THE EFFECT OF SOFTBALL BAT VIBRATIONS ON ANNOYANCE RATINGS

Larry Noble[1], Hugh Walker[1], Joseph M. Ponte[2]

[1]Kansas State University, Manhattan, KS, USA
[2]United Cerebal Palsy Clinic, Seattle, WA, USA

INTRODUCTION

In a recent laboratory study by Noble and Walker (1994b) using softball bats designed to produce significant changes in fundamental frequency (129-300 Hz) and node-center of percussion (COP) differences (.025-.095 m), a significant inverse relationship was found between impact annoyance and fundamental frequency. These findings are consistent with other laboratory studies finding significant relationships between annoyance and vibration frequency of hand-held devices (Reynolds and Keith, 1977; Reynolds, Standlee, and Angevine, 1977; Verillo, 1979). However, follow-up field tests using bats with smaller differences in fundamental frequencies (180-220 Hz) have not demonstrated a significant relationship between frequency and annoyance. Methodological differences in these studies, such as the degree of control for sound perception, human-machine interface conditions, and the degree of control of relevant related parameters (e.g., displacement and acceleration), may be the source of these inconsistent results. For example, the auditory perception of the sound associated with the vibration apparatus was controlled in only one of the aforementioned studies. Also, in the studies by Reynolds and Keith (1977) and Reynolds, Standlee, and Angevine (1977), subjects grasped a rod that was vibrating at varying frequencies while the vibration amplitude was held constant across frequency levels. Thus, energy, acceleration, and power increased with frequency. In the study by Verillo (1979) a small contactor (2.9 cm^2) vibrated at varying frequencies while in contact with the thenar eminence. This study was designed to further elucidate the relationship between vibration frequency and intensity on annoyance with hand-held implements, such as baseball and softball bats, tennis racquets, and other striking implements used in work and play.

The purpose of this study was to determine annoyance level associated with gripping a softball bat handle vibrating at varying frequencies and intensities. Because of previous findings of sex differences in vibration sensitivity (Goff, Rosner, Detre, and Kennard, 1965) the effect of subject gender was examined.

METHODS

Twenty-six (26) college males (n=13) and females (n=13) volunteered to participate in this study. Subjects ranged in age from 18 to 30 years (mean = 20.8, SD = 2.7). Informed consent was obtained prior to participation.

An apparatus similar to that described by Reynolds and Keith (1977) was used to excite an aluminum tube (1.905 cm diameter, 15.24 cm long) at each of the following frequencies while each subject grasped it with gradually increasing grip pressure: 100, 125, 160, 200, 250, 315, and 385 Hz. A 3/4 - inch plywood box was constructed to cover the shaker to reduce ambient noise. Also, each subject was given an orientation session prior to each test session and asked to wear ear plug and ear muffs with noise reduction ratings of 31 and 21 decibels to reduce the rather substantial ambient noise associated with the vibration instrumentation. Subjects placed their right hand on the vibrating rod with the first knuckle of the forefinger, wrist and elbow joints in alignment with the movement direction of the rod. The shaker provided two levels of excitation at 100 Hz (6 and 12 Amps) and three levels of excitation (6, 12, and 18 Amps) at each of the other frequencies. For each test, each subject grasped the vibrating rod with grip firmness gradually increasing from slight to maximum. After each condition, the subject rated the annoyance level on a visual analog scale 5 cm in length. A 2X3X6 (sex X intensity X frequency) factorial analysis of variance design was used to compare treatments and to determine the effect of sex, if any. The ω^2 statistic was used to estimate the proportion of the total variance accounted for by each of the independent variables and their interaction using procedures described by Thomas and Nelson (1990, p. 152).

RESULTS

The actual frequency, displacement, and acceleration for each experimental condition is provided in Table 1. For each frequency, both acceleration and displacement were directly proportional to intensity. Also, for each intensity level, displacement decreased as frequency increased. Greater accelerations were noted at the higher frequencies (315 and 385 Hz) than at the other, lower frequencies.

Table 1. Parameters Associated with Each Condition

Condition		Associated Parameters		
Frequency (Hz)	Intensity (Amp)	Actual Freq (Hz)	Displacement (mm)	Acceleration (g)
100	6	100	.310	12.393
100	12	100	.612	24.862
125	6	125	.201	12.662
125	12	125	.418	26.031
125	15	---	---	---
160	6	152	.194	18.177
160	12	154	.219	20.993
160	15	153	.337	33.132
200	6	195	.066	10.069
200	12	197	.138	21.447
200	15	197	.217	34.032
250	6	244	.037	8.862
250	12	247	.076	18.516
250	15	242	.133	31.362
315	6	303	.041	15.023
315	12	308	.079	30.162
315	15	302	.135	49.432
385	6	369	.025	13.708
385	12	370	.055	30.278
385	15	370	.086	47.440

The ANOVA summary of group comparisons of these data is given in Table 2. Clearly, there was no relationship between subject gender and annoyance. Annoyance was significantly related to both frequency and intensity , increasing with increased intensity, and decreasing as the frequency increased. The significant frequency X intensity interaction indicates that the magnitude of these differences was not consistent across intensity levels. This may be due to the smaller differences in annoyance across intensity levels at the higher frequencies compared to those lower frequencies. The proportion of total variance accounted for by each of these effects was: (1) frequency - 29%, (2) intensity - 25%, and (3) frequency X intensity interaction - 2%. Post hoc group-by-group comparisons (least significant difference method) showed annoyance levels for 250, 315, and 385 Hz were significantly below those of all lower frequencies. Also, annoyance levels were highest at 100 and 125 Hz. These frequency-by-frequency comparisons are illustrated below with lines connecting groups that are not significantly different at the .0001 level of confidence.

100 125 160 200 250 315 385

Table 2. ANOVA Summary			
Source	**Df**	**F-ratio**	**Pr > F**
Frequency	6	56.28	.0001
Intensity	2	144.23	.0001
Sex	1	.02	.8791
Freq*Int*Sex	11	.45	.9304
Freq*Int	11	3.16	.0004
Freq*Sex	6	.36	.9036
Int*Sex	2	.36	.6995

DISCUSSION

Results of this study show that annoyance from grasping a vibrating bat handle is directly related to both the frequency and intensity of the vibration with 29% and 25%, respectively, of the total annoyance variance accounted for by these variables. These results are consistent with those of a large number of studies exploring the relationship between vibration frequency and tissue impedance/resonance (Lundstrom, 1984) as well as those regarding relevant sensory properties of the hand (Lundstrom, 1986; Johansson, Landstrom, and Lundstrom, 1982). Results of this study can only be extended to the range of frequencies used. However, the range of frequencies used in this study (100-385 Hz) transcend the range of frequencies commonly found in baseball and softball bats. Vibration characteristics of bats during impact are largely sinusoidal following the initial, impulsive waveform with the primary difference being magnitude and duration of the events. Schafer, Dupuis, and Hartung (1984) recommended that the same standards that are used to evaluate the acute effects of non-impulsive vibrations on humans could be used for shock-type vibrations such as those associated with ball-bat impacts. Thus, the results of this study are probably applicable to the setting of hand-held bats impacting with balls. Vibration intensity associated with ball-bat impacts can be minimized by selecting a bat with small differences between the distal node of the fundamental vibration mode and then guiding the bat during the swing so that the area near the node and COP (Noble and Walker, 1994b). Furthermore, amplitude of the fundamental mode waveform at the portion of the bat interfacing with the hands during impact is minimal if the proximal node is located near the midpoint of the bat-hand interface.

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