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Translation of Vibration From a Vibrational Plate to the Human Body

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Abstract

This study was done to validate the results of our previous study [1] as well as analyze how the Soloflex Whole Body Vibration Platform translates vibration to the human body. The purpose of causing vibration within the human body is to increase bone density, possibly by activating osteoblasts within the bone. When the body is subjected to stress, it adapts as quickly as possible to counteract this stress. There is evidence that vibration caused by low magnitude mechanical signals (LMMS) increases bone in children with disabling conditions [2] and young women (15-20 years) with low bone mineral density [3]. Our results show that Soloflex dial settings of 0.8g or greater produce frequencies as expected by the manufacturer. Lower dial settings produce frequencies that are higher than expected values. The results obtained showed that vibration at the foot had no linear association with increased acceleration ($R = 0.56$, $p = 0.20$), but vibration frequencies increased with increased acceleration at the hip ($R = 0.86$. $p = 0.01$). The mean frequencies measured over the range of accelerations (0.3-1.1g) were not different between the foot and the hip (56 ± 5 vs. 52 ± 12 Hz, $p = 0.45$; mean ± SD; respectively). Mean frequencies measured at the four different locations on the plate over the range of accelerations (0.3 – 1.1g) were not different when tested by Tukey's HSD test.

INTRODUCTION

The goal of this project is to help provide evidence of the performance of a LMMS vibrational plate for future studies that may increase the bone density of children. The premise of the future project is that the human body rapidly adapts to conditions that it is subjected to. One such example would be that a person who lives at altitude is expected to have a higher red blood cell count due to the increased need to deliver oxygen to the tissues in the body. This project investigates the effects of subjecting a test subject to a continuously alternating load, such as vibration. The future purpose of this work is to look at increasing the bone density in youth by creating a regimen that involves them standing on the plate for a specified amount of time each day. Before this test can begin, background information must be understood. Zachary Croatt and Josh Roberts started this investigation in a previous study [1]. This next portion of the study was done as a continuation of the first project by reexamining the observed vibrational frequency at the same four points on the plate and continuing on to analyze how vibrations from the plate translate to the human body. It is important to test this using the Soloflex Whole Body Vibration Platform because is a commercial grade plate. Knowing how the vibration of the plate translates up the leg can be applied to additional research looking at the effects of how to increase bone density with this device, which is more affordable than a research grade plate, or possibly even redesigning this device to provide better performance.

PROCEDURE

The equipment used included a vibrational platform, accelerometer, signal conditioner, and oscilloscope. The equipment was used to determine the observed frequency at several different points on the unloaded platform and two points on the human body.

Equipment Used

The most important equipment that is used in this experiment is the vibrational platform itself. Since this is the device being analyzed, it is important to understand the background information on the platform. It is manufactured by Soloflex (Hillsboro, OR) to be used as a supplement to workouts by challenging the muscles while they are being used as well as to strengthen bones. It stimulates the muscles by causing them to rapidly lengthen and contract thus strengthening them. This continued load on the bone causes them to work to increase their strength possibly by activating osteoblast. The equipment that will be used for analysis is an accelerometer to record the acceleration that is observed on the board, a signal conditioner that will be used to clean and amplify the output and an oscilloscope to visualize the output created by the accelerometer. A complete list of information about the equipment used can be seen in Table 1 with a picture of the materials seen in Figures 1 and 2.

Table 1: Equipment Used for Project

Equipment Type	Brand	Model #	Serial #
Soloflex Whole Body Vibrational Platform	Soloflex	n/a	n/a
Signal Conditioner	Endevco	133	CB71
Four Channel Digital Storage Oscilloscope	Tektronics	TDS 2024B	C03312

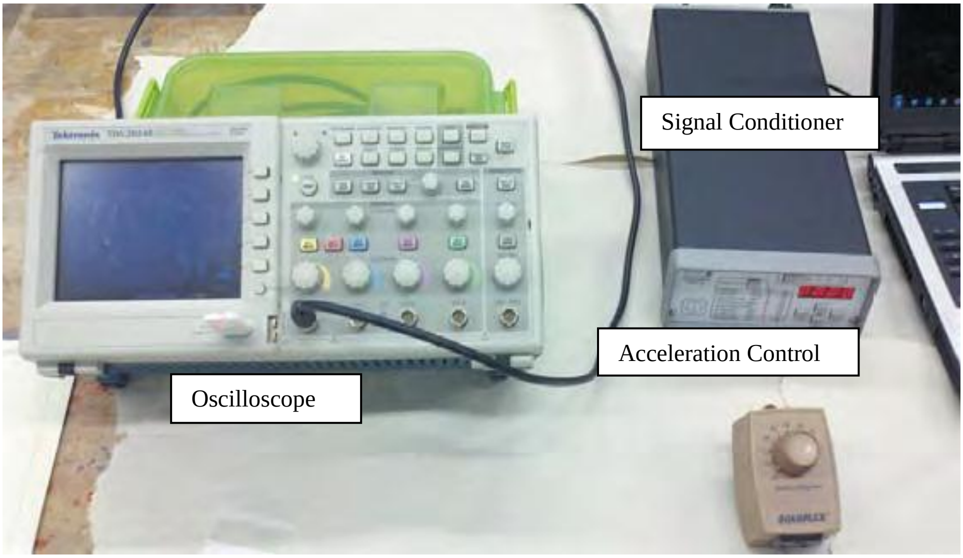


Figure 1: Oscilloscope, Signal Conditioner, and Control Used in Experiment

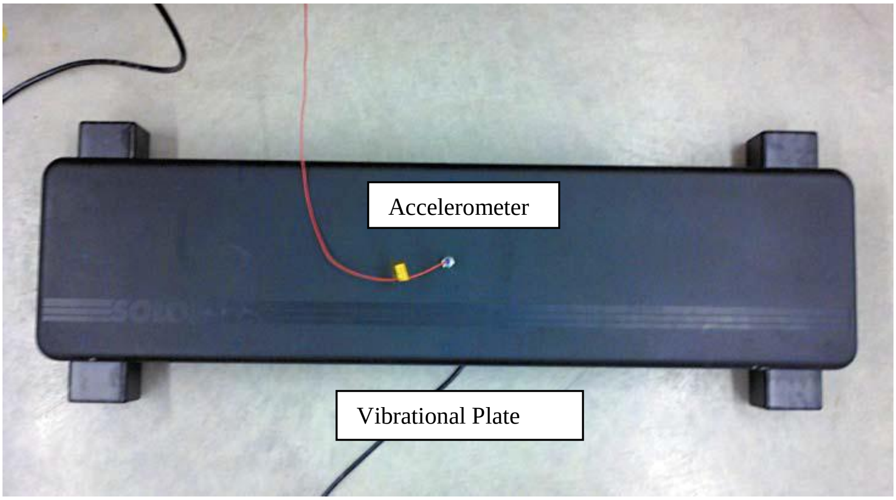


Figure 2: Whole Body Vibrational Plate and Accelerometer

Methods

To complete the analysis required by this project, a simple protocol was established. The acceleration would be observed at 4 points on the plate, which was attached to a large mass, but not loaded to reexamine how the plate performs compared to its expected parameters. Next, vibration would be analyzed at two points on the human body: the foot on the shoelaces and the hip on the belt. For this analysis the test subject was a 78 kg male with a hip height of 104 cm. The four points chosen for the analysis were D (left far), E (left middle), G (center far), and H (center middle). They were chosen because it was assumed that across each axis of symmetry of the plate the frequency would be the same. Thus, D, F, J, and L all have the same vibrational frequency. This would also be true for E and K as well as G and I. The points along the edge were excluded from analysis, as it was not expected that patients would use this area of the board very much.

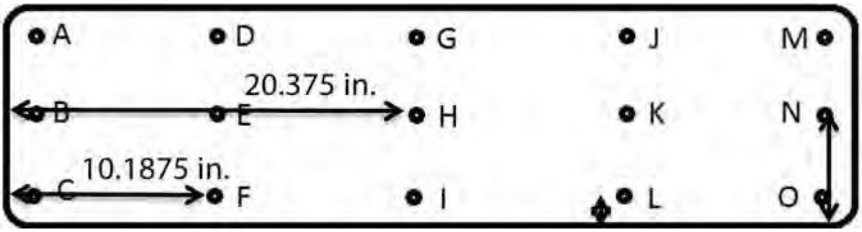


Figure 3: Location of Analysis Points

Statistical analyses were completed using JMP 10 software (SAS Institute Inc.). Mean frequencies measured from the plate for each dial reading (0.3, 0.5, 0.7, 0.8, 0.9, 1.0, and 1.1 g) were tested for difference from manufacturer's expected frequency values and for difference from each other. Tukey's HSD (honestly significant difference) test was used in conjunction with ANOVA to test the difference in the means of each dial reading level and each location. Regression analyses were used to test for associations between dial settings and measurements from the test subject for the foot and hip locations.

Results

Sample output from the accelerometer can be seen in Figure 4.

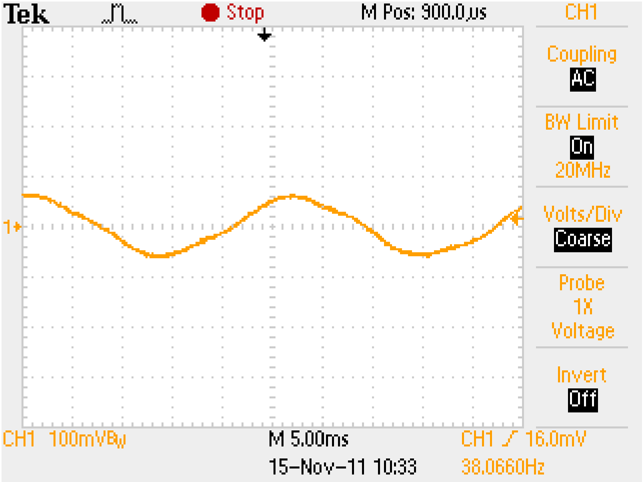


Figure 4: Sample Oscilloscope Output

Analysis from the accelerometer data was slightly more difficult given the fact that a large amount of noise is induced due to the nature of the setup. Using the available functions on the oscilloscope, it was possible to limit the noise and obtain output that allowed the frequency to be calculated. Table 2 shows the observed frequency readings measured in Hertz (Hz) for each dial level setting level in units of Earth's acceleration or g's. Figure 5 shows these data graphically. Our results show that Soloflex dial settings of 0.8g or greater produce frequencies as expected by the manufacturer (Table 3). Lower dial settings produce frequencies that are higher than expected values. The dial reading of 0.3 g was lower than that of 1.0 and 1.1 g, but not different from other dial readings (Table 3).

The results obtained showed that vibration at the foot had no linear association with increased acceleration (R = 0.56, p = 0.20), but vibration frequencies increased with increased acceleration at the hip (R = 0.86. p = 0.01; data not shown). The mean frequencies measured over the range of accelerations (0.3-1.1g) were not different between the foot and the hip (56 ± 5 vs. 52 ± 12 Hz, p = 0.45; mean ± SD; respectively). Mean frequencies measured at the four different locations on the plate over the range of accelerations (0.3 – 1.1g) were not different when tested by Tukey's HSD test. There were no differences in the means of the readings from the different locations. It should be noted that the standard deviations at 1.0 and 1.1g (Table 3) are almost two-fold those at the lower dial settings. This could be due to the inconsistent output of the vibrational plate, which doesn't a very good job of controlling its output frequency. An improved design could help to eliminate this problem

Table 2: Observed Data

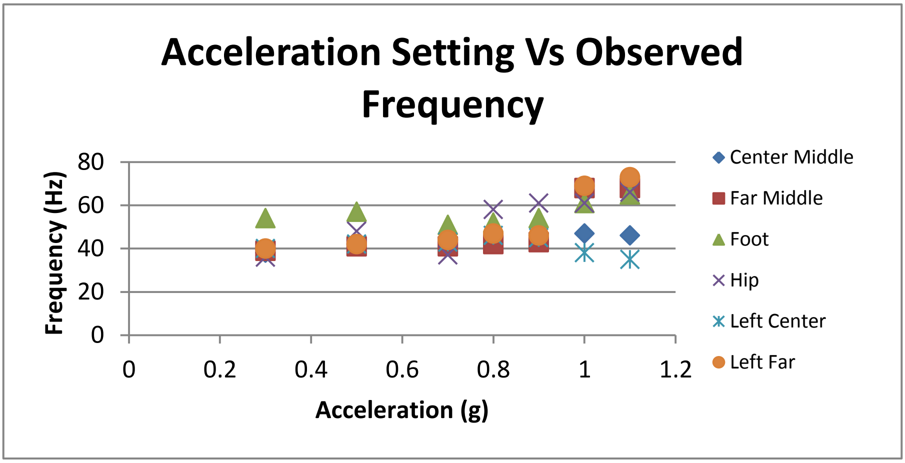
. Dial Setting	0.3 g	0.5 g	0.7 g	0.8 g	0.9 g	1 g	1.1 g
Center Middle (Hz)	38	42	43	45	46	47	46
Far Middle (Hz)	39	41	41	42	43	68	68
Left Center (Hz)	40	42	43	46	45	38	35
Left Far (Hz)	40	42	44	47	46	69	73
Foot (Hz)	54	57	51	52	54	61	65
Hip (Hz)	36	48	37	58	61	61	66

Table 3: Expected values, means (SD), and mean comparisons.

Expected value is per manufacturer. Mean is from observed values. P-value is from test of mean different from expected. Tukey HSD mean comparison levels not connected by same letter are significantly different.

Dial Reading (g)	Expected Value (Hz)	Mean (SD) (Hz)	p-value	Tukey Mean Comparison
0.3	28	41 (6)	<0.01	A
0.5	30	45 (6)	<0.01	A B
0.7	35	43 (5)	<0.01	A B
0.8	45	48 (6)	NS	A B
0.9	50	49 (7)	NS	A B
1.0	55	57 (12)	NS	B
1.1	60	59 (15)	NS	B

Figure 5: Graphical Results



Conclusion

This study provided very interesting results including results that were consistent with our previous work. A wide range of frequencies were observed at different points on the plate, but there were no statistical differences found. We would suggest using dial settings of 0.8 g or greater in future research with the Soloflex, since these settings produce the expected values. The feet on the whole body vibrational plate stayed at a relatively constant vibrational frequency regardless of what the plate was set as we found no association between the dial setting and the frequency readings at the foot. On the contrary, the frequency measured at the hip increased with increasing dial settings. The next step of this project will be to create a better dial with better control over the frequencies that are imparted into the human subject.

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