Evaluation of Human Response under Vibration Condition

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Abstract **- The purpose of this study is to investigate the human response under different vibration frequencies. A total of nine frequencies (1.6, 2.0, 2.5, 3.15, 4.0, 5.0, 6.3, 8.0 and 10.0Hz) were chosen as stimuli for testing in the experiment. In this experiment, two tests were conducted: Comparative Test and Feet Supporting Test. Ten males and ten females were invited to participate in the experiment. The major findings revealed that (i) the uncomfortable feeling increases with an increase of vibration frequency, (ii) the feet support does have better influence to the feeling of comfort for females than males.**

Index Terms **– comparative test, human response, supporting test, vibration**

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I. INTRODUCTION

In Hong Kong, most people take the public transport to various destinations like schools and offices every day. Common vibrations we can experience come mainly from the uneven road, changing of speed, sound produced when a sudden stop of the bus and train, etc, and these vibrations can cause damages to us. Different vibrations can cause different levels of uncomfortable feeling on males and females. Some past studies have investigated how vibration affected working efficiency, safety and health [5]. However, few studies investigated the gender differences, if any, in the human response under different vibration frequencies. Therefore, we fill this research gap in this study.

II. LITERATURE REVIEW

Vibration interferes with people's working efficiency, safety and health [5]. It also causes discomfort, fatigue and physical pain [3]. Our health are affected if the strength of vibration is too large or the duration of vibration is too long [1]. Past research results showed that feeling of discomfort increases when the frequency increases [8]. 5Hz is the resonance frequency for whole-body vibration. It was also shown that the spine, inner organs and muscle are in resonance when vibration frequency reaches 8Hz [6], [7]. The feeling of discomfort increases even higher when more than one organ of our body are in resonance. The thigh's stiffness can only affect little on the feeling of discomfort during

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vibration [7] while the tensed posture can increase our stiffness and decrease the feeling of discomfort [4]. In addition, the posture of tensed upper body increases the stiffness of body so as to increase the resonance frequency [2]. Due to the resonance of spine and inner organs, the uncomfortable index increases rapidly [6]. Besides, the uncomfortable feeling is much worse than the relax pose or even cause damage to our back if the vibration strength reaches the resonance frequency [3].

III. RESEARCH METHOD

A. Participants

Twenty people (10 males and 10 females) were invited to participate in the experiment. They were of average age 21.95 years, 168.1cm tall and 59.1kg weight.

B. Design of experiment

To acquire the data, the following two tests were conducted:

(i) Comparative test

(ii) Feet supporting test

(i) Comparative Test

- Method of magnitude estimation

1. To take the stimulus of 5Hz as a reference
2. Try other stimuli
3. Give an uncomfortable index comparing with the reference stimulus

(ii)Feet Supporting Test

- Method of magnitude estimation

1. Try stimulus without feet support/upper body relax as a reference stimulus
2. Try the same stimulus with feet support/ upper body tensed
3. Give uncomfortable index comparing to the reference stimulus

C. Experiment procedure

For the comparative test, participants were tested under different vibration frequencies to analyse discomfort effect at different frequencies. If the test did not mention about the posture, then the posture was assumed as upper body relax without feet support. As many literatures pointed out that 5Hz was the first starting resonance frequency, a comparative test referencing at 5Hz was carried out. Firstly, the participants were asked to take a stimulus of 5Hz for 4 seconds and a random selected frequency for another 4 seconds. After the testing of the two stimuli, participants were asked to fill in an uncomfortable index survey as 100 was the mark for 5Hz. For example, if the participant felt that the selected frequency caused half uncomfortable feeling compared to that at 5Hz, then he/she should fill in 50. If they think the uncomfortable feeling is twice, they should fill in 200. Through the test, we could see whether there were any differences between the male and female's responses at the same vibration level.

For the feet supporting test, participants were exposed under all vibration frequencies with feet support for 30 seconds. After that, they were asked to fill in the uncomfortable index survey.

The test and frequency sequence was randomized and counterbalanced across trials but each pair of males and females was under the same sequence for the analysis of difference in males and females.

IV. RESULTS AND DISCUSSIONS

(a) Comparative test

Table I: Results of Comparative test

Frequency	Index-combination	Index-male	Index-female
1.6Hz	32.25	43	21.5
2.0Hz	39	48	30
2.5Hz	42.75	52	33.5
3.15Hz	62.5	70	55
4Hz	80	82.5	77.5
6.3Hz	117.25	119	115.5
8Hz	144.5	144	145
10Hz	184.5	183	186

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From the Table I, the correlation between uncomfortable index and frequency for male and female participants are 0.999 and 0.998, respectively. Feeling of discomfort basically increased when the frequency increased. This finding is consistent with the results of Subashi *et al.* [8]. Feelings of both males and females were similar after the resonance frequency 5Hz. The feeling of discomfort started to increase obviously at 5Hz. That may be due to the appearance of resonance since 5Hz which was mentioned by many researchers as the resonance frequency for whole-body vibration [6], [7]. As the resonance frequency will make participants feel more uncomfortable than other frequencies, the feeling may become similar for both males and females. There is a large difference for the response of male respondents than females for all frequencies except 10Hz. Besides, the difference between males and females in response became smaller after 5Hz, we can estimate that the vibration strength may be too large to make both male and female feel very uncomfortable, so that the response of males and females are similar after 5Hz. Therefore, it can be concluded that the resonance made the response in males and females become similar after 5Hz. At 8Hz and 10Hz, the uncomfortable feeling increased rapidly, the uncomfortable index for 10Hz was almost twice of 5Hz. That may be due to the resonance of our organs. The spine, inner organs and muscle was in resonance when the frequency reached 8Hz [6]. If more than one organ of our body were in resonance, the feeling of discomfort increased even higher.

(b) Feet Supporting Test

Table II: Results of feet support test

Frequency	Index-combination	Index-male	Index-female
1.6Hz	97.5	95	100
2.0Hz	96.5	98	95
2.5Hz	88.5	92	85
3.15Hz	89.25	90	88.5
4Hz	81.5	87	76
5Hz	80.75	84	77.5
6.3Hz	79	84	74
8Hz	72	82	62
10Hz	74.5	88	61

From the results (Table II), we noted that the feet support does have better influence to the feeling of comfort for females than males. The correlation coefficients for males and females are 0.708 and 0.994 respectively. The uncomfortable index keeps on decreasing when the frequency increases up to 5Hz for females. This indicates that the feet support can help to reduce the feeling of discomfort. We also noted that the uncomfortable index for females is lower at almost all frequencies in the condition of using feet support. That may be due to the difference in strength of buttock for male and female. Besides, the feet support can decrease the feeling of discomfort. As mentioned by some researchers [7], the thigh's stiffness will affect little on the feeling of discomfort during vibration. Instead, tensed posture can increase our stiffness and decrease the feeling of uncomfortable [4]. Therefore, the difference in response between male and female becomes more obvious after 5Hz. Also, the variation of uncomfortable index at the same frequency is quite similar for both male and female as shown from the table 2. The difference in response between males and females become most significant at 8Hz and 10Hz. The figure shows a significant difference between male and female at 8Hz and 10Hz. The uncomfortable index keeps on decreasing but rising at 10Hz for males, it may be due to the resonance in organs as mentioned from the comparative test [6]. But the feet support test is not suitable for all people as some participants claimed that the feet support will make them feel more uncomfortable at some frequencies.

V. CONCLUSION

A series of human factors experiments concerning the human response under different vibration conditions was conducted in this study. It was concluded that the uncomfortable feeling increased with the increase of vibration frequency. The difference in response for males and females is

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not significant after 5Hz. Also, the feet support was more useful for females than males. It seemed that feet support provided more help to females than males especially at 8Hz and 10Hz. It may be due to the difference in strength of buttock because the feet support increased the loading of the buttock.

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