From the center of pressure to the center of gravity through a simple calculation

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Previous solutions

Many authors attempted to assess the position of the center of gravity [CoG] from the center of pressure [CoP] by solving differential equations of second degree expressing the mechanics of the inverted pendulum. They were forced, either to circumvent the lack of knowledge of initial data through various means, (Spaepen & Vranken 1977; Shimba 1984; Levin & Mizrahi 1996; Morasso & Spada 1999; Barbier & Allard 2003) or to seek first for initial data (King & Zatsiorsky 1997).

Current solution

Simple, effective, rigourous ...

If G_i is a particular solution of the differential equation:

$$P = G + k.G''$$

all the other solutions of this equation are of the form:

$$G_i + f$$

where the functions f, solutions of the $f = k * f''$ equation, are mathematically known and have the characteristic: $f \approx 0$

f is practically zero over the entire measurement interval, except at its limits.

So, all you have to do is calculate the values of a single solution to the differential equation for n positions of the CoP and eliminate some positions at the limits of the measurement interval, where f is not zero; And, for some initial conditions, this calculation amounts to solving a linear equation with n unknowns (Gagey, Ouaknine & Bourdeaux, 2012).

Comparison of solutions

The previous solutions give results very close to the current solution (Fig. 1).

FIG. 1 - Lissajous of the CoG obtained by the current solution (red) and by a previous solution (blue).

Position of the CoG

Only the positions of the CoG allow the measure of the stability of a subject.

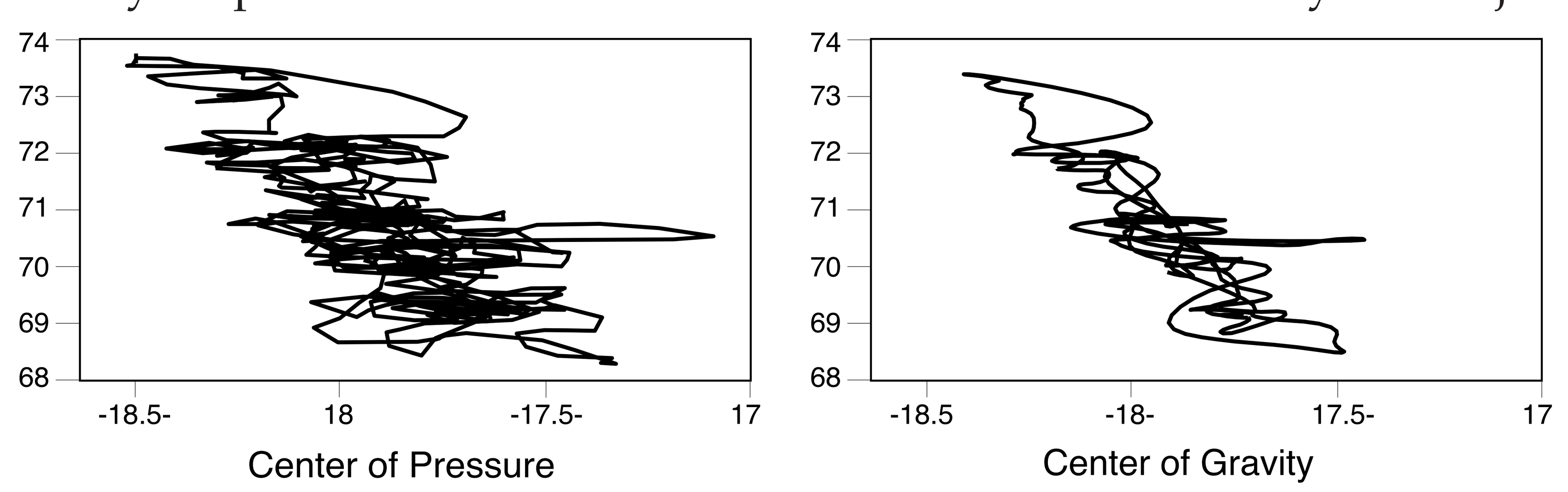

FIG. 2 - Movements of the CoG and CoP of the same record.

The stability expresses the property of a body to return to its mean position whenever moved away from it . The average deviation of the body to its mean position measures its stability. The average deviation of the CoP from its mean position does not measure the stability of a subject.

Speed of the CoG

Only the speed of the CoG has a mechanical meaning. The speed of the CoP does not show anything (Fig. 3).

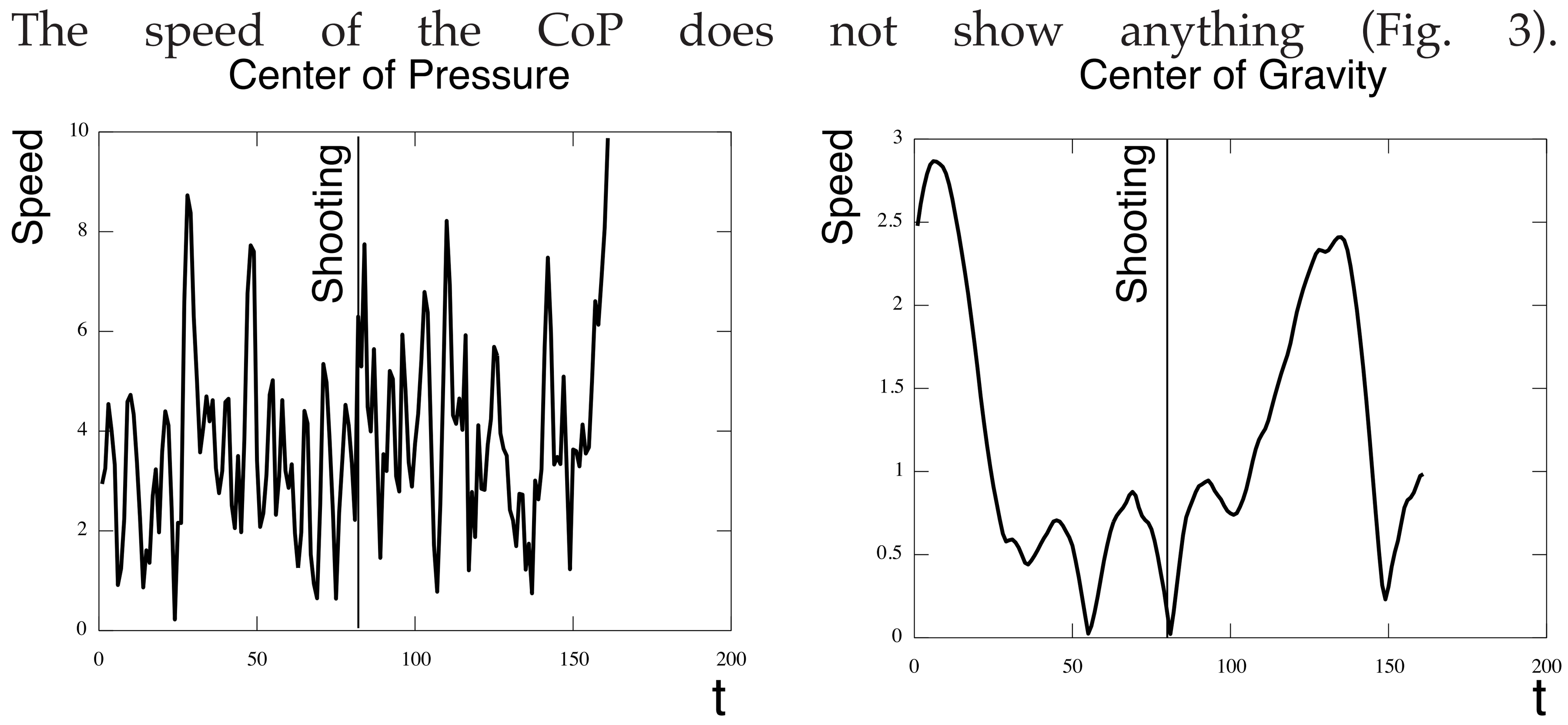

FIG. 3 - Curves of speed according to the time of theCoP and CoG of the same recording at the same times (2 seconds before and after a shooting, only the CoG curve shows that the marksman shoots at the moment when the speed of his body is zero).

Acceleration of theCoG

Only the acceleration of the CoG gives a clear stabilization delay on the diffusion curves (Fig. 4) (Collins et al. 1995). So, the acceleration of the CoG is the best parameter to measure the time constant of the postural system.

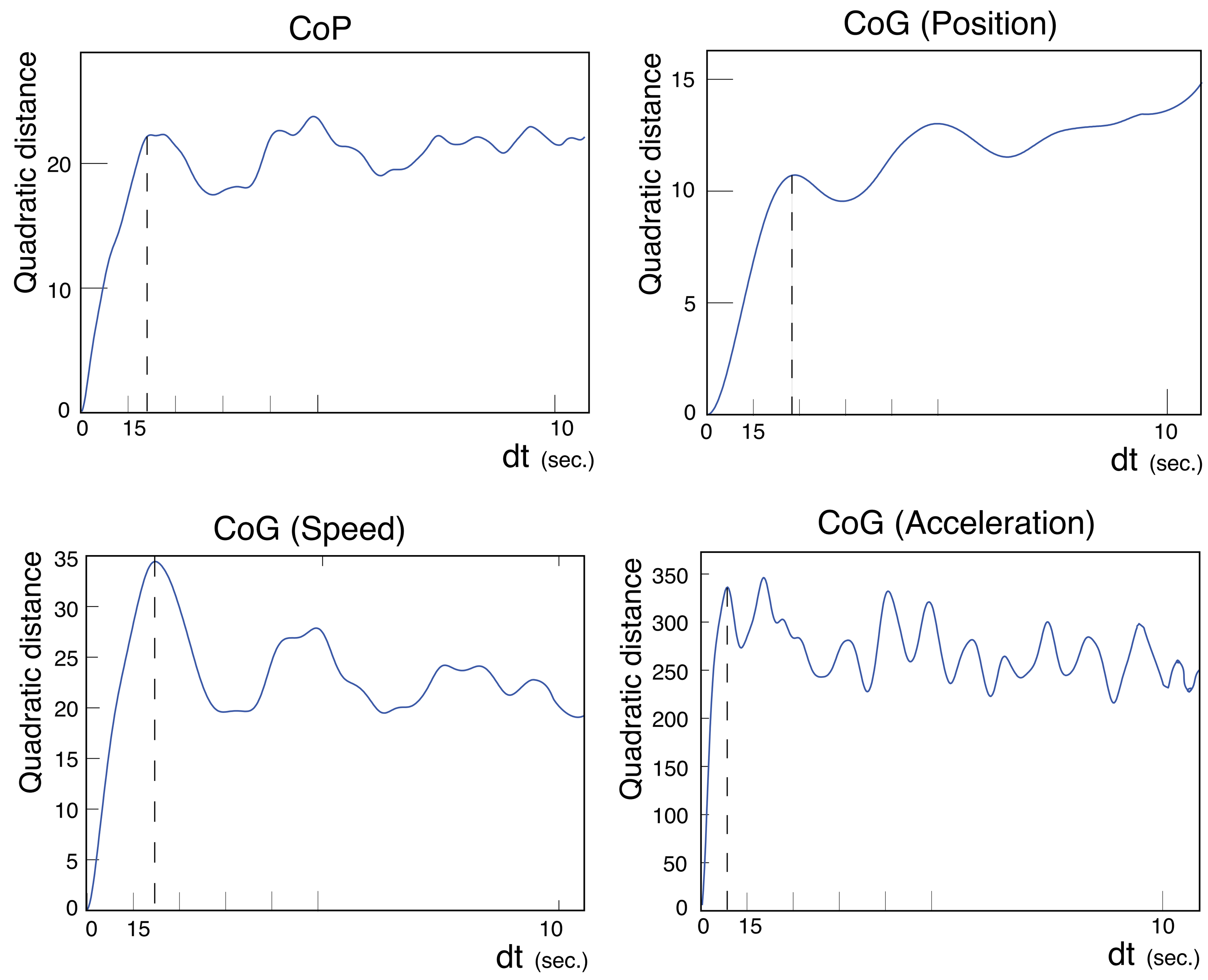

FIG. 4 - Comparison of the stabilization delays of theCoP, position, velocity and acceleration of the CoG.

As the diffusion curve and the autocorrelation curve of a vector are topologically equivalent (Ouaknine 2009) and as it is easier to work on the autocorrelation curve, the time constant of the postural system was defined as the abscissa of the 0.5 crossing of the autocorrelation curve of the acceleration of the CoG (Ouaknine & Boutines, 2011) (Fig. 5).

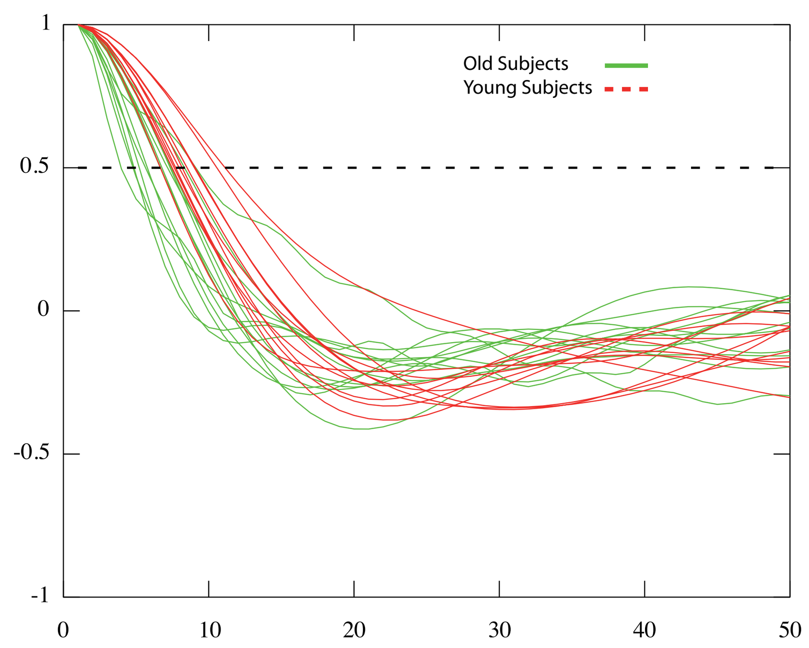

FIG. 5 - Autocorrelation curves of the acceleration of the CoG of young (red) and old (green) subjects. The abscissa of 0.5 crossing of the curve defines the measurement of the time constant of the system. (After Ouaknine & Boutines, 2011)

Length of the CoG displacements

Only the movements of the CoG have a length independent of the sampling rate, the CoP movement length depends on this rate (Fig. 6).

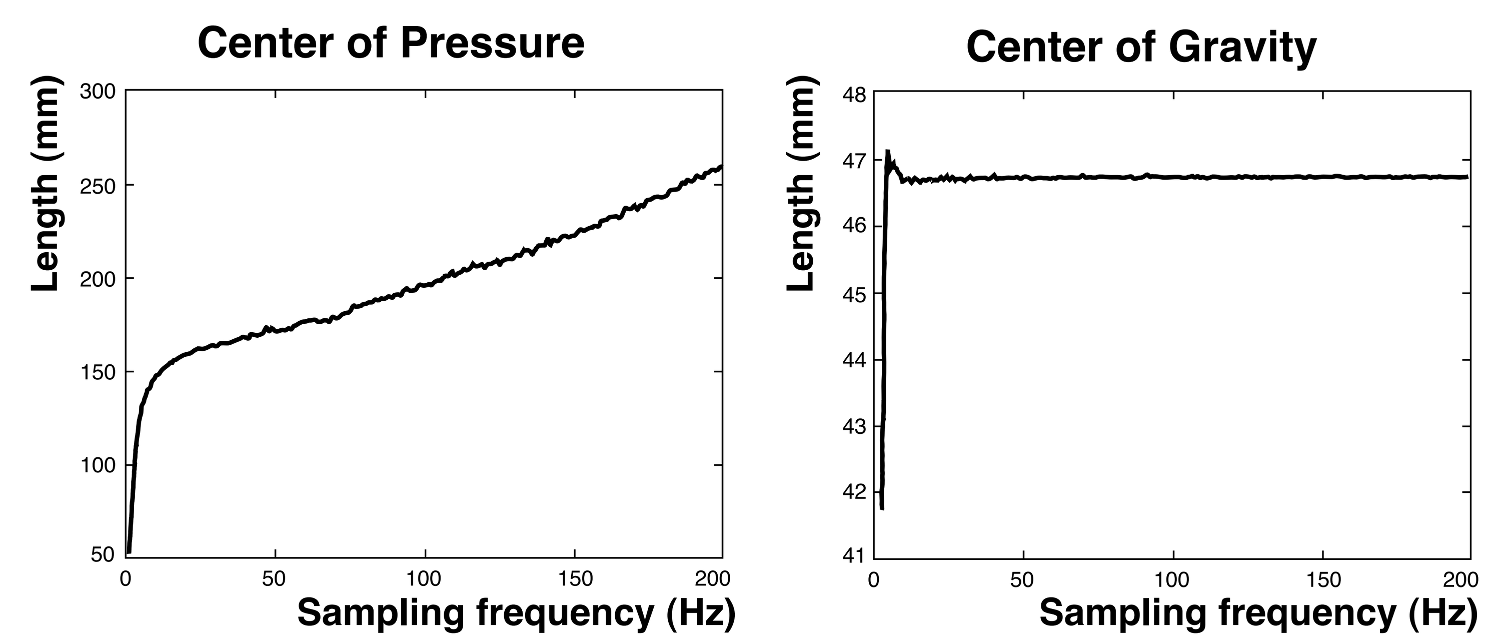

FIG. 6 - Changes in the length of the CoP and CoG displacements according to the sampling rate.

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