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Effect of Simultaneous Exercise and Noise Exposure (Music) on Hearing

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Abstract

Hearing thresholds were measured in 12 subjects prior to and following their participation in three experimental conditions: (a) riding a cycle ergometer for 20 minutes; (b) listening to a selection of music at an equivalent intensity of 96 dB(A) SPL for 20 minutes; and (c) listening to the music while riding the cycle ergometer for 20 minutes. Analysis of the results shows a measurable and statistically greater noise-induced temporary threshold shift (NITTS) for the music plus exercise condition than for either of the other two conditions. The greatest differences were seen in the 3–6 kHz frequency range. These results suggest an increased susceptibility to NITTS and, by extension, to increased potential for permanent hearing loss when noise exposure is coupled with exercise. The results have implications related to contemporary lifestyle issues such as aerobics and the utilization of personal music systems during physical exertion.

Key Words: Exercise, noise exposure, temporary threshold shift

Noise-induced hearing loss (NIHL) may be the result of an acoustic trauma but most often develops from an accumulation of repeated noise exposures over a period of years (Kryter, 1970). It is a common assumption that noise-induced permanent threshold shift (NIPTS) often results after repeated episodes of noise-induced temporary threshold shift (NITTS) (Kryter et al, 1966; Kryter, 1970; Burns, 1973). Attempts to predict NIPTS from NITTS have been made (Ward, 1965; Buck and Francke, 1986) but thus far, the available evidence only suggests that noise that does not produce NITTS will not produce permanent hearing loss (US Department of Labor, 1981).

It is well known that the characteristics most influential on the development of NIPTS or NITTS are the physical parameters of the noise exposure including the frequency, intensity, and duration of the stimulus. However, factors within an exposed individual have also been shown to influence the type and degree of NITTS. These factors include inherent anatomic structures of the peripheral ear, such as size, shape, or volume of the ear canal (Gerhardt et al, 1987), acoustic stapedius reflex properties (Borg, 1968), age (Humes, 1984), gender (Ward, 1966, 1973), and even eye color (Hood et al, 1976; Cunningham and Norris, 1982).

It has been suggested that physiologic changes in the body may contribute to changes in susceptibility to NITTS (Dengerink et al, 1984; Lindgren and Axelsson, 1988). Evidence in the literature supports the concept that factors such as tobacco use (Dengerink et al, 1984; Dengerink et al, 1987), cardiovascular function (Sanden and Axelsson, 1981), physical fitness (Ismail et al, 1973), and even psychological state (Dengerink et al, 1982) may affect NITTS susceptibility. Each of these factors have been hypothesized to have differential effects on hearing thresholds associated with NIHL due to the unique chemical, circulatory, and temperature changes they cause in the body.

There is evidence to suggest a relationship between exercise and NITTS susceptibility (Ismail et al, 1973; Dengerink et al, 1982, 1987). It has been proposed that increased heart rate and blood pressure associated with physical

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exertion may have a consequential impact on blood circulation to the cochlea. Sanden and Axelsson (1981) studied hearing and fitness levels in shipyard workers and found results that suggested that those workers with the most hearing loss were generally the least physically fit. Greater increases in heart rate and blood pressure were noted in this group during exertion, which resulted in a greater susceptibility to the effects of noise. Similar results were reported by Ismail et al (1973). Following an 8-month physical training program, individual NITTS values were significantly reduced compared to pre-experiment values. Subjects were also found to recover more quickly from auditory fatigue once physically conditioned.

In an attempt to identify the interactive effects of exercise and NITTS susceptibility, Lindgren and Axelsson (1988) conducted an experiment with nine male volunteer subjects. Each was exposed to narrow-band noise at 105 dB SPL for 10 minutes in four test conditions, three of which were combined with physical exercise. Subjects were exposed to noise only and to noise before, during, and after exercise. Their results showed statistically significant increases in NITTS with the noise during exercise condition when compared to the other test conditions. Although the authors stated that the specific mechanisms leading to these results were unclear, they did suggest elevated blood temperature and/or the release of chemical substances as possible causes.

Although music may be a pleasurable source of noise exposure, overstimulation of the auditory structures with this type of stimulus is still potentially damaging (Axelsson and Lindgren, 1977, 1978; Lindgren and Axelsson, 1983; Swanson et al, 1987). Axelsson and Lindgren (1977) examined the hearing in 83 musicians who had been exposed to "pop" music for an average of 9 years. Although only 13 percent were found to have NIPTS, the risk of hearing loss reportedly increased with age, exposure time, and the use of stereophonic earphones. A later study (Axelsson and Lindgren, 1978) examined NITTS in pop musicians and their audience. NITTS was found to be more pronounced in listeners than in the musicians themselves.

Although relatively little is known about the specific interactive effects of physical exercise and music exposure, one might assume that the interaction of these two variables is as unfavorable as the combination of exercise with narrow-band noise. Given the contemporary utilization of music combined with exercise programs (e.g., aerobics or the use of personal stereos while running), a significant impact on the population may be hypothesized. Therefore, the purpose of the present investigation was to determine if the risk or degree of temporary noise-induced hearing loss due to the exposure to music is increased with simultaneous exercise.

METHOD

Subjects

Twelve subjects were selected for inclusion in the study. All subjects were healthy females and ranged in age from 21 to 29 years, with a mean age of 24.1 years. Only females were utilized in this study to reduce the potential variability in NITTS introduced by gender and/or work capacity. Each subject met the following criteria: (a) hearing thresholds less than 20 dB HL for octave frequencies of 0.25–8 kHz bilaterally; (b) normal tympanograms with middle ear pressure of 0 ± 0.25 kPa; (c) nonsmokers; (d) normal resting systolic and diastolic blood pressure (upper limit of 140 systolic/90 diastolic); and (e) no other contraindications to participating in the study. Each subject signed an informed consent document prior to participating.

Experimental Conditions

Each subject was required to participate in three experimental conditions: (1) music exposure only; (2) exercise only; and (3) music exposure coupled with exercise.

The music only condition consisted of a 20-minute selection of pop music presented binaurally at an equivalent sound pressure level of 96.4 dBA. The exercise only condition required riding a cycle ergometer for 20 minutes. The third condition, music during exercise, consisted of the previous two conditions combined (i.e., subjects rode the cycle ergometer while listening to the music for a 20-minute period).

Prior to testing, the subjects were informed as to the type and length of each exposure condition. At least a 48-hour interval between experimental conditions was required to prevent any additive effect of the NITTS. The order of experimental conditions was counterbalanced across subjects.

The music stimulus was delivered to each subject via a JVC (KD-W110) stereo double cassette deck through a Grason Stadler (GSI-16) audiometer. Calibration of the stimulus is described below. In order to reduce variations caused by headphone placement, the music stimulus was delivered through E.A.R. TONE 3A insert earphones with E.A.R. foam eartips. The earphones remained in place for the entire experimental session.

During the exercise portion of the study, subjects rode a cycle ergometer while maintaining a steady-state heart rate of 140–160 beats/minute. The physical workload was chosen to approximate 70 percent of each individual's maximum work capacity (a common workload for typical exercisers). Prior to beginning the study, the amount of work necessary to reach this level was established using a guide to setting workloads for females (Golding et al, 1982). This required subjects to pedal at a steady rate of 50 RPMs while gradually increasing the workload. Once the specific work level was established for each individual, the exercise level was maintained so as to sustain the target heart rate. A warm-up period of approximately 3–4 minutes was generally required to establish target heart rate. The subjects then began exercising at the predetermined workload for 20 minutes, the last 1½ minutes of which were devoted to cool down. All participants wore appropriate exercise apparel (shorts and T-shirt) in order to maintain similar body temperature for each session. Room temperature was maintained between 71° and 74°F during exercise portions of the study.

Music Stimulus

A noise (music) stimulus tape was specifically constructed to meet the needs of this study. A commercially available compact disc with the soundtrack of "The Big Chill" (Motown Record Corporation, 1984) was recorded onto cassette tape. A 20-minute selection of that tape was then rerecorded in order to eliminate quiet portions within and between songs.

In order to quantify and calibrate the intensity level being delivered, the music tape was played from the JVC (KD-W110) stereo double cassette deck through an audiometer (GSI-16) into a Precision Integrating Sound Level Meter (Bruel and Kjaer Type 2230), which was coupled to the insert earphones using a 2-cc coupler. Dial settings were adjusted so that the output was equal to approximately 95 dB SPL. The entire music selection was delivered to the integrating sound level meter to evaluate the overall sound pressure level. The equivalent sound pressure level for the 20-minute selection was 96.4 dB(A), with a peak intensity of 107 dB(A). This level was chosen in order to elicit measurable NITTS without posing a substantial risk for permanent damage to the subjects.

Measurement

Hearing thresholds for frequencies of 2, 3, 4, 6, and 8 kHz were established for the left ear immediately before and 2 minutes following each experimental condition. Only a single ear was chosen to evaluate for NITTS to avoid any potential recovery in function that might occur during a more extended audiometric evaluation. The choice of the left ear was arbitrary. Audiometric data were gathered by pure-tone testing in 2-dB increments using a modified Hughson Westlake method (down 4 dB, up 2 dB). NITTS was defined as the difference in dB between pre- and postexposure thresholds at each frequency. Presentation order of frequency was counterbalanced, and the examiner was blinded to any previous test results to reduce bias.

Heart rate and blood pressure were monitored and recorded throughout each session to ensure stability of the cardiovascular response between the exercise conditions. A three-lead cardiotachometer was affixed to the subjects during each session to measure heart rate. An aneroid sphygmomanometer was used to measure blood pressure. Physiologic measurements were taken at the following intervals: (a) immediately prior to each experimental condition; (b) following warm-up to a steady-state heart rate during exercise; (c) 10 minutes into each experimental condition; and (d) 20 minutes into each condition.

All sessions were conducted in a sound-treated booth, with background noise levels below those recommended by the American National Standards Institute (1977). All equipment was calibrated immediately prior to beginning the study (ANSI, 1989).

RESULTS

All subjects completed every phase of the experiment without difficulty and with at least 2 days between each of the three test conditions. The mean pre- to post-exposure threshold differences in NITTS between test conditions are illustrated in Figure 1. For the exercise only condition, mean differences for

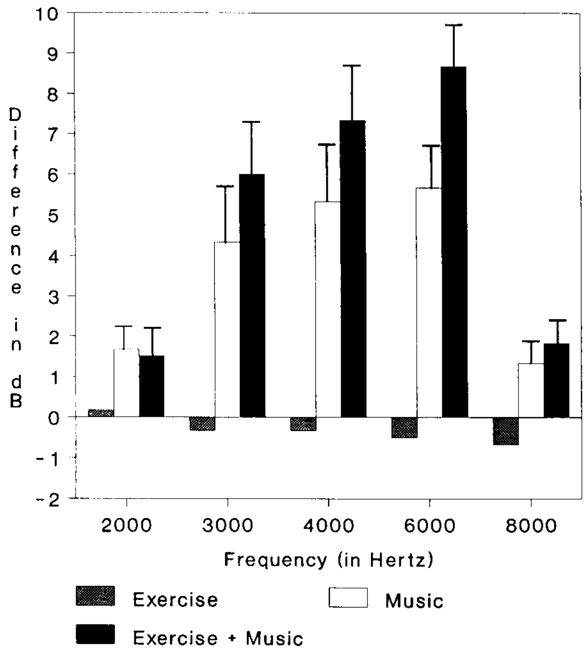

Figure 1 Mean differences (dB) between pre- and post-thresholds for each experimental condition. Stippled bars are changes following the exercise only condition, white bars are changes following the music only condition, and black bars are changes following the music + exercise condition. Standard error of the mean is indicated by the error bar.

pre- and postexposure thresholds ranged from +0.17 dB at 2 kHz to –0.67 dB at 8 kHz. For the music only condition, mean differences ranged from +1.33 dB at 8 kHz to +5.67 dB at 6 kHz. For music during exercise, average threshold differences ranged from +1.50 dB at 2 kHz to +8.67 dB at 6 kHz. In general, the music exposure during exercise condition produced the greatest amount of threshold shift.

Statistical analysis (paired t-tests) of the data revealed no significant differences in pre- to postexposure hearing thresholds for the exercise only condition for any test frequency. Significant changes were noted, however, for both of the conditions in which music was employed. For the music only and music + exercise conditions, significant differences from pre- to postexposure thresholds were noted at 3, 4, 6, and 8 kHz ($p < .05$). Significant differences were not noted at 2 kHz for either of these conditions. Repeated measures analyses of variance (ANOVA) across the three conditions for each frequency showed no significant differences between the sample means of the three experimental conditions for 2 and 8 kHz. However, significant effects were noted for 3 kHz ($p < .01$), 4 kHz ($p < .001$), and 6 kHz ($p < .0001$).

As the purpose of this study was to determine if music during exercise resulted in greater NITTS than music only, paired t-tests on the differences in NITTS between these two conditions were performed. The mean NITTS values at 2 and 8 kHz were not significantly different. At 3, 4, and 6 kHz, the mean differences in NITTS were significantly greater for the music during exercise condition when compared to the music only condition ($p < .05$). The greatest change in pre- to postexposure hearing thresholds was seen at 6 kHz, where the mean difference of 8.67 dB for the music during exercise condition was significantly larger than the 5.67 dB difference in the music only condition ($p < .0001$).

Blood pressure (BP) and heart rate (HR) measures were averaged within and among subjects (Table 1). In order to determine similar exertion throughout each condition, one-way analysis of variance (ANOVA) was performed across the interval measures for each condition. Warm-up data were not included in the analysis. No significant changes were noted for the music only condition. During the exercise only and music during exercise, systolic and diastolic BPs remained the same. The results do show a small increase in HR with increased duration of exercise, an expected result.

Further analyses of physiologic measures were made to show similarity in exercise regimes between test conditions. Paired t-tests were performed for systolic and diastolic BP as well as HR, to compare cardiovascular function. As expected, there were significant differences in BP and HR in the two exercise conditions when compared to music only. Upon examining the differences between the two exercise conditions, the only statistically significant changes were for diastolic blood pressures at the 10-minute interval. The mean diastolic BP of 68 mm (Hg) in exercise only was found to be statistically different than the mean of 65 mm (Hg) for music during exercise ($p < .05$), but this difference is not considered to contribute to the differences observed in this investigation. No other significant differences were revealed between exercise only and music during exercise.

DISCUSSION

It has been suggested that noise can damage the cochlea by either a mechanical and/or a metabolic process (Bohne, 1976; Saunders et al, 1985). Mechanical injury to the inner ear results from extreme oscillations of the basilar

Table 1 Mean (and Standard Deviations) for Blood Pressure and Heart Rate during each Experimental Condition

Condition		0 Min*	10 Min	20 Min
		Heart Rate		
Music Only		75 (9.73)	76 (9.61)	74 (6.65)
Exercise Only		142 (5.56)	153 (8.55)	152 (7.18)
Music + Exercise		144 (5.95)	155 (8.68)	154 (6.68)
		Blood Pressure		
Music Only	S	103 (7.60)	100 (7.84)	98 (8.35)
	D	62 (5.29)	62 (5.29)	60 (5.15)
Exercise Only	S	142 (5.56)	153 (8.55)	152 (7.18)
	D	67 (4.12)	68 (3.32)	64 (4.16)
Music + Exercise	S	144 (5.95)	155 (8.68)	154 (6.68)
	D	67 (3.42)	65 (3.36)	64 (2.76)

S = systolic; D = diastolic.

*Values obtained following a 4-minute warm-up for the exercise conditions.

membrane, due to the intense stimulation, with a subsequent breakdown of structures in the organ of Corti (Hamernik et al, 1984). This mechanical damage may be the result of a single stimulation. Metabolic injury, however, is consistent with continued exposure to low or moderate level noise over an extended time period. Metabolic exhaustion occurs when a hair cell fails to convert nutrients and expel waste in accordance with the stress demands placed upon it. When nutrients such as glucose and oxygen are not adequately supplied, the cell is fatigued beyond its functional capability, resulting in permanent cochlear damage (Dunn, 1988).

A third etiologic proposal for noise-induced cochlear damage suggests a vascular origin (Hawkins, 1971). This concept assumes that noise may damage the vascular structures of the cochlea, reducing blood and oxygen supplied to the organ of Corti. In conjunction with the metabolic and mechanical damage processes, the auditory system is even more likely to sustain injury. Other vascular theories link cochlear blood flow to hearing loss (Perlman and Kimura, 1962; Lawrence, 1966; Cunningham and Goetzinger, 1974), but overall the findings remain contradictory and unclear.

Several authors have proposed a link between susceptibility to NITTS and cardiovascular physiologic responses. Dengerink et al (1984) examined the effects of smoking and environmental temperature on NITTS and determined that both smoking and cold temperature elicited peripheral vasoconstriction, thereby inhibiting NITTS essentially by increasing blood flow to more central body systems. Another study by Dengerink et al (1987) examined the effects of smoking and physical exercise on NITTS and suggested a causal relationship between vasoconstrictive response and NITTS. Results indicated that smokers experienced less NITTS than nonsmokers. Furthermore, they found that lower body temperature was predictive of less NITTS. Heart rate and blood pressure changes due to physical exercise were also found to be related to NITTS. Heart rate was positively related to NITTS while blood pressure was negatively related. These findings support the theory that factors influencing the cardiovascular system may have a direct or indirect effect on the auditory system (Sanden and Axelsson, 1981).

SUMMARY

The results of the present investigation suggest that physical exercise influences susceptibility to NITTS. Although exercise alone was not found to cause NITTS, when exercise was combined with simultaneous noise exposure, susceptibility to NITTS was significantly increased when compared to the other test conditions. Previous research suggests that physical changes in the body connected with increased physical output, namely those associated with chemical, circulatory, and temperature regulation may be responsible for this increased susceptibility to NITTS.

The results of this study suggest the need to evaluate further the combination of exercise and music, particularly as it relates to the impact on lifestyle issues such as aerobics or the utilization of personal stereos during exercise. The results of the present study suggest an increased risk of NITTS and therefore an increased risk of NIPTS within the general population. Further investigations, including an examination of the role of degree of fitness of individuals, is warranted.

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