JOINT CO-ORDINATE SYSTEM AND ATTITUDE VECTOR: INFLUENCE IN THE INTERPRETATION OF MOVEMENTS

Juan V. Durá, Arturo Forner, Ana C. García, Roberto Ferrandis, Gabriel Brizuela.

Institute of Biomechanics of Valencia (IBV). Valencia, Spain.

INTRODUCTION

In movement analysis there is great interest in describing the relative position of body segments from an anatomical point of view, with three angles that denote, respectively, flexion-extension, internal rotation-external rotation and abduction-adduction. To define a 3-D body segment position the general steps are: 1) Calculation of the 3-D position of markers fixed over the body segment, three markers at least. 2) Calculation of the attitude or orientation matrix **R** and position vector **p**. 3) Expression of the **R** information in three angles referred to three anatomical axes: $\mathbf{y} = \mathbf{R}\,\mathbf{x} + \mathbf{p}$; where **x** is the position of a point in the body segment's local coordinate system,and therefore constant, and **y** is the same point in the global coordinate system. If we have a proximal body segment ($\mathbf{R}_p$) and a distal body segment ($\mathbf{R}_d$) the relative attitude matrix distal respect proximal is $\mathbf{R}_{pd}=\mathbf{R}_p'\mathbf{R}_d$, where $\mathbf{R}_p'$ is the transposed matrix. There are different methods for expressing $\mathbf{R}_{pd}$, the most popular ones are Joint Coordinate Systems (JCS), also known as Cardinac angles, and the attitude vector that has the direction of the finite helical axis (FIH). A JCS expresses the attitude of a body segment like three consecutive rotations around the axes of local reference system and it is possible to select six different orders of rotation. The JCS is the direct interpretation of the angles obtained with triaxial electrogoniometers (Chao, 1980; Grood et al.,1983) but by filming, the researchers can select any other method. The attitude vector expresses the attitude of the body segment like only one rotation around the FIH.

Woltring shows some mathematical advantages of attitude vector (Woltring, 1994): a) It is less sensible to errors than JCS, b) It has less problems of continuity (gimbal-lock effect in JCS), c) the absolute value of the angles are the same describing the position of distal segment referred to proximal or proximal referred to distal, and d) The attitude vector is like a mean of the different JCS. In spite of the advantages that Woltring finds in attitude vector, a lot of researchers prefer the JCS. The aim of this work is to check in a practical case the possible advantages of attitude vector or JCS and to decide which could be the best.

METHODS

A rapid lateral braking movement and a rapid turning movement were recorded with two Photo-Sonics 16 mm cameras at 200 frames/s. To perform the lateral braking movement, the test subject starts from standing position, he makes a lateral jump stopping with the right foot and comes back to the original position. The turning movement is a 90° degrees turning movement made as fast as possible being the right foot the supporting one. Four body segments were defined: foot, leg, thigh and hip. Three markers were used to define the 3D position of each segment. The position of the markers on the skin was selected following the criteria that the movement of muscles and skin had not a big influence on the measurements. Different trials were done until the best position of the markers was found. The criteria to do this was to minimize the change of the distances between the markers that define the movement of one body segment and to avoid any trends in the change of distances. The best result was that the distances between the three markers that define each of the different segments did not change more than 5% and this variation was without any trend.

To define the anatomical axes, the anthropometrical model proposed by Vaughan et al. (1992) was used with some variations, because of the supposition that some markers belong to two body segments at the same time is not correct for the movements studied. The anatomical landmarks of Vaughan's model were recorded together with the markers in standing position and the relative position of the anatomical landmarks with respect to the markers was calculated. In this way it is possible to calculate the anatomical frame of a body segment from technical frames in each fotogram (Cappozzo, 1995). The original model considers that there are anatomical landmarks that belong to two body segments. This supposition is not correct in sports where the movements are faster and wider and could give erroneous results if the body segments are not completely independent. For this reason, the anatomical landmarks were duplicated, for example, the relative position of femoral epicondyle was calculated twice in standing position: respect the markers of thigh and respect the markers of leg. Therefore, during the movement, we have one femoral epicondyle that is considered as a part of the thigh and another as part of the leg. In this way, it is possible to calculate the local reference systems of body segments with the security that they are independent. The coordinates of markers were calculated with the DLT and every marker was smoothed separately with general cross validation (GCV) using quintic B-splines.

RESULTS

To observe the influence of the different JCS versus attitude vector the angles of the three joints (hip, knee and ankle) were calculated and represented. In the braking movement the time represented starts when the foot contacts the floor and finishes when the foot takes off. In the turning movement the time represented starts when the subject initiates the movement and finishes when the foot takes off. The origin of angles (0 degrees) is considered to be the standing position. The different JCS defined are:

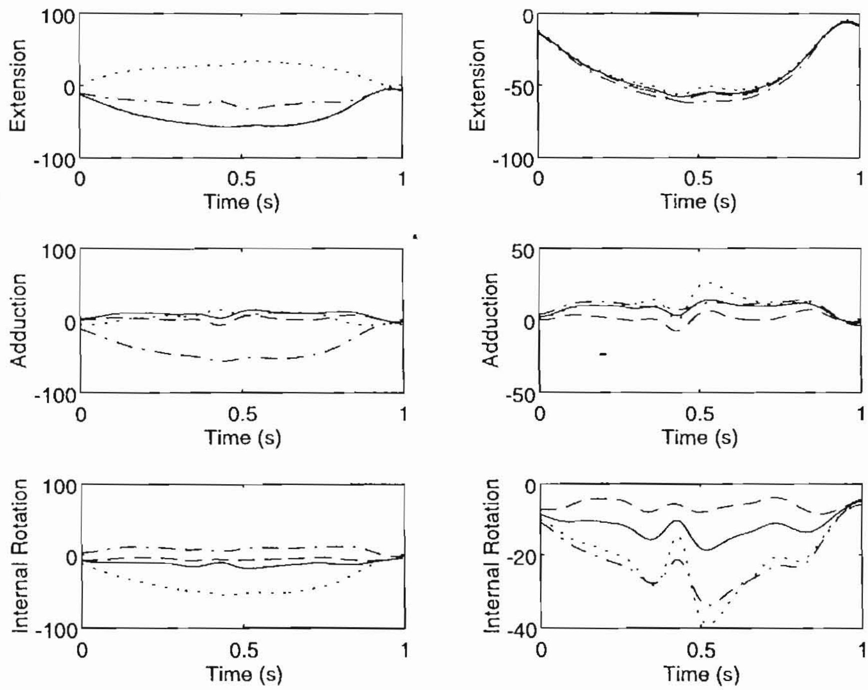
JCS-3	JCS-2	JCS-1	JCS+1	JCS+2	JCS+3
213	321	132	123	231	312

Where the axis 1 is the flexo-extension axis, axis 2 is the add-abduction axis (supination-pronation in the ankle) and the axis 3 is the internal-external rotation. The numbers 213 indicate the order of axis computation.

The results are similar to those obtained by Woltring (1994) in a slow walk, the vector attitude is like a mean of the different JCS and the selection of JCS can change to a great extent the interpretation of movement.

In the two movements studied the angle's curves calculated with the attitude vector have a form similar to those of the curves calculated with JCS-1 and JCS+1 which the Joint Coordinate Systems recommended as standard in Cole et al. (1993) and ISB (1995), but the absolute value of the angles is displaced. It is clear that the selection of the JCS has an influence in the angle's value and, in some cases, it can change the description of the movement. There are some JCS that change the description of movement in a wrong direction. In lateral braking movement JCS+3 changes the hip flexion for hip extension and knee flexion for knee extension. And JCS-3 changes hip adduction for hip abduction and hip internal rotation for hip external rotation.

In the turning movement JCS+2 changes hip flexion, hip adduction, knee adduction and ankle supination. JCS+3 changes hip flexion, hip adduction, knee extension and knee internal rotation. JCS-3 changes hip adduction. As an example the figure shows the knee angles in lateral braking movement.



The line drawings in figure correspond to the following:

________ attitude vector _ _ _ _ _ JCS+1 (left), JCS-1 (right)

_ . _ . _ . _ . JCS+2 (left), JCS-2 (right) .... JCS+3 (left), JCS-3 (right)

CONCLUSION

In this study it is shown that some JCS could cause an incongruent description of movement. Although the attitude vector has some mathematical advantages, the matter of which is the more anatomical is still open. The attitude vector represents the movement in one helical displacement around an axis. The different JCS represent the movement in three ordered helical displacements around three consecutive axes. More research and studies with different movements are needed to come to an agreement.

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