ICBET 2013: May 19-20, 2013, Copenhagen, Denmark

An Easy Platform for Postural Balance Analysis by the Evaluation of Instantaneous Center of Gravity

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Abstract

The aim of this paper is to present an easy instrument and method for postural balance analysis based on evaluation of instantaneous center of gravity (COG) were the subject is stand on innovative force platform. The instrument is realized with three identical composite sensor supporting a feet plate were used to measure the ground reaction force applied by subject during postural balance analysis. A Microsystems based on microcontroller was built in order to drive the instrumentation and a graphical user interface was realized. The signals acquisitions are displayed on the PC screen when the COG moves in the xy plan. After the calculation and programming of the COG coordinates point, the plot of the XG and YG time series of the COG position during a postural balance analysis is easily obtained and recording. The effect of visual input is studied by performing the test with eyes open and then closed. The dynamic parameters show clear indicator of the postural balance. Objective method of diagnosis is to access to postural stability for identifying persons at risk of falling.

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Selection and peer-review under responsibility of Asia-Pacific Chemical, Biological & Environmental Engineering Society.

Keywords: Postural, Balance, Stability, Gait, Platform, COG, COP.

1. Introduction

The need to assess postural stability and balance arises in area of medicine such as vestibular problems, head injuries, risk to the elderly and many other areas. This need has led to development of new instruments and new analysis techniques. Objective methods of diagnosis may be useful by identifying persons at risk [1].

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Nowadays, various methods have been devised to quantify postural stability based on measurement of ground reaction forces, center of pressure (COP) and center of gravity (COG) as the subject stands on a platform equipped with force transducers [2], [3]. Force platforms are widely used both in posture and gait analysis [4]. Foot-to-floor interaction is commonly studied using force and pressure measurement systems [5], [6]. Different types of transducers have been proposed for this purpose based on piezoelectric film, piezoresistive, sensors capacitive, conductive polymer effect and strain gauge. Resistance strain gauge is widely used for stress and strain measurement in industry, and also in the field of biomechanics recently [7]. In foot-ankle biomechanics, strain gauge is often used to measure strain of joints, muscles, ligaments, and plantar soft tissues [8], [9], [10]. The present paper illustrates a prototype of an easy and a low-cost innovative made instrument for analysis the postural balance.

2. Material and Methods

The force platform is realized with three identical composite sensor supporting a feet plate were used to measure the ground reaction force applied by subject during postural balance analysis. Figure 1 shows the force platform and the analog conditioning circuit. The static or dynamic efforts exerted by the subject on the platform are converted into an output signal and then analyzed by a special instrumentation. This conversion is realized by using three commercial composite sensors. The composite sensor is constituted from four metallic strain gauge mounted on test body and covered from protective sheet. The strain gauges in each Wheatstone bridge of each composite sensor convert the resistance change to differential voltage. The output signals issued from the bridge is carried onto an analog circuit for amplification and filtering. The circuit is based on instrumentation amplifiers (AD622) with low offset voltage, low noise and high CMRR. Hence, the signal from each composite sensor is conditioned and adjusted in order to have zero output for zero force. After amplifications, each signal is feed on a low pass filter constituted from a second order Butterworth filter with 15Hz cut-off frequency. The three signals issued from the analog circuit are also conditioned in concordance to embedded ADC reference. A microsystems based on a microcontroller (18F4550 from Microchip) was realized for driving the whole instrumentation: ADC timing control and USB interface management. This microcontroller contain a 32kocet of flash memory, an EEPROM, a RAM, 4 timers, 10 bits ADC and USB bus.

![Fig. 1. (a) Force platform; (b) Analog conditioning circuit](image)

The postural balance analysis is based on evaluation of instantaneous center of gravity COG were the
subject is stand on a platform. Analysis may include lateral and anterior/posterior movement of the COG in a
time series. The system proposed is based on the three sensors to sense the ground reaction force. Figure 2
shows the position of detecting effort by the three sensors and an example of the position of the COG during
disequilibrium standing. The coordinates of the COG point of ground reaction vector application is calculate
by the resulting force moment about the axis yoy’ and xox’:

\[
\sum \hat{M}_{F_{/yy'}} = 0
\]  
(1)

\[
F_3 \cdot \frac{L}{2} - F_2 \cdot \frac{L}{2} + F \cdot X_o = 0
\]  
(2)

\[
X_o = \frac{L(F_3 - F_2)}{2F}
\]  
(3)

\[
\sum \hat{M}_{F_{/xx'}} = 0
\]  
(4)

\[
F_2 \cdot d + F_3 \cdot d + F \cdot Y_o - 2 \cdot F_1 \cdot d = 0
\]  
(5)

\[
Y_o = \frac{L\sqrt{3}(2F_3 - F_2 - F_1)}{6F}
\]  
(6)

where

\( F \) : the resulting effort applied in COG position

\( \overline{F} = \sum_{i=1}^{3} F_i \)  
(7)

\( F_1, F_2 \) and \( F_3 \) : the ground reaction force measured by each sensor.

\( L = 400 \text{mm} \) : the separate distance of the three application force sensor.

\( d \) : is the distance from the \( F_2 \) and \( F_3 \) applied force to the xox’ axis.

\[ d = \frac{L}{2} \cdot \tan 30^\circ \]  
(8)

After hardware realization and calibration, a graphical interface was realized by using a software program

![Fig. 2. Positions of three sensors and COG](image-url)
3. Results and discussion

The experimental test has been carried out concerning the postural balance conducted by a subject (Fig.3). The effect of visual input is studied by performing the test with eyes open and then closed during static standing. Figure.4 shows the migration of COG during eyes open and eyes closed. The variable that is generally taken into consideration is a marker to quantify balance related to the force relationships between body and environment. The quantitative assessment of balance is usually obtained by the measures describing the amount of motion of the COG in terms of amplitude and velocity. These measurements are based on the hypothesis that the further the COG travels, the more unstable the postural control is. Other classical approaches take the rhythmical properties into account, and thus extract parameters based on the spectral distribution of the COG variable. The result obtained from the study was not designed to investigate a specific clinical issue, but rather to demonstrate operation of methods and the prototype of an easy force platform. The postural graphic instrument quantifies the balance disorder of the sensory visual which help maintain postural balance, and analyses postural abnormalities and risk of falling. Previous investigators have used the instrument in clinical for postural control system by coordinating information from the visual and neuromuscular systems.

Fig. 3. Position feet during a postural balance test

Fig. 4. (a) Migration of COG during eyes open; (b) Migration of COG during eyes closed
4. Conclusion

An easy force platform for postural balance analysis has been realized, where preliminary results have shown the feasibility of such system. After the calculation and programming of the COG coordinates point, the plot of the \(X_G\) and \(Y_G\) time series of the COG position during a postural balance analysis is easily obtained and recording. The dynamic parameters show clear indicator of the postural balance. A physiological signals recording has been done for future clinical examination in addition to the analysis performed by the innovative force platform.

Acknowledgements

This work was supported by MESRS (Ministère de l’Enseignement Supérieure et de la Recherche Scientifique) under the supervising of the PNR, http://www.nasr-dz.org/ Project N°: 06 / PNR R 13/ 2011 entitled: “Development of an instrument for the diagnosis and rehabilitation of ankle sprain.”

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