

## CLINICAL STABILOMETRY STANDARDIZATION: FEET POSITION IN THE STATIC STABILOMETRIC ASSESSMENT OF POSTURAL STABILITY

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### ABSTRACT

**Introduction:** We address the topic of feet position during the quiet upright stance balance test over a force platform. Such position is widely discussed and three among the most accepted criteria were submitted to comparison.

**Materials and methods:** 55 subjects devoid of any evident motor dysfunction were receiving the test in the three selected feet positions configurations: Joined Parallel [JP], 30° degrees with 5 cm heels apart [30°], Parallel Apart [PA] at about 15 cm distance from each other. Six sequences have been selected and applied in a random way to the subjects in order to avoid learning effects or fatigue bias in the test results.

**Results:** The data have demonstrated that: 1) The Romberg quotients (the ratio between homologous parameters calculated in the Closed Eyes Test vs. the Open Eyes Test), although affected by the feet position, keep their standard meaning independently by the feet position; 2) A significantly greater variability of Sway Parameters is afforded by the Joined Parallel Feet [JP] while the Parallel Apart Feet position [PA] seems to afford the lowest sensitivity in quantifying balance performances; 3) The [30°] test seems to be the most comfortable one and therefore likely to be the most convenient for unstable or dysfunctional subjects that cannot keep the [JP] position; 4) The [PA] and the [30°] test are showing very similar results.

**Conclusion:** We can therefore conclude that the first choice for feet positioning to perform balance tests on force platform should be towards the Joined Parallel Feet, the others, however, might represent a valid choice for impaired patients.

**Keywords:** stabilometry standardization, postural stability, Balance.

DOI: 10.19193/0393-6384\_2017\_4\_105

Received November 30, 2016; Accepted March 20, 2017

### Introduction

Stabilometry is a technique employed to study the body sway of human subjects in a standing position using a force platform<sup>(1)</sup>. Similar to a weighing scale, a force platform is a device that uses a set of force transducers to quantify the ground-reaction vector force and its point of application, known as the center of pressure (CoP)<sup>(2)</sup>. The Romberg Test on Force Platform is aimed primarily

to detect proprioceptive deficit through the ratio among the homologous values of the parameters calculated over the Closed Eyes vs Open Eyes Test measurements. The computerized analysis, that providing a analysis of the motor control capabilities and performances, could show the possible impairments leading to an appropriate diagnostic path. The parameters must be calculated with the best accuracy to allow to the clinician, based on such data, to have correct diagnostic clues.

Recently, the literature showed many study that have used this type of analysis. Studies dealing with public health<sup>(3-6)</sup>, sports science<sup>(7-9)</sup>, medicine<sup>(10-13)</sup>. Hereupon, a test standardization is required for homogeneous diagnostics. Several efforts have been made and recently ISPGR appointed a specific Committee with the task of providing common guidelines and standards for the test in clinical practice.

*In the framework of the process:*

1) environmental conditions as set forth in by Kapteyn et al in 1983<sup>(1)</sup>, were discussed and confirmed;

2) the issue of the force platform design<sup>(14)</sup> should be overruled by a set of functional specifications: the COP (Center Of Pressure) path is to be provided with metrological dependability;

3) the length of the recording and the sampling frequency were also discussed and the recommended choices were set forth<sup>(15)</sup>;

4) the effect of anthropometrics (height, weight, foot size) should be considered<sup>(16)</sup>;

5) the effect of foot position was also analyzed, but no final and agreed conclusion has been found yet<sup>(15, 16)</sup>;

6) the process of verification and metrological validation of the devices and of their software, as well as of their calibration should also be discussed even beyond the suggestions provided<sup>(17-19)</sup>. The aim of this study is to provide an indication for the selection of the most appropriate feet position. We analyzed, to the test, the three positions used most commonly on the literature healthy subjects was enrolled to assess the impact of feet position on the force platform measures balance while performing the tests.

## Materials and methods

As said earlier 55 subjects were enrolled for the study. Our study was carried out in compliance with the Declaration of Helsinki and the principles of the Italian data protection act (196/2003). The sample was composed by 55 young subjects (age:  $30 \pm 6,78$ ; Weight:  $69,96 \pm 12,83$  Kg; Height:  $172,58 \pm 9,04$  cm; foot size:  $41,07 \pm 2,88$ ;) devoid of any functional impairment evident. All participants were recruited from Posturology Master in La Sapienza University (ROME).

### Anthropometric measurements

Anthropometric measurements were per-

formed according to the evaluation procedures reported in by Patti et al<sup>(20)</sup>. Afterward, for each subject, the same researcher measured the body weight (body weight, kg), with approximation to 100 g, using a scale (Wunder 960 classic). Height was measured by a standard stadiometer (maximum height recordable: 220 cm; resolution: 1 mm), with subjects barefoot and standing upright (Fig. 1).

### The test design

The test and performances are generally considered as sex-independent, however we report that our sample was composed by 25 females and 30 males.

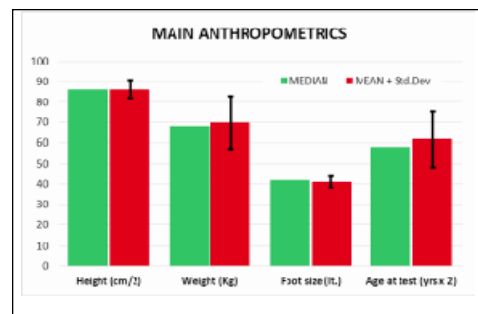


Figure 1: Feet position on the platform.

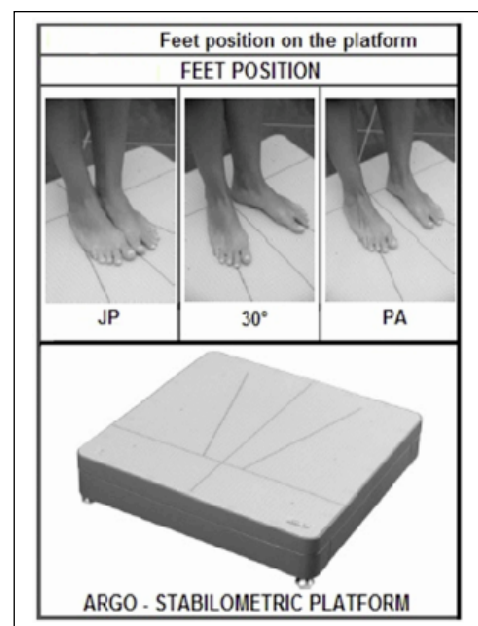


Figure 2: Main anthropometrics of the sample.

Among the most popular positions (Fig. 2) there are:

- The “standard” indication of the Romberg Test (feet parallel and in contact to each other) cited by many authors<sup>(21)</sup> and defined as Joined Parallel (JP);
- Mostly coming from the French

Posturographic School, there is an indication of test with feet forming an angle of 30° degrees and heels slightly apart (3 to 5 cm);

- Known as the “Osteopathic Approach”, there is an indication of test with feet parallel to each other at some distance (both feet should rest parallel to each other in a plane vertical under the omolateral trochanter to form an ideal parallelogram on the Coronal Plane). Such is identified as feet parallel (PA)<sup>(22)</sup>. The Subjects, duly informed about the test characteristics and about the purpose of the study, gave the appropriate informed consent in writing. The subjects were to be submitted to the tests, both in closed and open eyes conditions, in all the above indicated three conditions (Figure 1).

To the purpose the reference feet positions were established on the platform surface. Such surface (600 x 600 mm) is covered by a Cartesian grid (origin on the left posterior corner) with a BASELINE parallel to X axis at Y=150 mm and a CENTERLINE parallel to Y axis at x=300 mm. Two lines from the BASELINE opening forward at 15° on both sides of the CENTERLINE are also indicated.

The three different positions were indicated as follows:

- (JP): heels were positioned against the BASELINE and in contact with each other along the CENTERLINE;

- (30°): heels were positioned touching the BASELINE with the second toe and the center of the heel of each foot on each of the two 15° reference lines;

- (PA): from the BASELINE two perpendicular lines at 15 cm from the CENTERLINE were drawn on purpose and heels were positioned touching the BASELINE with the second toe and the center of the heel of each foot on each of the two lines symmetrical to the CENTERLINE.

Exclusion criteria, based on subject declarations:

- Smokers;
- Any musculoskeletal trauma in the past six months,
- Practice of any Sport discipline at competition level;
- Subjects under rehabilitation treatment;
- Assumption of drugs either on a regular basis or in the last five days prior to test;
- Assumption of alcoholic beverages in the previous 24 hrs;
- Assumption of coffee in the previous 3 hrs.

### ***Outcome Measurements***

The test was performed using the ARGO® Force Platform (RGMD - Italy) endowed with a metrological validation<sup>(23)</sup> and duly calibrated<sup>(24)</sup>. Acquisition time was set at 45 seconds and the first 5 seconds were discarded being considered as adaptation time. Such condition meets the requirements set forth in a previous work<sup>(15)</sup>. Environmental conditions meet the already accepted requirements<sup>(1)</sup>. The Closed Eyes test was performed before the Open Eyes one to the purpose of limiting the oculomotor control memory on balance keeping in Closed Eyes condition. The sampling frequency of the device is 100 Hz.

A post-processing filter is used for a signal frequency band up to 10 Hz.

### ***The device provides***

The device provides:

a) Classical Parameters (Oscillations, Sway Path, Sway Area, Confidence Ellipsis);

b) Sway Density Parameters (Mean Stay Time, Mean Spatial and Time distances) as defined by Baratto, Morasso and Jacono in 2002 and 2004<sup>(25,26)</sup>;

c) Harmonic Analysis (FFT) on the Coronal (X) and Sagittal (Y) planes each divided into 8 bands<sup>(27)</sup>.

## **Results**

### ***Learning Effects***

To check whether the sequence of tests was affecting the result of each test, the mean parameters measured for each of the three tests in each of the six groups were grouped into nine subgroups into which the same type of test was performed as 1<sup>st</sup>, 2<sup>nd</sup> or 3<sup>rd</sup> of the sequence. Values were then averaged and all values were then normalized to such average. The plot of the normalized main parameters show no learning or fatigue effect and the parameters seem to be just slightly floating around the mean value (see Figure 3). There is in fact no coherent change in parameters that might be related to the sequence of tests most probably because, even if there were some learning or fatigue bias, their effect would be well within intrinsic variability of the COP sway. The findings in respect to the different feet configurations are therefore not affected by any specific bias due to the test sequence and the overall results of a comparison of three test configurations with a solid 55 subjects sample are strongly reliable.

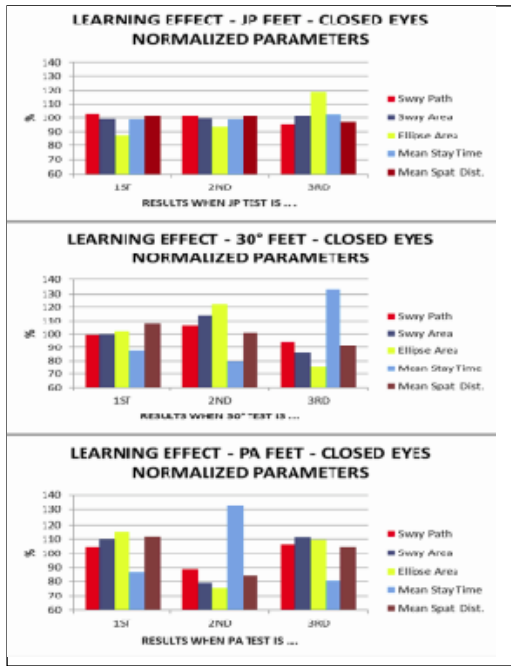


Figure 3: Results tests with the different positions.

**Main Parameters**

See Figure 4. The plot of data on the Sway Plane (Time Normalized Sway Area vs Time Normalized Sway Path) is immediately suggesting that, while data obtained in the (PA) and in the (30°) position are very similar, data obtained in the (JP) position are significantly different and afford a much greater dispersion.

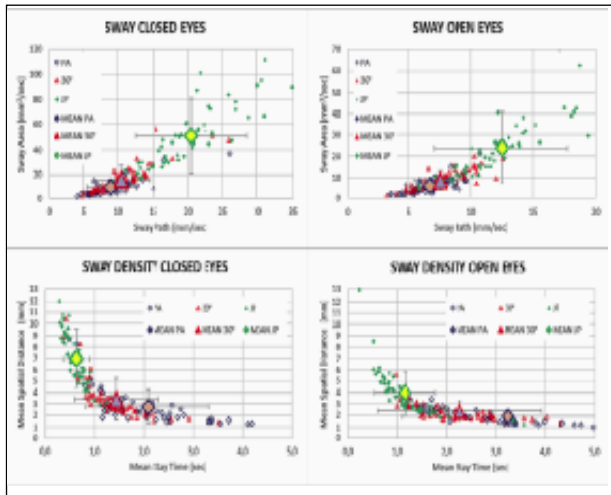


Figure 4: The plot of data on the Sway Plane.

However, the three groups are over the same ideal power curve ( $Sway Area \approx 0.5 \times (Sway Path)1.5$ ), somehow suggesting a correlation beyond the feet position. In the Sway Density Plane (Mean Spatial Distance vs Mean Stay Time) the three groups are even more clearly apart from each other but, once more, along a common power curve

(Spatial Distance  $\approx 4 \times (Stay Time) 0.9$ ) confirming the idea of an Invariant that is not affected by the feet position. However, such invariants could be modified by functional alterations: a good theme indeed for further analysis that will require the comparison between “curves” obtained from homogeneously dysfunctional subjects.

**Spectral composition of Sway**

Sway components (Fig. 5) were analyzed in the Frequency Domain by means of the Fast Fourier Transform from its time domain recording. The total harmonic power (mm<sup>2</sup>/Hz) of the Sway in the band 0.05-10 Hz was then plotted (The lower limit to 0.05 depends on the lowest harmonic that can be spotted with an acquisition set at 40 sec). The Total Sway harmonic power on the Antero-Posterior oscillations is very similar in both Open Eyes and Closed Eyes tests but also the differences between the recordings in the three feet positions are almost identical. The differences are however only for the Latero-Lateral component of the Sway as a proof of the changing incidence of the feet position in the performance of the test.

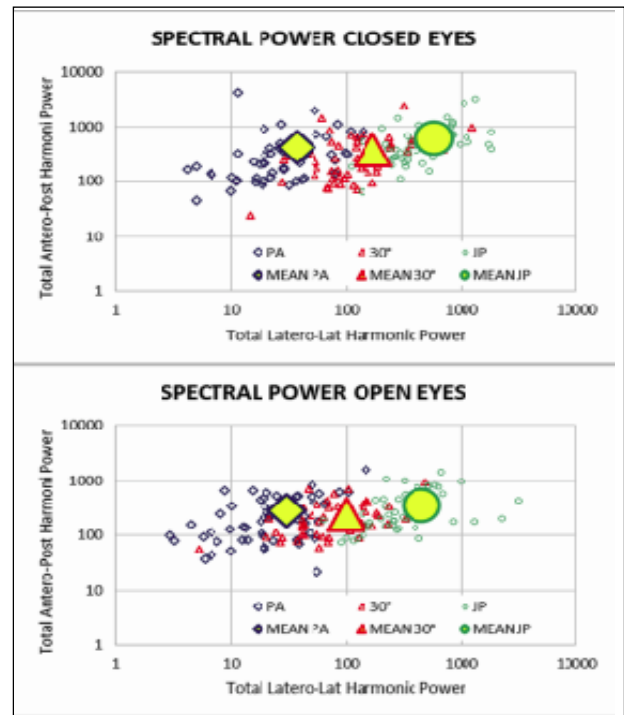


Figure 5: Sway Harmonic Power.

Worth noticing is the fact that in the (JP) position Antero-Post and Latero-Lat oscillations show almost identical values for total harmonic power. Motor Control Indicators (Figure 6). The graphs of the Romberg Quotients (Fig. 6) applied to the fol-

lowing parameters: Sway Path, Sway Area, Confidence Ellipse Area, Mean Stay Time and Mean Spatial Distance, show a monotonic component trend to become smaller with the increasing steadiness afforded by the feet position. In a similar way, other indicators of potential interests, such as the ratio between Sway Area and Sway Path (likely to express a measure of the Postural Tonus), or the ratio between the Mean Spatial Distance and the Mean Stay Time (likely to express a measure of the Motor Control capabilities in the balance control and, hence labeled as CTRL in our graph), tend to shrink with the higher comfort afforded by the increasing size of the footprint. In the limit condition of a circular COP Path, the ratio between the Sway Area (Area of the circle) and the Sway Path (Circumference of the same circle) would be equal to half the radius of the circle itself according to the equation:  $(\text{Sway Area})/(\text{Sway Path}) = \frac{[\pi r]^2}{2\pi r} = r/2$ ; and is therefore proportional to the “free” oscillations of the subject. Such value, multiplied by 4, is the ideal diameter of the circumference equivalent to the measured Sway Path (Table 1). It might be interesting to note that the Square root of the sum of the square values of the std.dev. of the oscillations on the latero-lateral and antero-posterior planes are comparable values to the Oscillations diameter calculated from the SA/SP ratio:

The ratio between the Mean Spatial Distance (the smaller the better, as it indicates the capability to regain balance) and the Mean Stay Time (the higher the better, as it indicates the presence of unbalancing factors) should ideally converge to the value of 3.5 obtained by the proposed:  $\text{Mean Spatial Distance} = 4 \times \text{Mean stay time}^{0.9}$ . We submit that the easily noticeable shrinking of all the above parameters do reflect a progressive loss of “concern” for the task that becomes easier to perform - might this “concern” be the the “fear of falling” that seems to be one of the most important factors in the falls of senior persons? Emotional aspects could therefore have a role, not easy to assess, affecting the neurophysiological aspects of the test itself. At any rate, it is self evident that the more demanding is the balance keeping task, the higher are its capabilities to demonstrate dysfunctional characteristics of the performing subject.

	OSC (Std.Dev.)		4xSA/SP	
	CE	OE	CE	OE
JP	8,25	6,34	9,37	20,77
30°	5,22	4,17	5,56	5,91
PA	4,62	3,85	3,91	3,55

Table 1: Tests oscillations.

**Comparing the three sets of parameters**

All-in-all the three measurements were compared with each other applying the T-Test and posing as hypothesis the similarity between the two sets of data (Two Tails - Eteroscedastic). As it is evident from the Table 2, while there is some significant similarity between the tests performed with Feet Parallel Apart (PA)) and with Feet at (30°), there is almost no similarity between either (PA) or (30°) and (JP).

**Discussion**

The our results confirmed and are in line with the date both Uimonen, S et al.<sup>(28)</sup> that Kollegger, H et al.<sup>(29)</sup>. Test results are affected by the feet position and therefore the three different position can hardly be considered equivalent. In very general terms the greater values afforded by the (JP) position seem to suggest a greater numerical sensitivity of the test. This could be expected, by a more demanding task. The (30°) seems to mix up the sagittal and coronal plane motor control functions and thus would probably be less indicate for diagnostic purposes. On the

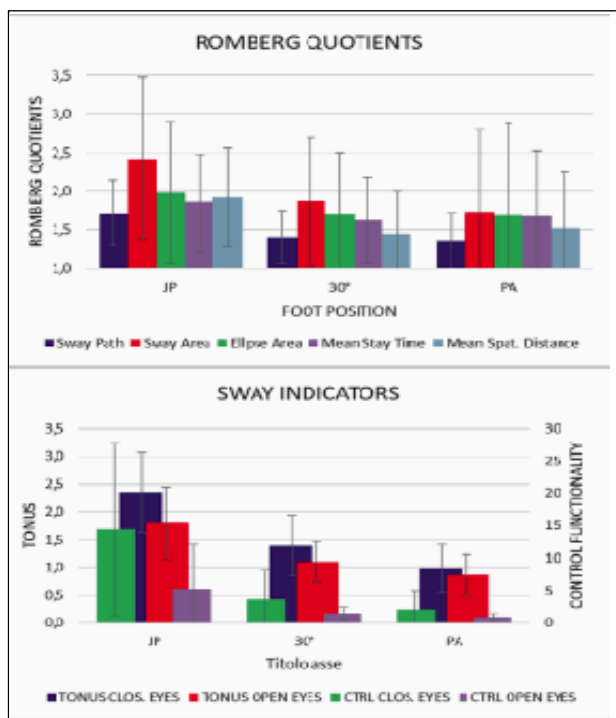


Figure 6: Motor Control Indicators.

	Closed Eyes p values			Open Eyes p values		
	PA vs 30°	PA vs JP	30° vs JP	PA vs 30°	PA vs JP	30° vs JP
LateroLat Oscillations (StdDev)	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
AnteroPost Oscillations (StdDev)	<b>0,857</b>	0,001	<0,001	<b>0,602</b>	<0,001	<0,001
Time Normalized Sway Path	<b>0,043</b>	<0,001	<0,001	<b>0,023</b>	<0,001	<0,001
Time Normalized Sway Area	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
95% Confidence Ellipse Area	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
Mean Stay Time	<b>0,030</b>	<0,001	<0,001	<b>0,008</b>	<0,001	<0,001
Mean Spatial Distance	<b>0,033</b>	<0,001	<0,001	<0,001	<0,001	<0,001
Mean Time Distance	<b>0,320</b>	<0,001	<0,001	<b>0,543</b>	<0,001	<0,001
Sway Area/Sway Path	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
Spatial Distance/Stay Time	<b>0,633</b>	<b>0,078</b>	<b>0,008</b>	<b>0,279</b>	<b>0,207</b>	<b>0,014</b>
Total Latero-Lat Harm. Power	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
Total Antero-Post Harm. Power	<b>0,033</b>	<0,001	<0,001	<b>0,034</b>	<0,001	<0,001
Sway Path QR	<b>0,480</b>	<0,001	<0,001			
Sway Area QR	<b>0,472</b>	<0,001	<b>0,003</b>			
Ellipse Area QR	<b>0,925</b>	<b>0,146</b>	<b>0,092</b>			
Mean Stay Time QR	<b>0,647</b>	<b>0,246</b>	<b>0,048</b>			
Mean Spatial Distance QR	<b>0,575</b>	<b>0,003</b>	<0,001			

**Table 2:** T Test analysis.

other hand, the (PA) and the (30°) provide a more comfortable balance control conditions than the (JP) and can be recommended both for persons that cannot keep the feet joined and parallel or for persons that are less confident. However, Kollegger, H et al. showed that the stabilizing effect of vision on overall body sway is most pronounced when the foot position chosen is associated with a high initial instability<sup>(29)</sup>.

### **The clinical recommendation**

As far as the proprioceptive deficit is concerned, the three different configurations seem to be apt to the purpose with the following remarks:

1) First choice should be the (JP) test configuration,

2) The (30°) or the (PA) configurations might be suggested as a clinical option when submitting to test impaired subjects.

It might be argued that when the balance test is performed to evaluate functional overall performances (such as for example a “Risk-Of-Fall” estimate), the (30°) and/or the (PA) feet positions, most likely resembling the normal subject standing are more realistic. In our opinion the test should be performed in the JP position anyway: the additional balance capabilities would be considered as a “reserve” for higher safety of the subject under test.

The most reasonable suggestions are therefore:

a) to standardize the adoption of the (JP) position to provide Full Diagnostic Report Data,

b) to adopt the other configurations mostly in auto-differential application (tomorrow vs. yesterday measurement),

c) to suggest the exploration of the correlation among Risk-Of-Fall indexes and force platform measurements in the three different configurations in order to select the best suiting one for this specific risk assessment requirement.

A further series of the three tests on rows of differently dysfunctional subjects could be recommended to quantify the differences in Dysfunction Sensitivity and to confirm the first choice option in favor of the (JP).

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