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Short Communication

Clinical stabilometry standardization
Basic definitions – Acquisition interval – Sampling frequency

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ABSTRACT

Several statements on the still debated issue of stabilometry standardization were agreed upon by the ISPGR Standardization Committee.

- A set of metrological characteristics for stabilometric platforms was defined.
- Relying both on practice and experimental verification it was agreed that, to obtain appropriate accuracy and sensitivity in the Romberg Test:
  - The acquisition interval should not be less than 25 s.
  - The sampling frequency should be at least 50 Hz.
- After careful consideration it was decided that the recommendations made in the previous Standardization proposal in 1983 regarding environmental conditions should be maintained.

1. Posturographic standards

During the last Meeting of the International Society for Posture and Gait Research (ISPGR) (Bologna, Italy 2009) a new International Standardization Committee was set up to address the still unresolved issue of standardization in posturographic or static stabilometry.

Agreement was reached on the following topics.

2. Metrological characteristics

It is strongly felt that there should be an agreement on standard requirements **for instrumental measurement performance** *(Technical Performance)* rather than **on device design.**

Since Force Platforms, regardless of the number, type and characteristics of the chosen sensors, provide the *COP Sway Signal* [1], it has been agreed that *Technical Performance* parameters for stabilometric measurement instruments should be based on the COP Sway Signal measurement.

The "COP Sway Signal", consists of the *X*, *Y* time plot of the COP during the test.

$$\mathrm{COP}(t) \rightarrow \begin{cases} X = x_{(\mathrm{COP})}(t) \\ Y = y_{(\mathrm{COP})}(t) \end{cases}$$

This topic has been widely discussed [2–4].

The conventional definition whereby

- the *X* axis is the horizontal trace of the Latero-Lateral plane aimed towards the right side of the patient,
- the *Y* axis is the horizontal trace of the Antero-Posterior plane aimed ahead of the patient

is recognized and accepted.

The origin of the coordinates is placed on the posterior left corner of the platform with reference to the subject's position during the test.

According to the stated principle, the time functions

$$X = x(t)$$

$$Y = y(t)$$

should be produced by the measuring device with the following *Technical Performances*:

- **Accuracy**: better than 0.1 mm.
- **Precision**: better than 0.05 mm.
- **Resolution**: higher than 0.05 mm.
- **Linearity**: better than 90% over the whole range of measurement parameters.

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- **Anthropometric range**:
  - **Weight**: 20–200 kg,
  - **Height**: 80–250 cm,
  - **Foot size**: up to 35 cm.
- **Frequency bandwidth**: 0.01–10 Hz.

3. Clinical parameters

The above requirements should be verified as the goal must be the accuracy of the clinical parameters. The process should be in fact inverted to set Technical Performances requirements capable of ensuring such accuracy.

It was however recognized that parameters are dependent:

(a) on the quality of measured coordinates,
(b) on the type and performance of the signal processing algorithms applied,
(c) on the adopted test method, mainly with respect to feet position and postural requirements.

4. Processing algorithms

Starting from the *COP Sway Signal* (COP(t) as defined) the following will be extracted:

(a) The two basic Stabilometric Graphs, namely the "STABILOGRAM", or the time plot of the two coordinates X, Y, and the "STATOKINESIOGRAM", or the Y vs. X plot as a function of time.
(b) A set of parameters describing the COP Sway Signal (COP(t)). "Classical" and new balance parameters, including Spectral Harmonic Analysis, "random-walk" [5], Sway Density [6], Fractal Analysis [7], Chaotic and Stochastic Analysis, etc. will be examined.

5. Test methods

The criteria proposed by Kapteyn et al. [8] are generally confirmed: some objections still need to be addressed with regard to Sampling Rate, Test Duration, Foot position and the patient's posture.

Some experiments addressed the first two issues.

The feet position was discussed by a number of qualified authors [9,10] but a conclusive recommendation on the subject has not been reached yet [11].

6. Environmental test conditions

It is recommended that the test conditions as defined in paragraph 8 of the aforesaid work on standardization [8] (except for item a) (feet position), which will be examined further, should be accepted.

7. Experimental activities

The topics of:

- Sampling rate,
- Test duration (acquisition time)

were experimentally investigated, as follows.

7.1. Sampling rate

There is no technical advantage in reducing either the sampling rate or the digital resolution (a 2 GB USB memory stick could store more than 15,000 COP acquisition tests (60 s, 100 Hz, 16 bits).

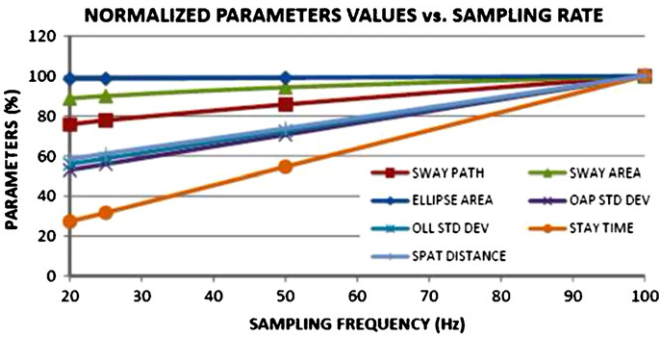

Fig. 1. Parameters stability vs. sampling rate.

From a theoretical standpoint, the maximum detectable frequency depends on the choice of sampling rate with a ratio of at least 2, although general practice suggests a ratio ranging from 5 to 10. This means that, if the maximum detectable frequency is 10 Hz, the sampling rate should not be less than 50 Hz.

It has been suggested that an increase in the sampling rate could add "noise" rather than "information" to the detected signal, which is conventionally cut off below 3 Hz, but more recent observations [12] suggest to consider an effective frequency range of up to 10 Hz (i.e. a sampling rate higher than 50 Hz).

An experimental verification was performed to check whether this assumption is correct. From an archive of 40-s recordings sampled at 100 Hz from a Force Platform (RGMD ARGO®), 14 recordings were randomly extracted. The recordings (timed series of x, y coordinates) were down-sampled at 50, 25 and 20 Hz using Matlab® software package and all the Parameters then calculated for a sampling rate of 100, 50, 25 and 20 Hz.

Calculated parameters were then normalized to the value obtained at the 100 Hz sampling rate.

As shown in the graph of Fig. 1, Classical Parameters (Sway Path, Sway Area and Confidence Ellipse Area) are reasonably steady and a sampling rate of 50 Hz seems to be acceptable to get reliable values.

Both Oscillations and Sway Density Parameters are instead requiring a higher sampling frequency and the 100 Hz sampling rate is recommended.

7.2. Test duration

It has been argued that

(1) any task requires an "adaptation phase" and will be affected by fatigue or lack of attention;
(2) the constantly changing conditions of the living body affect performances that can never be thought of as "steady" whatever the recording time used. This would cast doubt on the applicability of the Fourier Transform.

According to literature however, the most common recording time values range from 20 to 60 s. A previous study suggests a recording interval of around 40 s [13].

To check the effect of recording time, 25 randomly chosen series of 40 s recordings (5 s offset at start) sampled at 100 Hz from a Force Platform (RGMD ARGO®) were analyzed and processed to obtain parameters at different duration times (5, 10, 15, 20, 30, 35 and 40 s).

The following observations may be made (see graphs in Fig. 2):

(1) **Ellipse Area** – although the area is constantly increasing, there is an indication of convergence towards a "stable" value for recording intervals equal to or greater than 30 s.

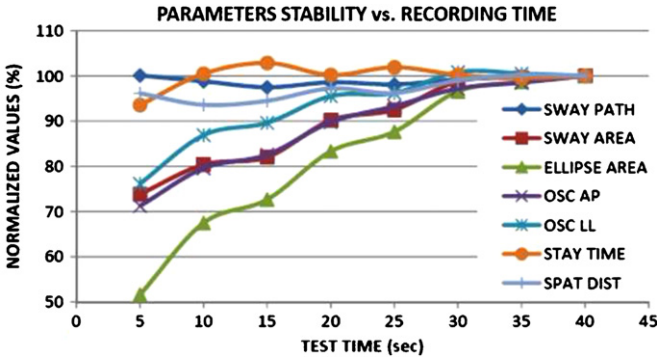

Fig. 2. Normalized parameters values vs. recording time.

(2) **Sway Path and Sway Density (Mean Stay Time and Mean Spatial Distance)** – stable values are achieved almost immediately but good "quality" parameters are obtained with at least 30 s.
(3) **Sway Area and Oscillations** – there is a strong indication of convergence towards a "stable" value for recording intervals equal to or greater than 30 s as for the Confidence Ellipse Area.

In general terms it can be concluded that from a recording time of 25–40 s the Sway Parameters are steady and reliable and a reasonable compromise could well be 30 s with some 5 s of adjustment time before starting the recording.

Clinical observations nevertheless suggest that, especially with impaired patients, maintaining an upright unperturbed stance is a demanding task and in many cases extending the recording time would just add "noise" due to fatigue or diminished attention. It has instead been suggested that random temporary effects possibly give rise to irregular responses and hence it would be advisable to calculate parameters as the average of those obtained in three successive recordings [14].

Authors' contributions

All the mentioned Authors took part in the whole process, sharing opinions and experiences under the Co-Chair of FS. RC and MG performed the data acquisition and processing while FS and RS were mainly involved in the clinical contribution.

Conflict of interest statement

The authors Fabio Scoppa, Roberto Capra, Roberto Schiffer declare that they have no competing interests. Michele Gallamini is the R&D Director of RGMD SpA an Italian Company designing and producing Medical Devices and in particular a range of Force Platforms.

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