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A Theoretical Study on the Evaluation of the Stability and Postural Sway, Based on the Results of the Confidence Ellipse

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Abstract: ***The aim of this theoretical study is to compare the results obtained by the confident ellipse with the postural sway identified during the balance test. The ability to control postural balance is an important factor of mobility starting with the performance of daily basic activities to competitive sports. Postural control is the ability to keep the body in an upright position and a good postural stability is needed during daily tasks. Postural sways in different directions, helps in maintaining the body stability. An increase of movements' amplitude can lead to equilibrium loss, subsequently falling. This study intends to present a method used for the evaluation of stability through the confident ellipse which has been substituted with the standard ellipse. The theoretical estimation of sway area has revealed that the area of the confidence ellipse strongly depends on the number of points of sway. It is suggested substituting the confidence ellipse with the standard ellipse, which allows the comparison of data collected under different conditions of duration and frequency of postural sway. The results drawn from the confident ellipse, show that 95% of the figures account for statistical data, which trace the shift of the pressure center as a result of postural sway.***

Keywords: stability, postural sway, confidence ellipse.

1. Introduction and Methodology

Balance, postural control or equilibrium are definitions used to describe how to keep our body in un upright position and, when necessary adjust this position [3], [5]. Postural control systems contain a complex organization that controls the orientation and the equilibrium of the body during upright stance [13]. Postural stability is defined as the ability to maintain the positions of the body within the specific boundaries for which the body still correct for in order to remain stable [1]. A good postural stability is needed during daily tasks. Postural sways in different directions, helps in maintaining the body stability and it is calculated through the estimation of sway area ellipse. Sway area ellipse is calculated by integrating the area of COP with regard to reference point in mm²/sec [3]. The theoretical evaluation of the stability and postural sway is based on the results taken from confidence ellipse. A real problem in stabiliometry and postural balance is to quantify the oscillation of a subject performing balance tests in jumping Leonardo Mechanography force plate. The balance test intends to evaluate the balance ability through the projection of the center of pressure (COP) in a $2D$ plane by force plate Leonardo Mechanography measurement [10]. COP is simply the point location of the vertical ground reaction resultant force vector, which can be easily measured using a force platform [3], [7]. From the above measurements are obtained the stabiliometry graphs (Fig. 1), which are adjusted by fitting circles in the x-y plane [2], [4].

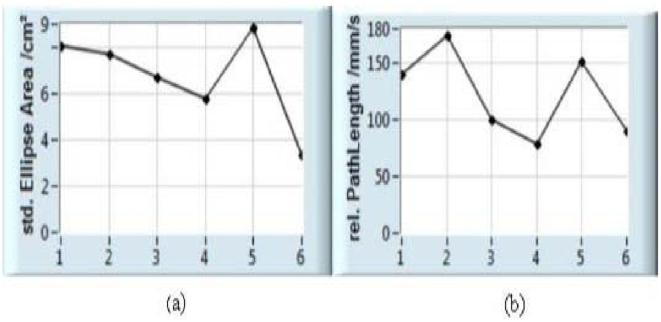

Figure 1: The stabiliometry data of standard Ellipse Area (a) and relative PathLength of COP (b)

These graphs show the standard ellipse area and relative path length in six different sequences of subject COP sway during 10 seconds of balance test. Also, from balance tests are taken the images of sway area standard ellipses (Fig. 2) during 10 seconds time. The most useful method [6], [8] is the analysis of area sway through 95% confidence ellipse, which is mentioned as a $(1-\alpha)\%$ confidence ellipses in the postural sway. This study intends to adopt confident ellipse with the standard ellipse (Fig. 2) during the balance test. The area of the confidence ellipse is used as a measure of energetic expenditure of the subject to maintain his balance [11].

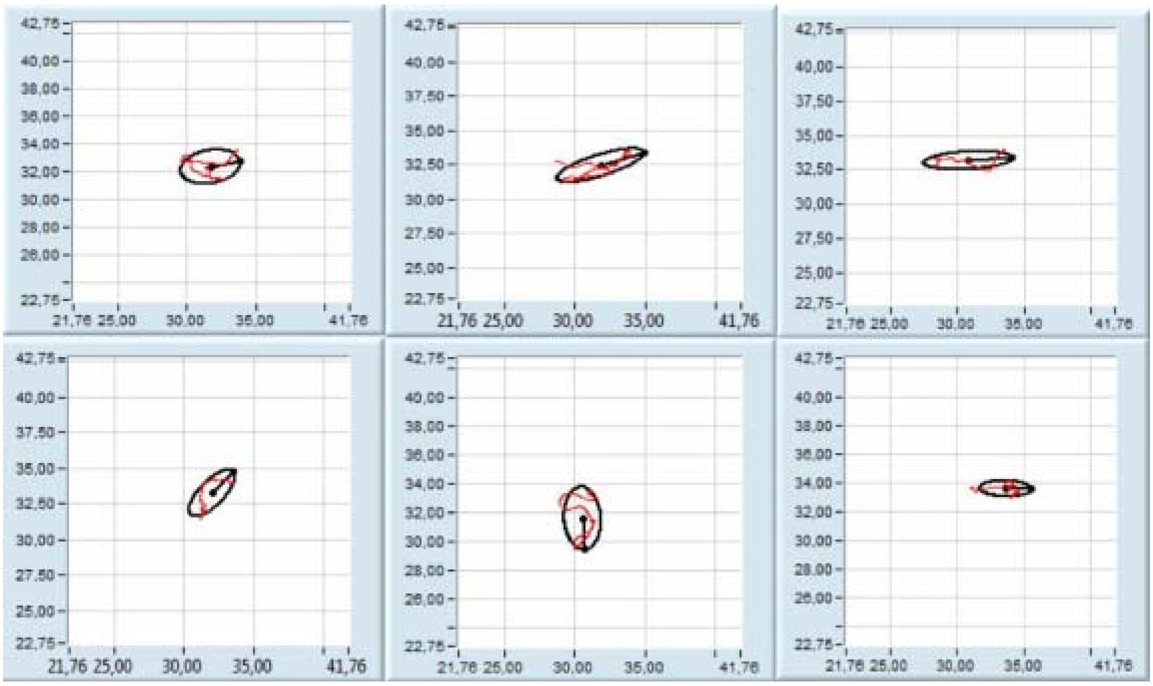

Figure 1: Ilustration of six images of Sway Area standard Ellipse during 10 sec. of balance test.

2. Results and Discussion

Prior et al [12] have shown that: "The 95 % confidence ellipse should enclose nearly 95 % of the COPpoint". This formulation is not much correct according to reference because (1-α)% confidence ellipse is taken as the ellipse which consists of (1-α)% points of sway. The more exact definition is: "The 95 % confident ellipse is one which has the (1-α)% probability of containing the COP of sway". Therefore, the area of confidence ellipse contains the COP of a subject with a corresponding probability [9].

In order to calculate the sway parameter, the data series taken from the force plate measurements [10] were transformed in a fixed reference coordinate system which is coincident with the mean position of COP. If $N\rightarrow$ represent the total number of data points of the COP data set, $x\rightarrow$ represents the Medio-Lateral (M/L) of the COP displacement, whereas y→represents the Anterior-Posterior (A/P) of the COP displacement

$$x_n = x_i - \overline{x} \quad (1)$$

and

$$y_n = y_i - \overline{y} \quad (2)$$

where x_n and y_n are the desired transformed data point of interest.

$\overline{x} \rightarrow$ the average value of the entire M/L COP data series, is determined by the equation:

$$\overline{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \quad (3)$$

Where $x_i \rightarrow$ is the data point of interest.

Similarly:

$$\overline{y} = \frac{1}{N}\sum_{i=1}^{N} y_i \quad (4)$$

Where $y_i \rightarrow$ is the data point of interest.

The sway ranges in $2D$ plane are as follow:

$$\text{M/L sway range} = |(x_n)_{\max} - (x_n)_{\min}| \quad (5)$$

Where the M/L sway range is the peak to peak amplitude of the COP traveled in M/L direction, $(x_n)\max$ and $(x_n)\min$ are respectively the highest and the lowest values in the M/L direction.

$$\text{A/P sway range} = |(y_n)_{\max} - (y_n)_{\min}| \quad (6)$$

Where the A/P sway range is the peak to peak amplitude of the COP traveled in A/P direction, $(y_n)\max$ and $(y_n)\min$ are respectively the highest and the lowest values in the A/P direction.

The mean velocity is the average speed that the COP moved, calculated by total distance traveled and diving by total time of test:

$$\text{Mean velocity} = \frac{\sum_{i=1}^{N}\sqrt{(y_{n+1}-y_n)^2 + (x_{n+1}-x_n)^2}}{t} \quad (7)$$

Where $t \rightarrow$ the total time duration of test.

RMS is the root mean-square distance of the COP data, which is calculated as the average distance that the COP travels from this mean location, which in fact is the standard deviation $SD(COP_x)$ and $SD(COP_y)$ displacements in relation to the main location

$$RMS = \sqrt{\frac{\sum_{i=1}^{N}(x_n^2 + y_n^2)}{N}} \quad (8)$$

The 95 % confidence ellipse is a statistical measure to describe the area of sway. The calculation fits the major axis to be coincident with the primary direction of sway. Then it fits an ellipse to the data, such that the ellipse contains the

COP data points with 95 % confidence ellipse [14], [15]. The calculation requires follow steps:
Firstly, the co-variance matrix of the data points is given in relation to the mean location of COP, accordingly to equations:

$$\text{Co-variance Matrix} = \begin{bmatrix} \sigma_x^2 & \sigma_{xy} \\ \sigma_{xy} & \sigma_y^2 \end{bmatrix} \quad (9)$$

Where $\sigma_x \rightarrow$ is RMS of M/L data COP moving away, calculated according to below equation:

$$\sigma_x = \text{M/L RMS} = \sqrt{\frac{\sum_{i=1}^{N} x_n^2}{N}} \quad (10)$$

While $\sigma_y \rightarrow$ is RMS of A/P data COP moving away, calculated according to below equation:

$$\sigma_y = \text{A/P RMS} = \sqrt{\frac{\sum_{i=1}^{N} y_n^2}{N}} \quad (11)$$

And $\sigma_{xy} \rightarrow$ is calculated according to equation:

$$\sigma_{xy} = \frac{\sum_{i=1}^{N} (x_n \cdot y_n)}{N} \quad (12)$$

Thus, the co-variance matrix is used to calculate the eigenvalues, which can be calculated by solving for the two eigenvalues, λ_1 and λ_2:

$$\det\left(-\begin{bmatrix} \lambda & 0 \\ 0 & \lambda \end{bmatrix} + \begin{bmatrix} \sigma_x^2 & \sigma_{xy} \\ \sigma_{xy} & \sigma_y^2 \end{bmatrix} \right) = 0 \quad (13)$$

The determinant results from this equation are:

$$\lambda^2 - (\sigma_x^2 + \sigma_y^2)\lambda + (\sigma_{xy}^2 - \sigma_x^2\sigma_y^2) = 0 \quad (14)$$

Two solutions λ_1 and λ_2 are the two eigenvalues. Multiplying each of these eigenvalues by desired confidence, gives the length of semi-axes of ellipse *a* and *b*. The standard Sway Area ellipse is computed based on x_{ML} and y_{AP} oscillation of COP amplitudes, by considering the main axes of the ellipse, which contains 90% of data points, accordingly as in [3], [9], [14]:

$$\textit{Standard Ellipse Area}(90\%) = \pi \times a \times b \quad (15)$$

For a 95% confidence ellipse, the corresponding statistical value is 1.96. Then, the major semi-axis of ellipse is:

$$a_1 = 1.96 \times \sqrt{\lambda_1} \quad (16)$$

and the minor semi-axis of ellipse is:

$$b_1 = 1.96 \times \sqrt{\lambda_2} \quad (17)$$

Finally, these values a_1 and b_1, can be used to calculate the area (Fig. 3), accordingly to equation:

$$95\ \%\ \text{confidence ellipse Area} = \pi \times a_1 \times b_1 \quad (18)$$

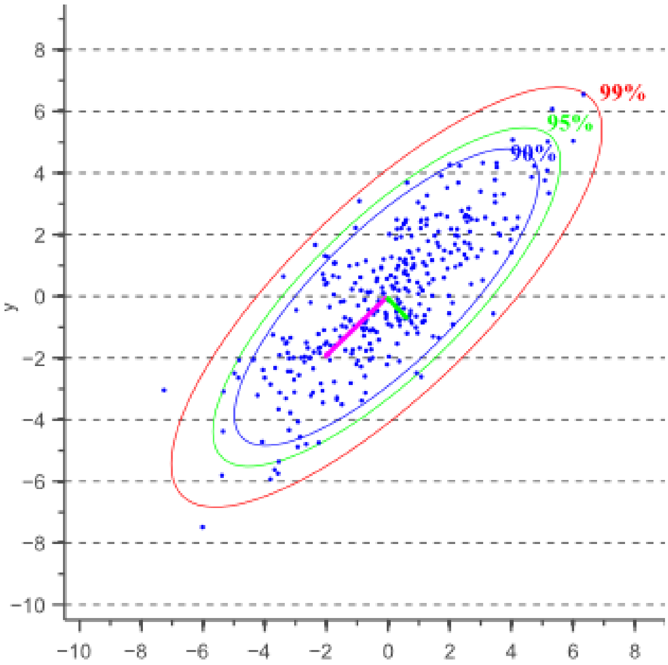

Figure 3: Confidence ellipses for normally distributed data

The assumption that the distribution of the points of the confidence ellipse is a normal bivariate distribution [14] is not showed for the points of sway. From the above equations of ellipse, is found that the area of the confidence ellipse strongly depends on the number of points of sway (it decreases when the number points increases). Therefore, the confidence ellipse does not describe the variability of the subject's sample points. Thus, the area can vary not only according to the balance ability of the subject, but also according to the duration of the sampling frequency of the points. Based on the results taken from force plate measurements on test balance and comparing them to the theoretical evaluation of ellipse are, it is suggested substituting the confidence ellipse with the standard ellipse [9], which allows the comparison of data collected under different conditions of duration and frequency of postural sway.

3. Conclusions

In conclusion, since postural sway is very essential in identification of different pathologies which are related with the risk of falls, it is used as an important measure on balance test. Postural sways in different directions, helps in maintaining the body stability. An increase of movement's amplitude can lead to equilibrium loss, subsequently falling. The theoretical estimation of sway area has revealed that the area of the confidence ellipse strongly depends on the number of points of sway. It is suggested substituting the confidence ellipse with the standard ellipse, which allows the comparison of data collected under different conditions of duration and frequency of postural sway. The results drawn from the confident ellipse, show that 95% of the figures account for statistical data, which trace the shift of the pressure center as a result of postural sway. If postural activity is reduced in one direction, it is compensated to the other direction in order to keep the balance of the human body over the base of support.

References

[1] Shumway-Cook, A., Woollacott, M.Motor Control: "Theory and Practical Applications". Baltimore, MD. Library of Congress Publications 1995, pp. 119-142, 357-376.

[2] Bhattacharya A, Morgan R, Shakla R, ramakrishan HK, Wang L. Non –invasive estimation of afferent inputs for postural stability under low levels of alcohol. Ann Biomech Eng 1987: 15: 533-50.

[3] Bendo A, Skënderi Dh, Veveçka A. "Effect of vision and orientation in human balance". Journal of Multidisciplinary Engineering Science & Technology (JMEST) 2014, Vol.1 (5): 336-341.

[4] Hassan S, Goldner D, Lichstein MJ, Wood A, Shiavi RA. Selecting a suitable biomechanics platform measure of sway. Proc. 12-th Int. Conf. IEEE Eng Med Biol Soc 1990: 12: 2105-6.

[5] Piirtola M, Era P. Force platform measurements as predictors of falls among older people - A review. Gerontology. 2006; 52(1):1-16.

[6] Hasan SS, Robin DW, Szurkus DC, Ashmead DH, Peterson SW, Shiavi RG. Simultaneous measuemets of body center of pressure and center of gravity during upright stance. Part II: Amplitude and frequency data. Gait & Posture 1996: 4: 11-20.

[7] Tallon G, et al. "Dynamical and stabilometric measures are complementary for the characterization of postural fluctuations in older women" (2012) http://dx.doi.org/10.1016/j.gaitpost.2012.10.021

[8] Prieto ET, Myklebust MM. Postural steadiness and ankle joint compliance in the elderly. IEEE Eng Med Biol Mag 1992: 11: 25-7

[9] Bruno M, Rocchi L, Sisti D, Ditroilo M, Calavalle A, Panebianco R. The misuse of the confidence ellipse in evaluating statokinesigram. Italian Journal of Sport Science 2005. Vol 12(2): 169-171

[10] Leonardo Mechanography Ground Reaction Force Platform (GRFP) v4.2 Standard Edition. Getting Started. Document Version: v1.1.0-en, 16.3.2010, RR

[11] Perrrot C, Moes R, Deviterne D, Perrin P. Adaptions posturales lors de gestuelles spécifiques aux sports de combat. Science & Sport 1998: 13: 64-74

[12] Prieto TE, Myklebust JB. Measures of postural sway. Clin Pharmacol Ther 1993: 54(2): 228

[13] Hoda Salsabili, Farid Bahrpeyma, Bijan Forogh, Sanaz Rajabali. "Dynamic stability training improves standing balance control in neuropathic patients with type 2 diabetes". Journal of Rehabilitation Research & Development, Vol. 48, no.7 (2011) 775-786

[14] Batchelet E. Circular statistics in biology. London: Academic Press, 1981: 129-144, 264-265

[15] Hotelling H. The generalization of Student's ratio. Annals of Mathematical Statistics 1931: 2: 360-378

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