Technical note

Specifications for building a vertical force platform designed for clinical stabilometry

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1 Fundamentals

AWARE of the growth which clinical stabilometry will attain in future years, the Association Française de Posturologie wants to see future stabilometric apparatus built according to standards, so that results gathered in different wards can be compared directly.

The Japanese Society for Equilibrium Research has already worked out 'industrial standards for stabilometry' (unpublished) which specify a number of performances required for a platform for it to be considered as a standard model. We have taken these as the foundation for our own work, and, indeed, we believe that it is possible to go further, providing anyone who wants to build a platform with specifications so detailed that nothing of importance is left to the manufacturer's discretion.

These specifications have been studied for clinical stabilometry of orthostatic posture only; it is not intended to standardise any laboratory platform for research on posture and movement.

As the advantage of a mathematical analysis of the stabilometric signal is universally acknowledged, the apparatus does not need a sophisticated analogue stage, it has only to deliver an analogue output from the forces applied onto each of the gauges of the platform, compatible with an analogue-to-digital convertor of a computer.

2 Definition of terms

The 'centre of pressure' is the application point of the resultant from forces applied onto the platform, at the instant t, by the body of a subject applying force to the platform with his feet only.

The 'vertical force platform' is a device which detects only the vertical component of the resultant force applied onto a horizontal platform by a body resting on it, unlike the force plates used in gait analysis which need to detect the horizontal component too. It measures, at the instant t, the vertical component of the reaction forces exerted by three supports under the platform to keep it in a state of equilibrium. From these values it is possible to calculate the co-ordinates of the centre of pressure at the instant t (SNIJDERS and VERDUIN, 1973).

The 'Cartesian frame of reference of the position of centre of pressure in the platform plane' is defined by the subject frame of reference during the test according to the standard ISO (AFNOR E90–003–3.19.5) modified by the Kyoto Convention in 1981: the $y'0y$ axis in the subject's sagittal plane, directed forward; the $x'0x$ axis in the subject's frontal plane, directed towards his right side; the centre of gravity of his support base being the point of origin of the axes.

3 Safety standards

In France safety standards for medical apparatus are laid down by AFNOR C 74010 (09-1983).

4 Construction

The relevant parameters are given in Table 1.

4.1 *Platform geometry*

4.1.1 *Height.* According to Kodde's calculations (KODDE *et al.*, 1978) the most important parameter of platform geometry for locating the centre of pressure from the vertical forces alone and for making a spectral analysis of the stabilometric signal, is the distance h from the horizontal plane containing the ankles to the horizontal plane defined by the position of the gauges (Fig. 1).

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Table 1 Relevant parameters

Construction:	$v = 65$ mm $t = 40$ cm rigidity: 2×10^5 N m^{-1}
Outputs:	range: 0–5 V (each channel) variation: 50 mV/9·8061 N filter: 50 Hz (or 60 Hz) frequency rejecter (60 dB)
Performance:	Resonant frequency > 20 Hz accuracy 1 mm (see text) Subject's weight range: 20–120 kg drift < 3 mm h^{-1} (see text)

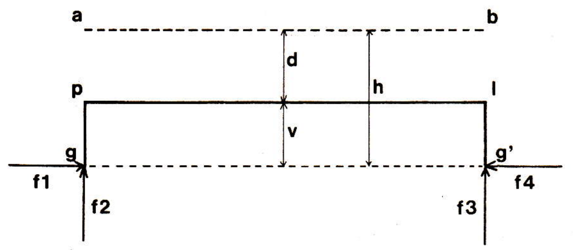

Fig. 1 *Schematic side view of the platform*
ab: level of the plane containing the ankles of the subject
pl: level of the upper surface of the platform
gg': level of the plane containing the gauges
f_1, f_4: horizontal reaction force acting on the platform (not measured by the gauges)
f_2, f_3: vertical reaction force acting on the platform (measured by the gauges)

Theoretically, according to Kodde, the gauges ought to be at the same level as the ankles. Yet it seems that a practical conclusion may be derived from this work, different from the author's own conclusion: all that is required is to standardise the position of the gauges, not in relation to the ankles—that is impossible because of anatomical variations—but at least in relation to the upper surface of the platform. This simplification is all the more justified since Kodde's calculations are based on a simplifying hypothesis which consists in disregarding the work of the plantar arch muscles, which is far from negligible.

By not using Kodde's conclusions an error is introduced in the measurement of the mechanical moment exerted by the subject standing on the platform (MASSEN *et al.*, 1976). The expression for this error along the y axis is

$$e = h(f_4 - f_1)$$

h: vertical distance from the horizontal plane containing the ankles to the horizontal plane defined by the position of the gauges
$f_4 - f_1$: difference between the horizontal reaction forces exerted on the platform, in a parallel direction with the y axis.

The decision to disregard this physical error is to some extent responsible for the necessary compromise between all the factors. It is to be hoped that this error is reduced to a minimum by taking a low value for h, which remains the same for all the platforms built according to these specifications.

Therefore, for the purposes of construction, interindividual anatomical variations of ankle height should be ignored, and attention paid only to the distance v from the plane of the gauges to the upper surface on which the subject's feet rest. Measured along the z axis this distance is positive, and its value is 65 mm, that is to say the gauges are 65 mm beneath the upper surface of the platform. This value of 65 mm has been chosen for historical and technological reasons only.

4.1.2 *Position of the gauges.* The platform has three vertical force gauges (g_1, g_2, g_3), placed at the top points of a strictly equilateral triangle, one pointing forward on the y axis, the two others backwards on a line parallel to the x axis (Fig. 2).

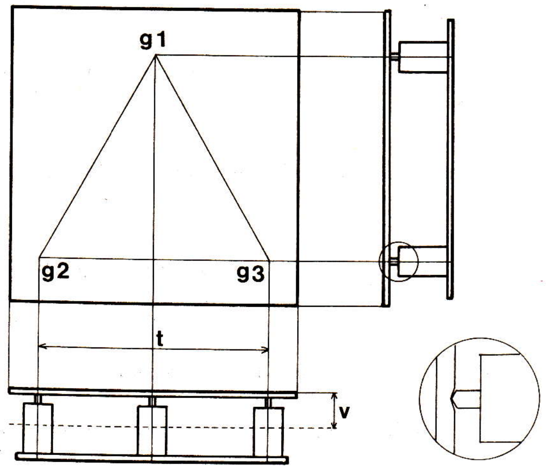

Fig. 2 *Top and side views of the platform*
g_1, g_2, g_3: points of application of the vertical reaction forces measured by the gauges
t: distance between the gauges (40 cm)
v: distance from the plane of the gauges to the upper surface of the platform (65 mm)

The choice of a platform with three points of measurement is dictated by the following considerations:

(*a*) Four points do not define a plane. Puting four points in exactly the same plane poses many construction problems, which could undoubtedly be resolved, but which could be avoided and at less cost. Above all, it is not known how to avoid the measurement ambiguities produced by using a hyperstable plane.
(*b*) The facilities for analogue differentiation given by a measurement from four points are no longer justified, as the signal is now computerised. The ratio of the signal-to-subject's weight is easier to obtain and more accurate by means of the digital processing of force data.

The sides of the equilateral triangle at the top points of which the gauges are located of 0·4 m long with a tolerance of 0·5 mm.

4.2 *Choice of construction material*

The rigidity of the platform bearing the subject's weight is the most important characteristic of the material used for construction. This rigidity must be of about the same order as the rigidity of the gauges, i.e. approximately 2·00 E5 N m^{-1}. One can use for instance a plate of 10 mm made from Dural AU4G, which is lighter than a stainless-steel plate.

4.3 *Choice of the strain gauges*

(*a*) Type: the height constraints referred to in Section 4.1.1 seem to justify the choice of compression strain gauges.
(*b*) Capacity: 100 kg.
(*c*) Resolution: one per thousand, to provide a good reading of 1 N of force variation.

(d) Sensitivity: approximately $2\,mV\,V^{-1}$ full scale.
(e) Nonlinearity: lower than 0·1 per cent full scale.
(f) Hysteresis: lower than 0·20 per cent full scale.
(g) Thermal drift from zero: lower than 0·01 per cent full scale $°C^{-1}$.
(h) Thermal effect on sensitivity: lower than 0·01 per cent full scale $°C^{-1}$.

4.4 *Platform outputs*

Differential amplifiers will be chosen and set up so that the three outputs, one from each strain gauge, have the following characteristics:

(a) A variation of 9·8061 N of the force applied onto a strain gauge corresponding to a 50 mV variation of the output.
(b) The output range, for each channel, runs from 0 to 5 V, according to a conventional conversion scale for analogue-to-digital convertors.
(c) Just before entering the analogue digital convertor the signal is filtered by a 50 Hz (or 60 Hz) filter, which rejects this frequency only (60 dB min).

(Note for user: The analogue-to-digital convertor must be a 12-bit type to obtain consistency between the resolution of the gauges and the least significant bit value.)

4.5 *Performance*

4.5.1 *Accuracy of measurement.* The accuracy of measurement of the platform must make it possible to measure to the nearest millimetre the location of a 10 kg weight placed about 10 cm from the mechanical centre of the platform (point of convergence of median lines of the gauges' triangle).

4.5.2 *Resonant frequency.* If the platform has been built according to these standards, using a dural plate with a modulus of elasticity of $80\,kN\,mm^{-2}$, a rigidity of $2{\cdot}00\,E5\,N\,m^{-1}$ and a distance of 0·4 m between the gauges, the calculated transfer function of the platform alone will be about 10 000 Hz, i.e. about 200 Hz when the platform is loaded by a subject. As the system is not damped, substantial resonance may be observed at these frequencies.

For clinical stabilometry it suffices that the platform resonant frequency has no component lower than 20 Hz, a value which is far below the calculated resonant frequency. Nevertheless it is advisable to verify that no resonant frequency component is observed in the frequency range used in clinical stabilometry (0–10 Hz) when a stepped force impulse is applied to the platform. In practice, the platform is loaded at its centre with a 40 kg weight and a data acquisition is made during which the load is suddenly removed.

4.5.3 *Drift.* When the platform has been loaded with a 50 kg load at its centre for one hour, drift in determining its position must be less than 3 mm.

4.5.4 *Frequency response.* Although the frequency response of the platform is rather higher than necessary, it must be pointed out that the response of the gauges probably ought to be high if it is also intended to use the apparatus to analyse very small movements.

4.5.5 *Subjects' weight range.* For subjects weighing less than 20 kg the platform can no longer be considered to have the same precision.

4.6 *Finishing of the platform's upper surface*

It is up to the user to tell the manufacturer what finishing is required for the platform's upper surface, as this depends on the testing conditions desired by the user. Nevertheless the user is strongly advised to place subjects on the platform so that the mean position of the centre of pressure of normal subjects ($x = 0$; $y = -38$ mm; GAGEY *et al.*, 1984) will as a rule be at the mechanical centre of the platform. The position of this mechanical centre must therefore be marked on the platform's upper surface. It is also a good idea to mark the position of the gauges.

5 Standardisation

Users are reminded that a standardisation committee has been established within the international Society of Posturography, whose work deserves to be widely known (KAPTEYN *et al.*, 1983). In clinical practice, for instance, the positioning of the patient on the platform ought to be achieved according to recommendation 8*a* of this committee, if there is no reason for using any other position. Once again the Association Française de Posturologie insists that it is essential to use international units to record results, i.e. N ms; there is no longer any justification for using arbitrary units.

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