Measure of 3D kinematics in sitting posture Implications for seat design

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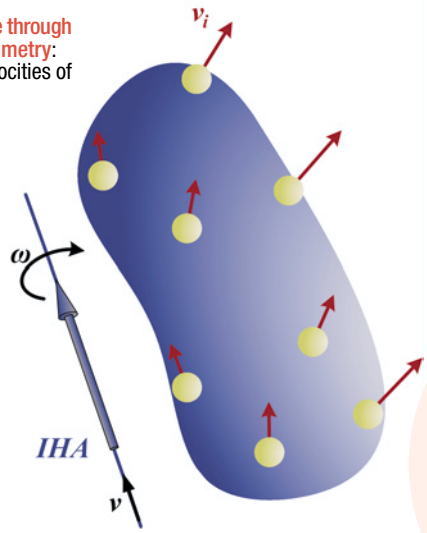
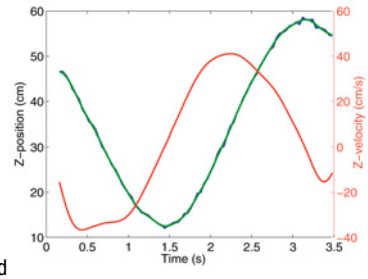
Method

What we measure through stereophotogrammetry: Instantaneous velocities of a set of markers



What we search: Instantaneous Helical Axis (IHA)

The positions of the markers at each instant are recorded by stereophotogrammetry. These positions are time functions which are smoothed through local cubic regression, thus obtaining their derivatives (velocities) too.



If markers are attached to a rigid body, their velocities are used to calculate the angular velocity of the body (ω) [1] and its linear velocity at the geometric center of the markers (v_g) [2]. These parameters have a linear behaviour; therefore, they may be summed for the analysis of composed or relative movements. At least 3 nonaligned markers are needed, but more may be used; thus there will be an overdetermined problem in which deformation effects will be cancelled, and errors reduced.

$$I\,\omega = L_g = \sum_{i=1}^{n} r_i \times v_i \qquad [1]$$

$$n\,v_g = p = \sum_{i=1}^{n} v_i \qquad [2]$$

Any rigid movement may be represented as a screw through some Instantaneous Helical Axis (IHA).
From the angular velocity (ω) and the linear velocity of the geometric center (v_g), the IHA position may be calculated through the formula [3].

$$OH = OG + (\omega \times v_g) / \omega^2 \qquad [3]$$

Why IHA?

Abnormal locations of the IHA in spine movements may be associated to injuries, and its characterization may be also useful for the mechanic design of chairs and other seating systems which conform body movement, as recommended by ergonomic studies.

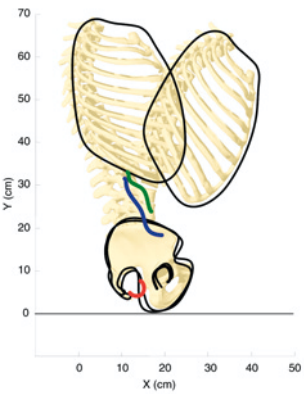
The problem

The experimental determination of the IHA in human movement is usually difficult, due to its extreme sensitivity to errors. Even modern techniques like optoelectronics, widely used for recording human movement, introduce small errors in the position of recorded markers, which may become large errors in IHA determination.

The solution

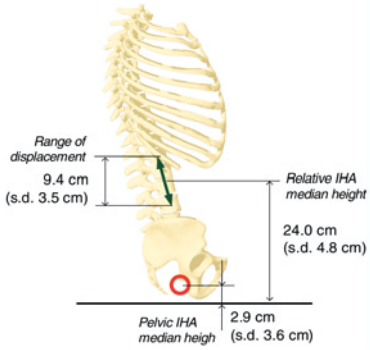
Thorax and pelvis were marked with **8 reflective markers** each; they were not directly attached to subject's body, but to metallic rods firmly tied to the corresponding body parts, which extended out of the body for achieving a distribution with **great inertia** and **centered around the rotation axes**, according to Woltring's criteria for minimizing the error. This achieved an error in the IHA with an standard deviation of 0.3 degrees for the orientation, and of 3 mm for its location

Results



IHA of human trunk flexion movement in sitting posture
Trajectories of the IHA. RED: Pelvis; BLUE: Thorax; GREEN: Relative movement.

Location and displacement of the pelvic and relative movements axes
All IHA of human movement are located over the seat. The IHA of the relative movement is displaced vertically along the lumbar spine during flexion.



Articulated chair mechanisms
The axes of articulated chairs mechanisms, on the contrary, are usually fixed below the seat pan. This leads to a mismatch between chair and human trunk movement, which is a possible cause of discomfort in dynamic sitting.

Possible improvements in chair movement analysis and design
The information provided by these experiments in simple controlled settings should be complemented with more complex studies in order to learn how does trunk kinematics change as a result of sitting on actual chairs.

Once trunk kinematics in realistic environments be known, the design of chairs for dynamic sitting could be improved changing the type or location of their mechanism joints, so that the chair axes be aligned or near the axes of human movement.

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