ACCELEROMETER APPLICATION TO MEASURE LOWER LIMBS BEHAVIOUR DURING PERTUBATION TRAINING

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Abstract. *The use of balance platforms is a common procedure in rehabilitation and ligament lesion prevention, for balance training and muscular control. In this way, it is necessary to define frequency parameters in order to determinate a situation of balance or imbalance. In the present paper, a two axes accelerometer was fixed on an inclination platform and its capacity to quantify the surface frequency oscillation and range of motion was evaluated. Under known applied oscillations, the sensor behaviour was studied. After sensor verification and system calibration, new tests must be done to determine the stability patterns for lower limbs joint stability in humans.*

Keywords*: Accelerometer, Perturbation training, Lower limbs injuries, Joint stability, Balance platform*

1. INTRODUCTION

The postural control or balance can be defined as the process that makes the central nervous system (CNS) to produce muscular activity necessary to coordinate the relation between the center of mass (CM) and the support basis (SB). This activity is a complex process that involves the evaluation and integration of mechanisms not only of the sensorial system but also of the motor system, such as, muscular force, muscle activation patterns and articulation flexibility (Matsudo *et al.,* 2000).

In healthy people, the ligaments and the neuromuscular actuation guarantee the articulation's stability like knee and ankle (Beard *et al.,* 1994; Sojka *et al.*, 1989; Rudolph *et al.,* 1998 and Eastlack *et al.,* 2001). In situations that involve the perturbation of the support surface, such as the balance platforms, used in rehabilitation and ligament lesion prevention, it is necessary that neuromuscular and ligament adaptations, associated to sensorial components, actuate in a proper way in order to guarantee balance.

The present study has the objective to analyse the balance oscillations of three healthy volunteers when submitted to perturbation training on an inclination platform. Also, frequency values that could represent balance and imbalance oscillations were defined.

2. METHODOLOGY

2.1. Platform

Nowadays, it is common in the rehabilitation procedures, the use of platforms, such as the ones shown in "Fig. 1", aiming to train balance, muscular control and proprioception. The platform types are: inclination, oscillation and translation. To perform the experiments of this paper, it was used an inclination platform, "Fig. 1a", because this is the most used model in perturbation trainings and also it was possible to easily adapt on it an accelerometer, in order to collect data.

(a) Inclination Platform (b) Oscillation Platform (c) Translation Platform

Figure 1. Main platform types used in clinical environment

2.2. Measurement system

The measurement system developed by Amaral (2007) at Bioengineering Laboratory of Universidade Federal de Minas Gerais was connected to the bottom base of an inclination platform in order to measure frequencies, "Fig 2". The system is composed by a two axis accelerometer model ADXL311 (±2*g*), fabricated by Analog Devices© and a data acquisition system. The acquisition device used a low-pass filter of 50 Hz and an analog to digital converter of 10 bits with a sample frequency of 200 Hz. After signal conversion, a IIR second order digital filter with cut off frequency of 8.8 Hz was implemented. Finally, the final signal was transmitted to a microcomputer via serial interface (RS232) with sample frequency of 20 Hz. All data analysis was done in the frequency domain, consequently no data with acceleration unit is shown and so only the data with voltage units are used to process and analyze the measurement results.

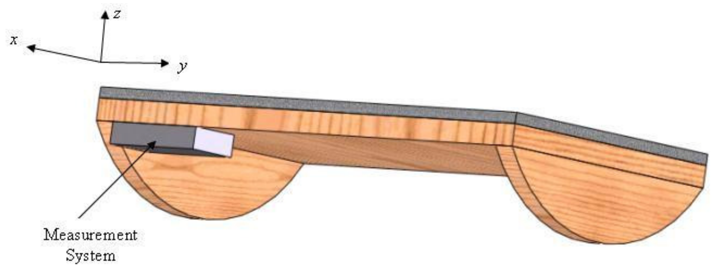

Figure 2. Combination of the inclination platform and the measurement system

2.3. Clinical procedure

The experiments were performed with three healthy women with ages from 22 to 25 years old. Four tests with one minute duration were made. The first one was performed with both feet on the platform, the second one with only the right foot on the platform, the third with only the left foot on the platform and the last testing was made also with both feet on the platform, although with concentration disturbance input. Whistling, clapping hands, whiff and arm movement were used to disturb the attention of the volunteers during the last testing.

3. RESULTS

It was observed that all tests with both feet on the platform, without concentration disturbance, presented the same behavior for all three volunteers. So, only the curves obtained by one volunteer will be shown. Firstly, "Fig. 3" represents the voltage *versus* time curve obtained by the measurement system during the first testing.

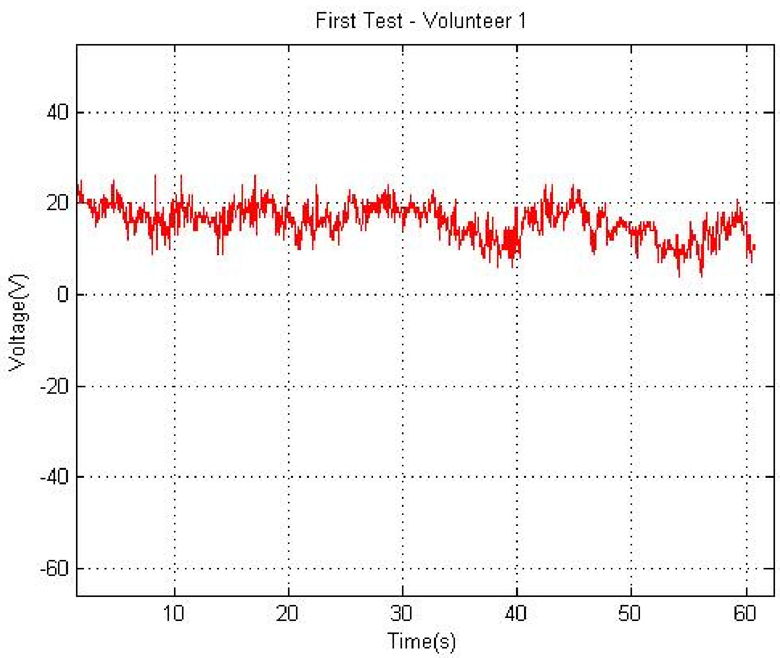

Figure 3. First applied testing, with both feet on the platform and no concentration disturbance

The signal presented three oscillations of great amplitude, which each oscillation presented a period of 20 s, thus could be observed a low frequency around 0.05 Hz. This low frequency is composed by a signal of low amplitude and could be related directly with a balance state.

"Figure 4" shows the signal generated by the second testing. Visually, the signal presented more oscillations with amplitudes slightly higher than the ones found in the first testing. This could be attributed to the fact that the volunteer used only one foot to control her balance, generating a greater imbalance situation in comparison to the first case.

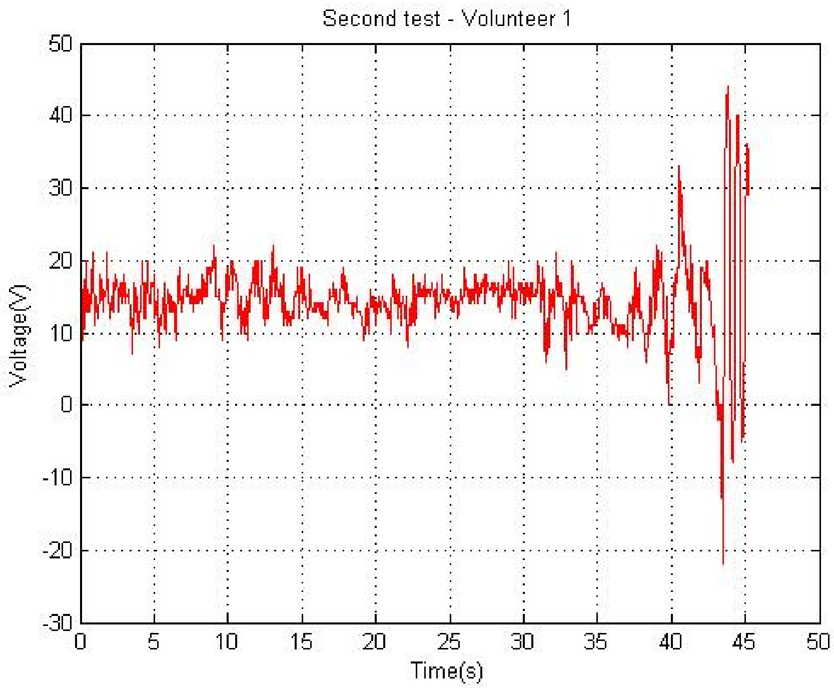

Figure 4. Second applied testing, with only the right foot on the platform and no concentration disturbance

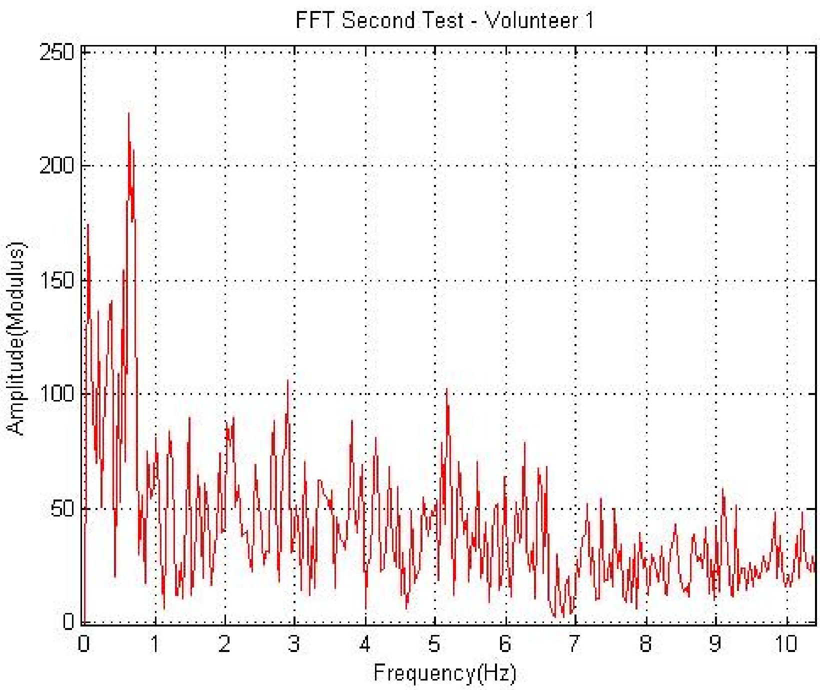

Figure 5. FFT transform of the second testing data

"Figure 5" illustrates the Fast Fourier Transform (FFT) of the signal presented in the "Fig. 4". It could be observed that the most actuating frequency was of 0.63 Hz. Considering the results found to the first three tests, but not shown in this article, and thinking that none of the three volunteers had balance problems, it could be observed that the frequency range of all tests varies from 0.09 Hz to 1.00 Hz. This interval was directly related with balance, because it was originated by pressure displacement sometimes under the foot plant and sometimes under the ankles. "Figure 6" shows clearly this pressure displacement from ankle to foot plant for the first applied testing, found by another volunteer (different from the one showed in "Fig.1").

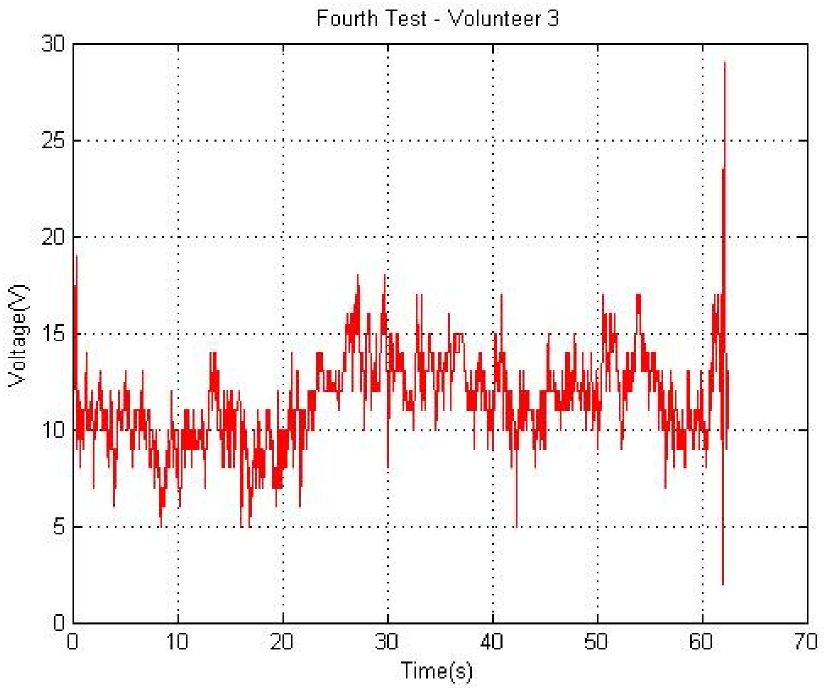

Figure 6. First applied testing, with both feet on the platform and without concentration disturbance

Taking into consideration the accelerometer position at the platform, the volunteer position during the exercise and the results presented in "Fig. 6", it could be seen that when the volunteer had her weight concentrated on ankle, the measured signal oscillated around 10 V. On the other hand, when the volunteer concentrated her weight on foot tip, the measured signal was approximately of 13 V. This weight displacement was responsible not only to generate balance but also the values of low frequencies reported previously.

"Figure 7" shows one of the results found by one volunteer during the fourth testing. When compared to the first three tests, it was clear to observe the difference on the oscillation amplitudes of higher frequency. It could be also noted that the component of low frequency, found earlier for the other tests, was presented.

"Figure 8" shows the Fourier Transform of the signal of "Fig. 7". The results confirmed the presence of two frequencies with the highest amplitudes: 0.08 Hz (next to the low frequency found for the other tests) and 3.8 Hz. Two other frequency values with amplitude smaller than the cited before, however also relevant can also be considered: 0.8 Hz and 3.5 Hz.

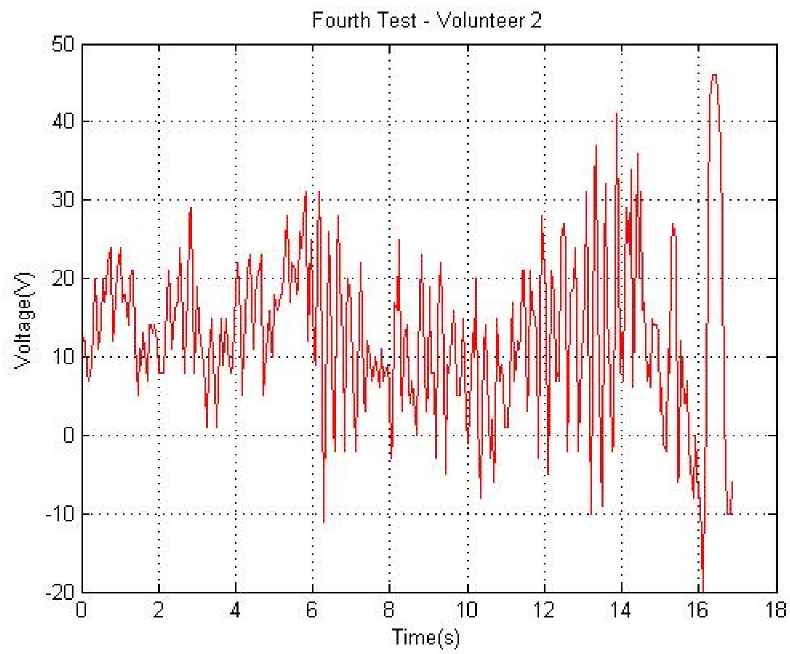

Figure 7. Fourth applied testing with both feet on the oscillation platform and with concentration losing

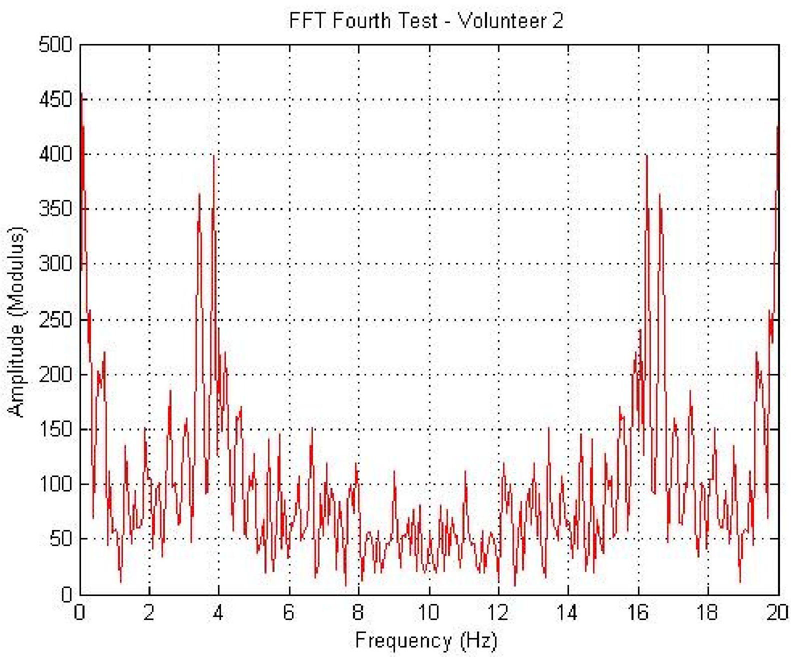

Figure 8. FFT of the fourth applied testing with both feet on the oscillation platform and concentration disturbance

After analysing the results of the testing with concentration disturbance, it could be reminded that beyond the low frequency component found on the first three tests, it was achieved a new frequency range from 3.3 Hz to 4.8 Hz, which could be attributed to the imbalance generated by concentration losing. “Figure 9” shows a histogram of the values of frequency obtained during the tests, where it can be clearly noted the presence of two remarkable levels of frequency.

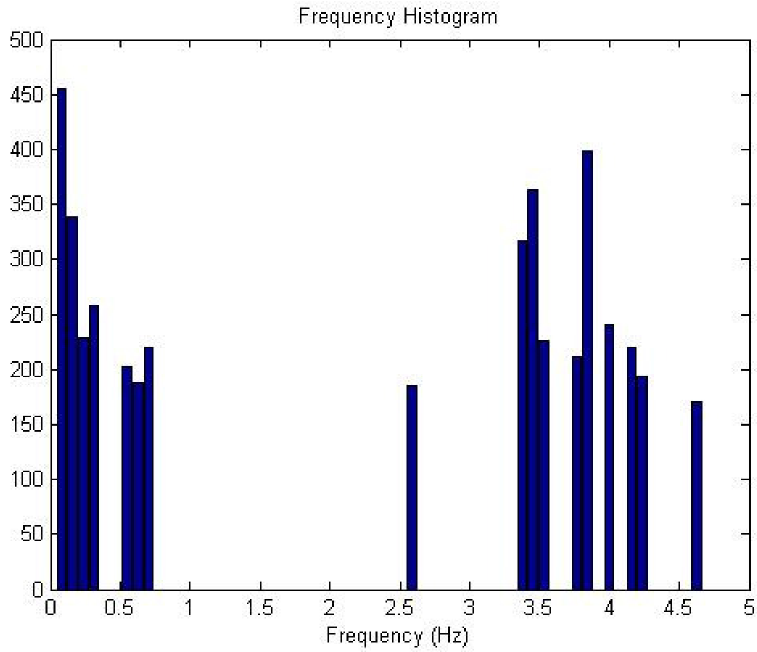

Figure 9. Histogram of obtained frequency values of all tests

3. CONCLUSIONS

The aims of this work were to test the measurement system functionality and to define values of frequency that could represent the balance and imbalance situations during perturbation tests. It could be observed that the system seamed to be adequate to evaluate lesion trainings in lower members, however, in some tests results, it was detected frequency values around 8.8 Hz, what brought doubts if the frequency range used was really able to capture all signal important to an adequate analysis. As future work, it could be performed an analysis with a bigger bandwidth range and with more volunteers and so better understand and compare the results and also reproduce confiability of them.

Nevertheless, it could be found frequencies able to represent different stages of balance. A probable low frequency range that could indicate balance could be from 0.07 Hz to 1.00 Hz. Conversely, an imbalance state could be shown by a frequency range from 3.00 Hz to 5.00 Hz. A detailed analysis to define the frequency ranges that exist during trainings must be done, and in this way, new experiments with different groups, one with a predefined lesion and other, without lesion, and also with a greater number of volunteers must be performed.

4. ACKNOWLEDGEMENTS

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