			
portable telephones			
spectator sports			
participant sports			

DAY FIVE

Date:

Activity	Before 9am	9am-3pm	3pm-9pm
firecrackers*			
target practice:			
-air guns*			
-pistols*			
hunting:rifle*			
moped			
motorcycle			
motocross			
snowmobile			
lawnmower			
chainsaw			
car racing			
models:			
-cars			
-airplanes			
-trains			
outboard motors			
spectator:			
-rock concert			
-pop concert			
-classical music			
dances:taped music			
music over speakers (portable or stationary stereo)			
music under headphones (walkman style)			
-intentional listening			
-background music			
music in car:			
-rock			
-pop			
-classical			
musician:			
-band			
-studio			
noisy tools(home shop)			/
noisy household appliances			
television			
computer printer			
video games			
portable telephones			
spectator sports			
participant sports			