Towards a new approach to stabilometric signal analysis: The Quality of the Equilibrium Function

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Introduction

The stabilometric signal analysis neglects some effects of the gravity field on the human body. It is interested in the stabilization phenomena of the body in its vertical position, but ignores the phenomena involved in venous return. But these appear as large postural oscillations of a period of a minute [1] that can cause significant variations in the conventional parameters: "X-mean", "Y-mean", "Area", "Length", "LFS ", " VFY " and " Romberg Quotient " because the mean position of the center of pressure can migrate during these oscillations of one minute [2-4]. It is therefore necessary to take into account this impact of venous return in stabilometry and to find parameters that are not disturbed by these oscillations of one minute.

Method

We propose a jump in complexity to solve these problems of classical parameters. To the spatial data they use - the positions of the center of pressure (or gravity) - we substitute spatio-temporal data represented by Okusono's velocity vectors [5]. We study the probability of the distribution of these vectors, characterized by its cumulative distribution function. "Quality of the equilibrium function" [QEF] is the name of the new parameter we propose, built on this cumulative distribution function of Okusono's vectors.

Okusono's velocity vectors

The straight line segments that join a sampled position from the center of pressure to the next one can be considered as vectors since they have a direction, a head and a tail and a module (fig. 1). Given the regularity of the sampling rate, the length of these line segments (modulus of these vectors) is proportional to the speed of the displacements of the center of pressure, it is therefore possible to name these vectors: "velocity vectors".

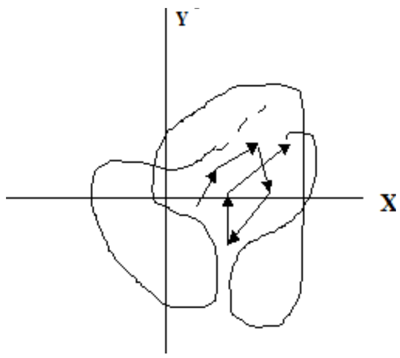

FIG. 1 - Speed Vectors of SKG (after Okusono 1983)

By translating the origin of these vectors to the origin of the Cartesian referential, we obtain what Okusono has called the "vectorial SKG" (fig. 2).

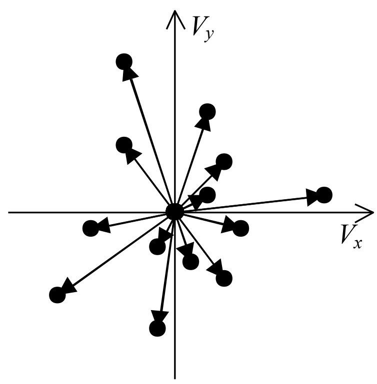

FIG. 2 — Okusono's vectorial SKG (1983).

The Quality of the Equilibrium Function (QEF)

The Okusono's vectorial SKG invites us to construct a histogram of the distribution of the modules of these vectors (fig. 3) thanks to a series of circles centered on the origin of the reference frame and which determine a series of rings of the same area as the central circle. The radius of the central circle, determined experimentally on a group of healthy subjects, is 3.46 mm, which corresponds to a speed of 173 mm / s at a sampling rate of 50 Hz. The area of the central circle, So, is therefore 37.6 mm^2. The rays, R [i], of the other circles are calculated so that the rings delimited by two consecutive circles have the same area as the initial circle.

$$R[i] = \sqrt{\frac{i\,So}{\pi}}$$

i; rank of the outer circle of the ring

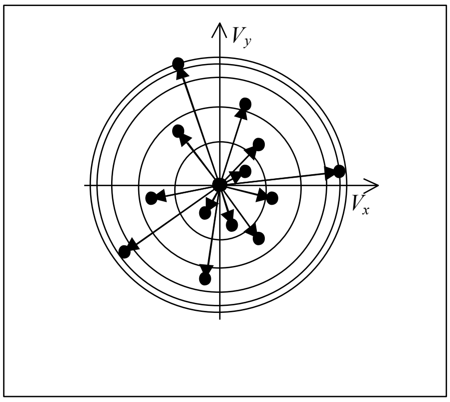

FIG. 3 — Histogram of the distribution of the modules of the Okusono's velocity vectors.

The curve of the cumulative distribution function of this distribution (fig.4) is constructed by carrying on the abscissa the rank, i, of the circle considered and on the ordinate the frequency, f [i], of the modules in this circle, where:

$$f[i] = n[i] \ / \ N$$

n [i]: number of modules counted in the rank circle i
N: total number of modules.

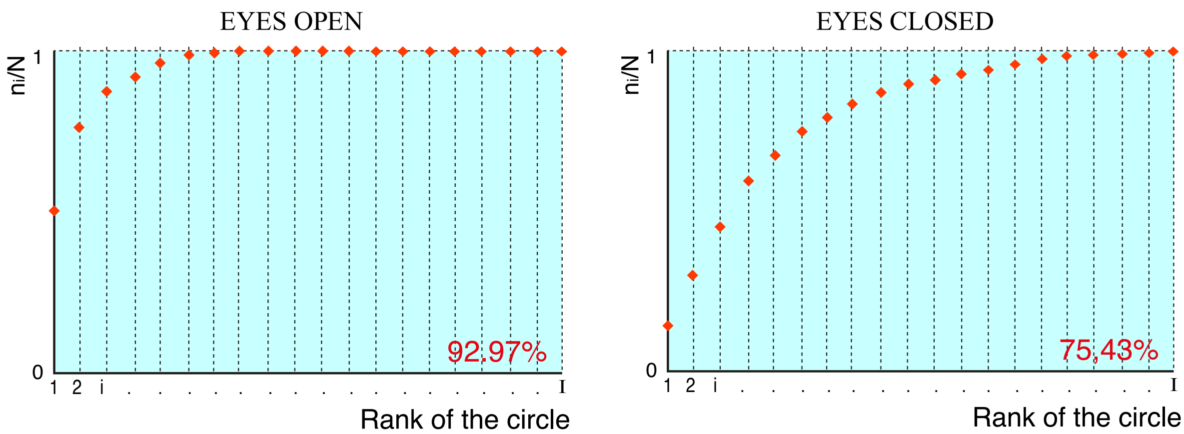

FIG. 4 - Cumulative distribution function of Okusono's vectors of a normal subject, in situations Eyes open and Eyes closed.

Each point of the curve represents the frequency of the modules having the value V≤R [i]. The sum of all these frequencies is:

$$\sum_{1}^{I} f[i]$$

I: total number of circles

This sum, all the more important as the frequencies in the circles of lower ranks is higher, can serve to characterize the curve. We use it, expressed as a percentage of the total number of circles, to set the parameter " Quality of the Equilibrium Function [QEF]:

$$QEF = \frac{\sum_{1}^{I} f[i]}{I} \times 100$$

Results

The comparison of the QEF parameter to the SKG Surface (fig.5) does not require any comment.

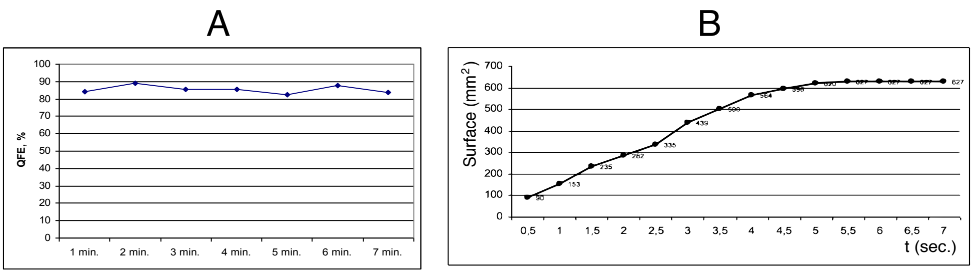

FIG. 5 — Comparative evolutions of the QEF (A) and SKG Area (B) parameters during a seven minute recording.

Each person has his own level of quality of equilibrium function.

This parameter, which is more stable over time than the SKG Area, can be used in professional selection (drivers, vehicle drivers) or to judge the effectiveness of a treatment or in court. It should be noted that the QEF fluctuates when a person's functional state changes, but in a small range.

When all the modules of the Okusono's vectors are contained in the central circle (fig. 6) the QEF parameter is equal to 1 and corresponds to the best quality of the equilibrium function.

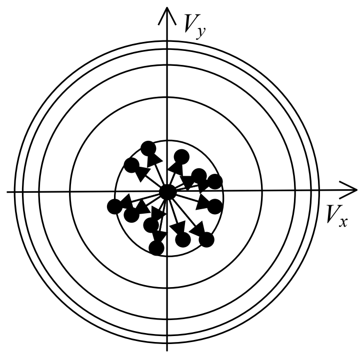

FIG. 6 - All the modules of the Okusono's vectors are contained in the initial circle. The QEF parameter is then equal to 1.

Discussion

The quality of the equilibrium function is a more stable parameter in time than the area of the SKG.

The Area is constructed from spatial data — positions of the Center of Pressure (or Gravity Center) in space — while the QEF is constructed from space-time data — speed of displacements of the pressure center (or of the gravity center) —. The factor-label method of the first could be noted: "L" (by analogy, because the movements of the Center of Pressure correspond physically as much to accelerations as displacements), one could believe that the factor-label method of the second one would be noted : "LT^{-1}", but in fact the QEF is built on the probability of the distribution of the speed modules, it is therefore interested in the variations in time of these speed modules, its factor-label method must therefore be noted:

« LT^{-2} »

i.e. the same label as an acceleration. The acceleration of the Pressure Center (or better the Center of Gravity [6]) allows us to escape the effects of the duration of the recordings during the stabilometric signal analysis.

It is regrettable that the extent of variations in the QEF is arbitrarily limited by the choice, however indispensable, of the area of the first circle.

Conclusion

The practice of stabilometry, whether in the therapeutic, forensic or orientation field, is still attached to the Area parameter of the SKG although its limits have been known for a long time. This attitude seems strictly unjustified because it is not more difficult to ask the computer to compute a more constant parameter, such as the QEF, rather than the Area, except that we are sorely lacking in statistical standards on these new parameters.

References

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Note on the QEF

By Bernard Gagey

Summary

In the search, quite legitimate, of a stabilometric parameter which is not influenced by the recording duration, V. Usachev et al. propose the Quality of the

Equilibrium Function, and when one looks for what lies beneath these mathematical formulas, one simply finds the mean speed.

Mathematical demonstration

See:

http://ada-posturologie.fr/The%20Quality%20of%20the%20Equilibrium%20Function-f.pdf