Biomechanics Instrumentation Design Laboratory II

Force Plate and Postural Stability

Abstract

The reaction force which is the ground reaction force, is basically the reaction to the force the body exerts on the ground. The ground reaction force along with weight is an important external force. The force is normally measured by a force plate. The objective of the lab is to examine postural stability, center of pressure with various situations, effects of vestibular and visual feedback on postural stability with force plate. Calibration of force plate is one technique that biomedical engineer should know to get reasonable data. This lab includes gait analysis and postural stability with quiet standing double limb support, quiet standing single limb support, no visual feedback, altered vestibular feedback, and no visual with altered vestibular feedback. With LabView and Matlab software, data were analyzed. Expected results for gait analysis with shoes and bare foot experiment were different from actual results from the experiments. Actual data shows the medial/lateral force is bigger with shoes. This might be caused because the subject was nervous or was very careful of walking on the force plate with shoes. Percent difference between calculated values and measured values are greater than 95% difference. This shows that force plate can have a lot of potential to cause huge errors. At position A, B and C, all errors between actual and calculated values are exceeded 2% which is the significant error % in statistics. Overall, x direction has less percent error than y direction.

Introduction

In biomedical engineering field, force plate is a very useful tool to analyze kinetics of human beings such as the gait analysis. Thus, biomedical engineers should be familiar with calibrating force plates, measuring the force plate reaction kinetics, verifying sensitivities, and understanding feedback. The purpose of lab is to gain experience of these requirements as a biomedical engineer to analyze patients under various circumstances. The objective of this lab is to examine postural stability, center of pressure with various situations, effects of vestibular and visual feedback on postural stability. In this lab, main focus is shoed and barefoot gait and it is important to understand fundamental principle of force plate to analyze reaction kinetics during shoed and barefoot gait. The force plate incorporates 4 tri-axial load cells at each corner. These load cells use strain gages (Wheatstone bridges circuits) for force measurements. This resistance in these gages is defined by the relationship between resistivity, change in length and cross sectional area. For most purposes, the force and moment components relative to a set of XYZ axes located at the top surface of the platform are interests. With using calibration matrix, sensitivity matrix, force matrix and voltage matrix to find interested unknown variables can be calculated.

The calibration matrix is very important to increase accuracy. The diagonal terms of the calibration matrix are the real calibration coefficients while the off-diagonal terms are the cross-talk terms. In an ideal situation in which there is no cross-talk among the channels, all the off-diagonal terms become 0. Some cross-talk always exists in the strain gauge-type plates. A calibration matrix enables applications to correct for cross talk between outputs of the force platform. Also this matrix application uses the full calibration matrix to correct for cross talk to provide accurate results when compared to applications that only have major diagonal components (Winters). Therefore, it is calibration matrix is referred to as the crosstalk matrix. The ability to maintain balance depends on information that the brain receives from three different sources such as eyes, the muscles and joints, and the vestibular organs in the inner ears. All three of these sources send information in the form of nerve impulses from sensory receptors, special nerve endings, to your brain.

Expected results of postural stability are with shoes, medial/lateral force is greater than barefoot one. With two legs with open eyes, it is the most stable position. Without visibility, subjects tended to lean posterior in other words, flex anterior or tended to move side to side.

Equations

R(resistance)=ρ (resistivity) ΔL(change in length)/A (area)

Moment in x direction $M_x = F_x*0 - F_y* Z_{COP} + F_z* Y_{COP} + T_x$

Moment in y direction $M_y = F_x* Z_{COP} + F_y*0 - F_z* X_{COP} + T_y$

Moment in z direction $M_z = -F_x* Y_{COP} + F_y* X_{COP} + F_z*0 + T_z$

x= -My/Fz and y=Mx/Fz (computed location)

Voltage = sensitivity * force [matrix]$\{V\}_{1X6} = [S]_{6X6}\{F\}_{1X6}$

Force = inverse sensiticity * voltage [matrix]$\{F\} = [S]^{-1}\{V\}$

Method

There are three parts in this experiment. First part is to calibrate force plate before collecting any data. Balanced the Wheatstone bridge with adjusting calibration screws and calibrated force plate with LabView program and 20 lbs weights. Repeated loading weights from none to 80 lbs to as close as the corner. Then used 2 lbs weight up to 10 lbs to place at the corner (-7 inches in x-axis and -8 inches in y-axis from the center of the force plate), between center and the corner (-4.5 inches in x-axis and -5.5 inches in y-axis from the center of the force plate), and the center.

Second parts, with 360 Hz scan rate and 3 seconds of acquisition, performed kinetic gait analysis. Collected data with shoed and barefoot gaits.

Third parts involved with quiet standing, no visual feedback, altered vestibular feedback, and no visual with altered vestibular feedback. These experiments were for testing postural stability. This part used postural stability LabView program instead of force plate one. For quiet standing, single and double limb support were compared. The scan rate of 360 Hz and 3 seconds of acquisition time was selected. Chosen subject stood with both heels together feet at approximately 30 degrees angle a part with eyes open. Later, same subject stood on one leg on the force plate with eyes open.

For no visual feedback experiment, settings were same, the subject stood ln the force plate with both heels together and feet at 30 degrees apart with eyes closed.

For altered vestibular feedback, the subject was span until felt dizzy and stood on the force plate with eyes open under the same settings as before.

For no visual with altered vestibular feedback, the subject was span again until felt dizzy and stood on the force plate with eyes closed.

Each output was copied and pasted as screenshots.

For analysis part, Matlab program is used to calculate expected voltage output matrix, expected force output, and computed positions by dividing the moments by the vertical forces.

Results

Table 1. Force plate calibration of forces with calibration matrix. (lbs)

	0lbs	20 lbs	40 lbs	60 lbs	80 lbs
Fx	0.5057	0.2156	0.1928	0.0963	0.0967
Fy	-0.2762	-0.3205	-0.3871	-0.2713	-0.1324
Fz	0.3180	0.2739	0.2538	0.2764	0.2168
Mx	-0.4015	-0.5235	-0.5268	-0.4932	-0.5350
My	0.7627	0.6974	0.6163	0.6837	0.5282
Mz	-0.5050	18.8312	37.9309	57.1455	76.1978

Table 2. Force plate output of voltages using input forces and sensitivity matrix (V)

	0lbs	20 lbs	40 lbs	60 lbs	80 lbs
Fx	0.4291	0.1840	0.1644	0.0836	0.0835
Fy	-0.2353	-0.2721	-0.3284	-0.2301	-0.1123
Fz	0.5546	0.4993	0.4837	0.5418	0.4573
Mx	-0.5859	-0.7840	-0.8081	-0.7785	-0.8592
My	1.0858	1.1514	1.1875	1.4394	1.3701
Mz	0.1911	7.0028	14.1084	21.2556	28.3440

Table 3. Comparisons between load positions with the positions computed by dividing the moments by the vertical forces.

	Real Location X	**Real Location Y**	**Theoretical X**	**Theoretical Y**	**Percent error X**	**Percent error Y**
Pos A	-7 inches	-8 inches	-6.53 inches	-7.35 inches	5%	8%
Pos B	-4.5 inches	-5.5 inches	-4.42inches	-4.46 inches	2%	19%
Pos C	0 inches	0 inches	-0.68 inches	-0.53 inches	100%	100%

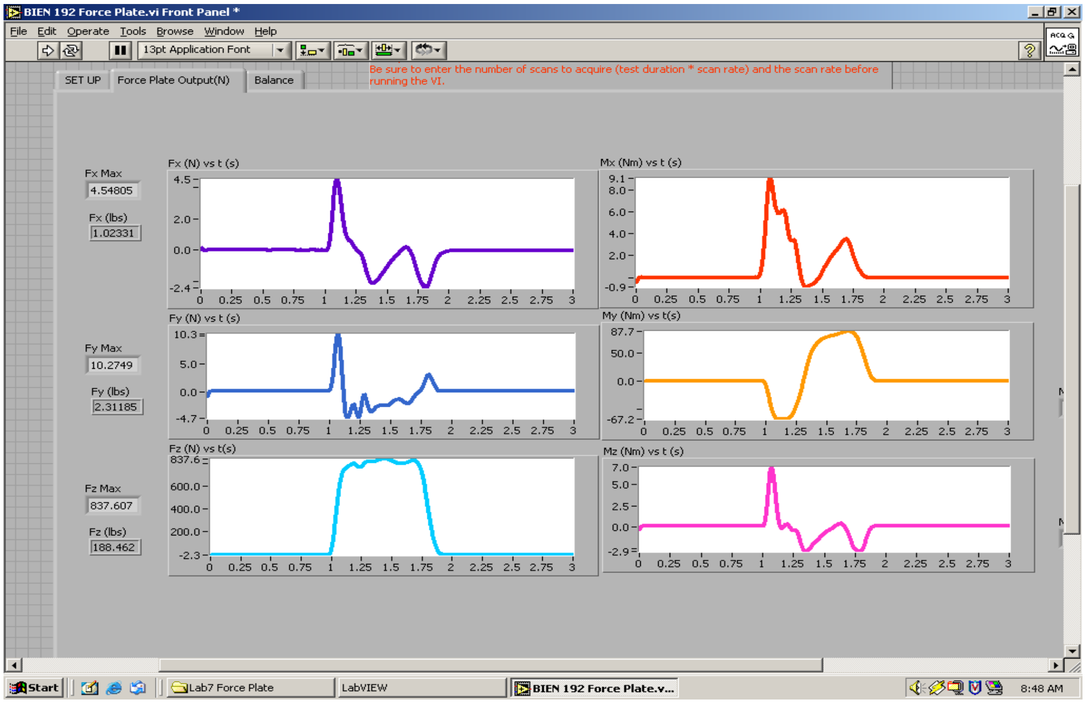

Diagram 1. Walk with shoes

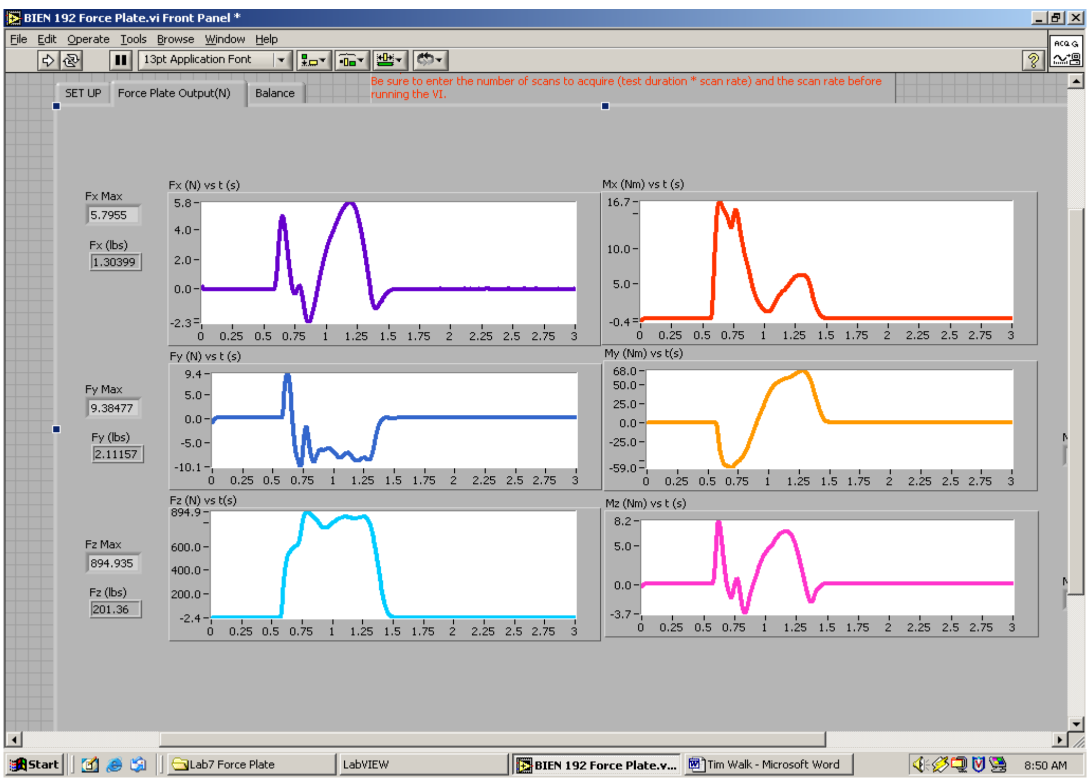

Diagram 2. Walk with barefoot

Stance time is approximately 0.8 seconds.

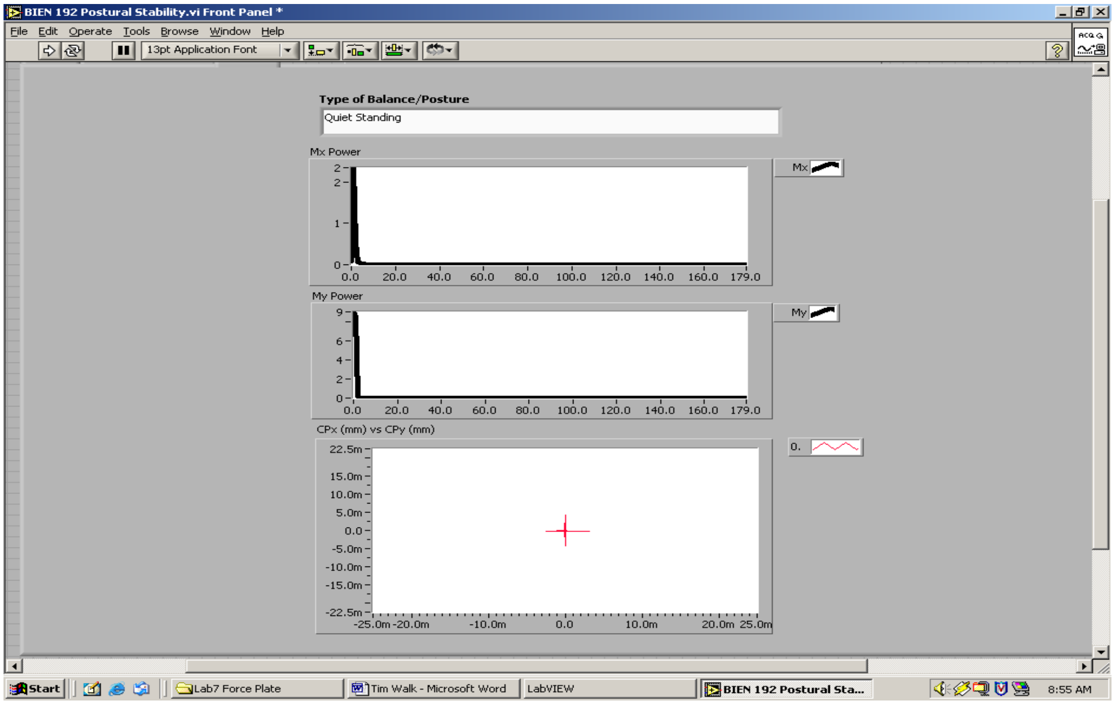

Diagram 3. Quiet Standing double limb support

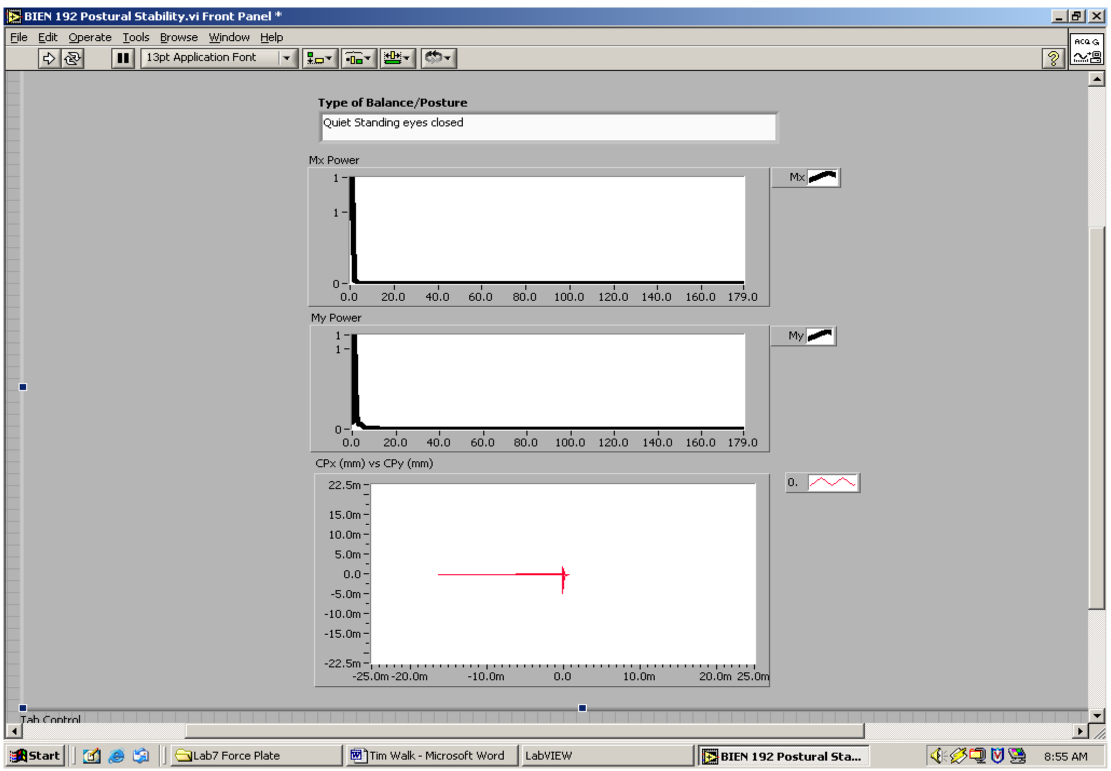

Diagram 4. Quiet standing with eyes closed

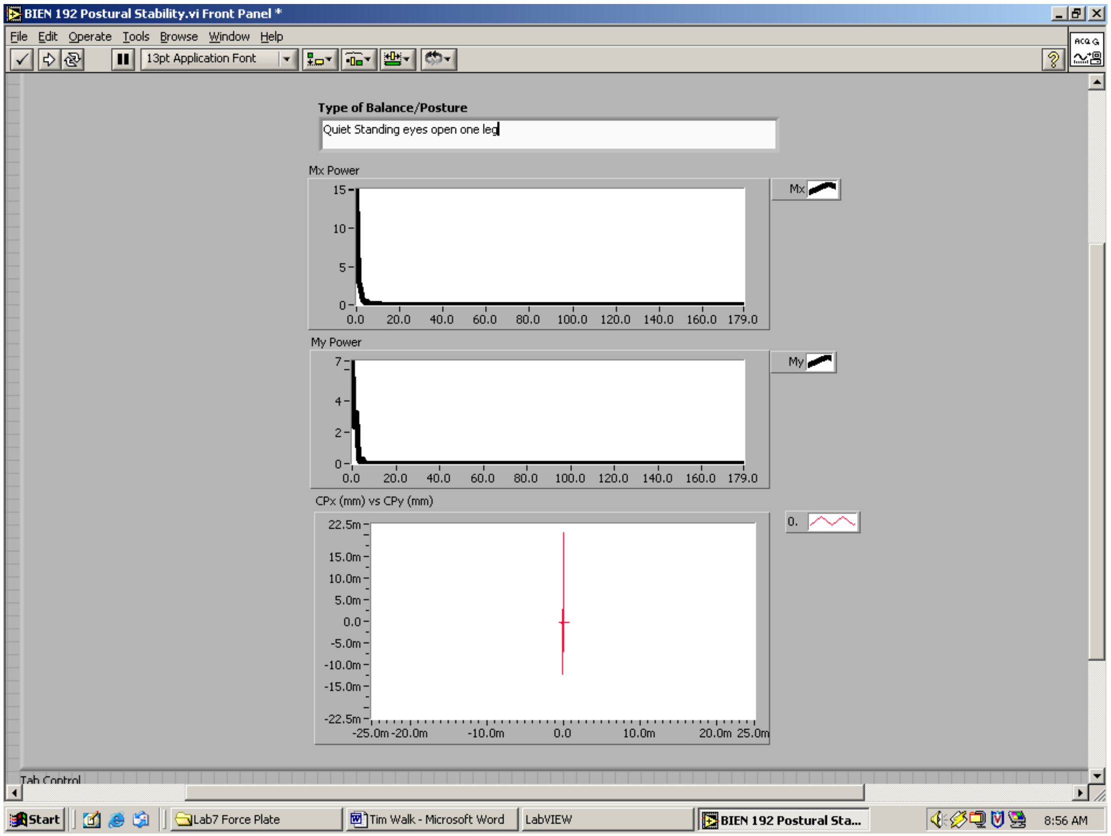

Diagram 5 Quiet standing eyes open one leg

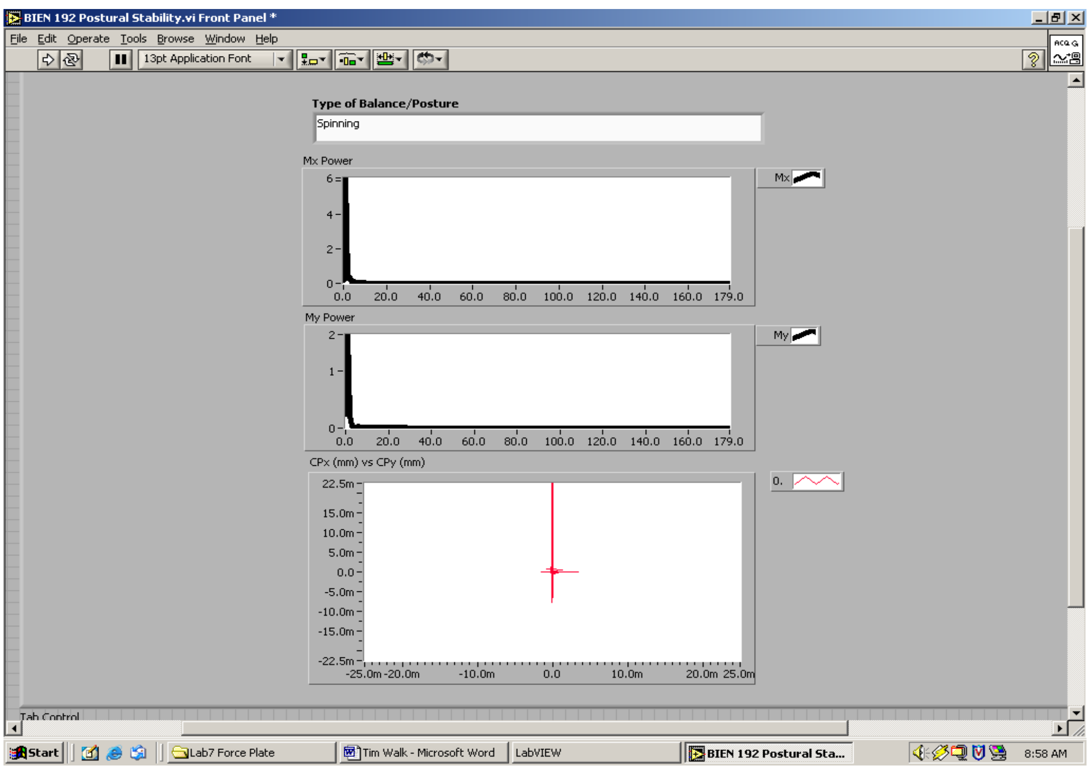

Diagram 6. Altered vestibular feedback

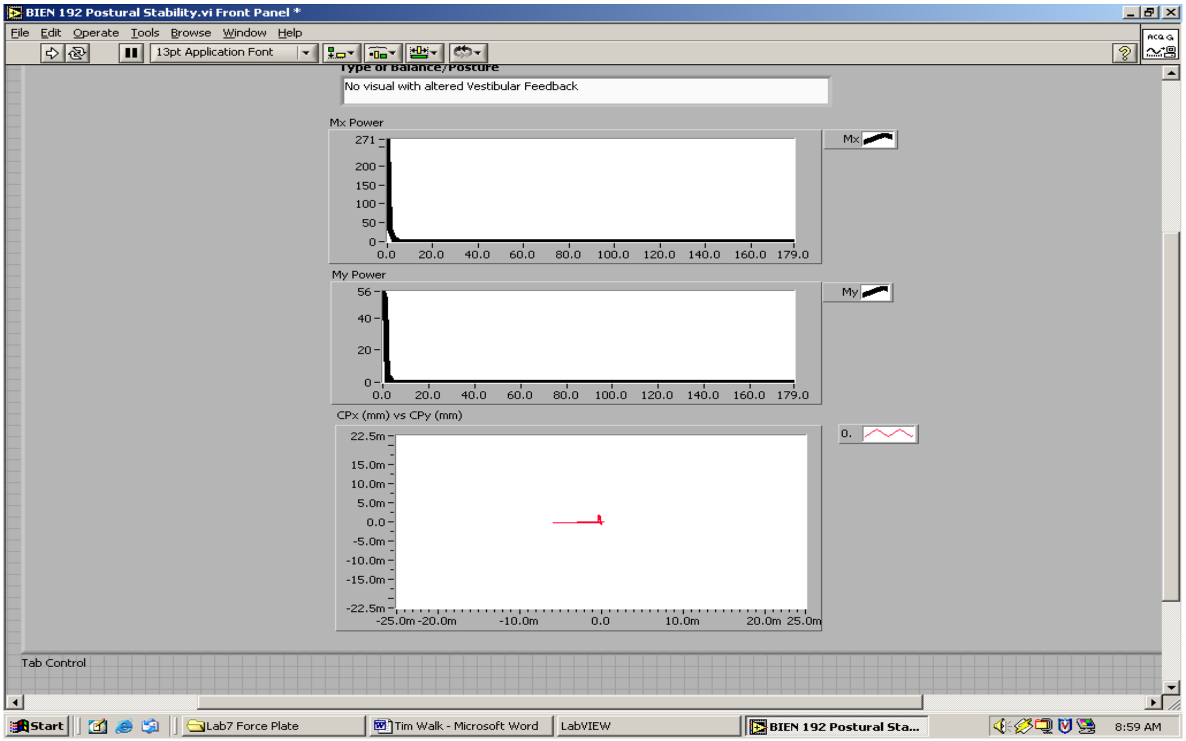

Diagram 7. No visual with altered vestibular feedback

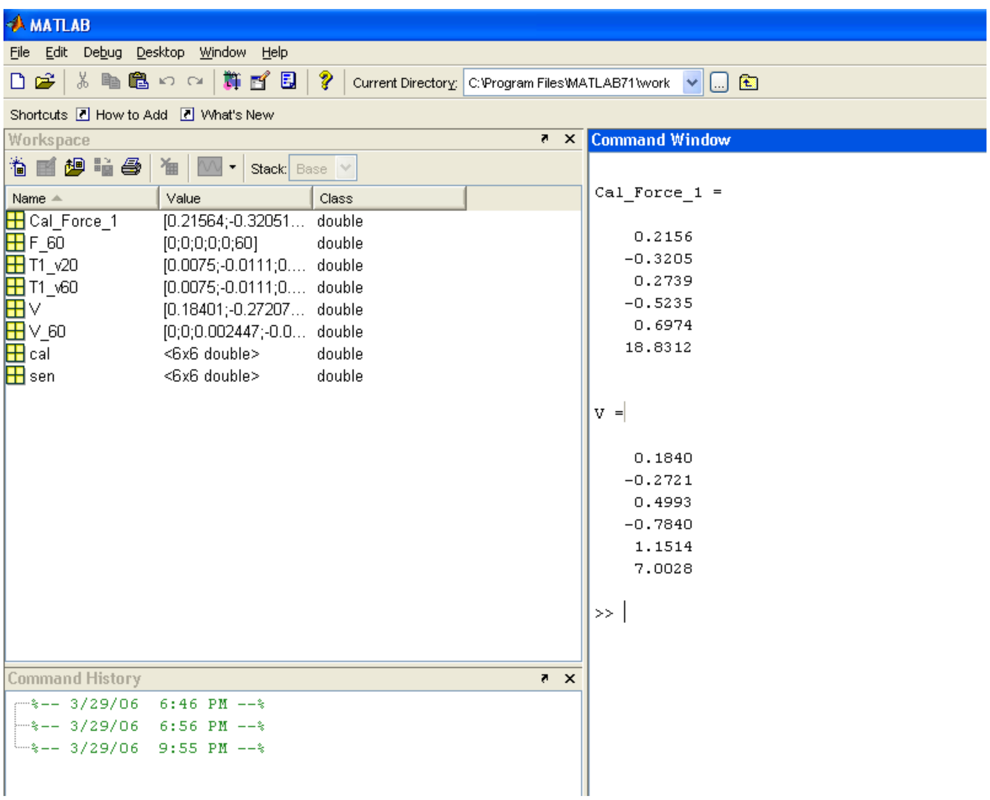

Diagram 8. Screenshot of Matlab program(result of F=60lbs)

Discussion

Expected results for gait analysis with shoes and bare foot experiment were different from actual results from the experiments. With shoes, medial/lateral force was expected to be larger than barefoot force. However, actual data shows the opposite results. This caused because the subject was nervous or was very careful of walking on the force plate with shoes. Otherwise, this result suggests the subject to change to new shoes.

Table 4. Comparison between actual voltage and measured voltage of forceplate.

*****0lbs**

	Calculated with matrix	Measured values	Percent error
Fx	0.4291	0.0175	95.9
Fy	-0.2353	-0.0096	95.9
Fz	0.5546	0.0226	95.9
Mx	-0.5859	-0.0239	95.9
My	1.0858	0.0443	95.9
Mz	0.1911	-0.0078	104.1

*****20lbs**

	Calculated with matrix	Measured values	Percent error
Fx	0.1840	0.0075	95.9
Fy	-0.2721	-0.0111	95.9
Fz	0.4993	0.0201	96.0
Mx	-0.7840	-0.0316	96.0
My	1.1514	0.0470	95.9
Mz	7.0028	0.2858	95.9

*****40lbs**

	Calculated with matrix	Measured values	Percent error
Fx	0.1644	0.0067	95.9
Fy	-0.3284	-0.0134	95.9
Fz	0.4837	0.0192	96.0
Mx	-0.8081	-0.0322	96.0
My	1.1875	0.0485	95.9
Mz	14.1084	0.5758	95.9

*****60lbs**

	Calculated with matrix	Measured values	Percent error

Fx	0.0836	0.0034	95.9
Fy	-0.2301	-0.0094	95.9
Fz	0.5418	0.0213	96.1
Mx	-0.7785	-0.0306	96.1
My	1.4394	0.0588	95.9
Mz	21.2556	0.8675	95.9

*****80lbs**

	Calculated with matrix	Measured values	Percent error
Fx	0.0835	0.0034	95.9
Fy	-0.1123	-0.0046	95.9
Fz	0.4573	0.0176	96.2
Mx	-0.8592	-0.0335	96.1
My	1.3701	0.0560	95.9
Mz	28.3440	1.1568	95.9

According to table 4, percent difference between calculated values and measured values are greater than 95% difference. This shows that there are huge factors of error even though calculations involved with wax factors, calibration matrices and sensitivity matrices. This shows that force plate can have a lot of potential to cause huge errors.

Table 5. Comparisons between load positions with the positions computed by dividing the moments by the vertical forces.

	Real Location X	**Real Location Y**	**Theoretical X**	**Theoretical Y**	**Percent error X**	**Percent error Y**
Pos A	-7 inches	-8 inches	-6.53 inches	-7.35 inches	5%	8%
Pos B	-4.5 inches	-5.5 inches	-4.42inches	-4.46 inches	2%	19%
Pos C	0 inches	0 inches	-0.68 inches	-0.53 inches	100%	100%

According to this table 5, at position A shows less error with x axis than y axis. At position B, percent error with x axis is much less than error in y axis. At position C, percent errors are not very significant since the real location of x and y axis are zero. Therefore, no matter what values of theoretical position in x and y axis, percent error should be 100%. Thus, with comparisons with just positions in inches is less than one inch. However, all errors are exceeded 2% which is the significant error % in statistics. Overall, x direction has less percent error than y direction.

Conclusion

This lab was successful because students got exposed to using a force plate, perform calibrate the force plates, and measure the force plate reaction kinetics during hoed and barefoot gait. Expected results for gait analysis with shoes and bare foot experiment were different from actual results from the experiments. With shoes, medial/lateral force was expected to be larger than barefoot force. However, actual data shows the opposite results. This caused because the subject was nervous or was very careful of walking on the force plate with shoes. Otherwise, this result suggests the subject to change to new shoes. Percent difference between calculated values and measured values are greater than 95% difference. This shows that force plate can have a lot of potential to cause huge errors. At position A, B and C, all errors between actual and calculated values are exceeded 2% which is the significant error % in statistics. Overall, x direction has less percent error than y direction.

Reference

[1] Harris, Gerald, ”BIEN 192, class notes”, Marquette University, Spring 2006

[2] Winters, D. A. *Biomechanics and Motor Control of Human Movement Second Edition.* New York 1990.