'Coupled motions' in cervical spine rotation can be misleading. Comment on V. Feipel, B, Rondelet, J.-P. Le Pallec and M. Rooze. Normal global motion of the cervical spine

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Letter to the editor

'Coupled motions' in cervical spine rotation can be misleading. Comment on V. Feipel, B. Rondelet, J.-P. Le Pallec and M. Rooze. Normal global motion of the cervical spine: an electrogoniometric study. Clin. Biomechanics 1999; 14: 462–470

In a recent paper Feipel et al. [1] report a very extensive study on the ranges of motion of the cervical spine. Next to the primary movements, they report additional 'coupled motions'. When, e.g., the subject makes an axial head rotation also the angles of flexion and lateral bending change. This is especially evident in combined motions, as axial rotation combined with neck flexion, see Fig. 3 in [1]. This finding has been reported by several earlier investigators [2,3] and is usually interpreted by the anatomy of the paravertebral joints.

The 'coupling' effect also caught our attention, when we made similar three-dimensional measurements of neck motion. To further investigate the effect we made some experiments with a dummy set-up. The 'dummy head' consisted of a revolving cylinder ('head') mounted on a plateau ('thorax'), which could be tilted to simulate flexion/extension or lateroflexion. As a matter of course, each rotation was completely independent of the other ones. Angles in flexion, extension and lateroflexion were measured with an inclinometer. A protractor of 360° was drawn on the plateau for reading the angle of axial rotation of the dummy head. In the experiment reported here, the plateau was tilted to a fixed angle of 50° to emulate a flexed position. The 'head' was axially rotated, from the neutral position (0°) 120° to the left, to the right and back to neutral, in separate measurements at intervals of 10°. The measurements were done with a Flock of Birds system (Ascension Technology Corporation, Burlington, VT, USA).

Results are given in Fig. 1. It is seen (Fig. 1(a)) that a considerable coupling is detected, while none can have occurred due to the experimental set-up. The angles in the coupled motion are comparable to those in Fig. 3(d) in [1], bearing in mind that maximum axial rotation in our measurements was an unphysiological 120° while Feipel et al. reached a more normal value of 60°. We concluded that the reported 'coupling' effects might well have been due to an artefact.

In part this artefact is due to the rotation sequence adopted for the angular representation of the three-dimensional rotation. A three-dimensional orientation can be represented by three so-called Euler angles [4], but the outcome depends on the order of the order chosen. In our measurements we have defined local coordinates with X-axis horizontal in the sagittal plane (flexion-extension), Y-axis vertical (axial rotation) and Z-axis fore-aft (lateroflexion). These axes have been defined by bony landmarks, nosebridge, chin, C1, C7, Th8 vertebral prominences, etc. The fact that the instantaneous axis of rotation does in general not coincide with one of the local coordinate axes, leads to the effect of cross-talk: rotations about one axis, e.g., the Y-axis, are also visible in the angles of other axes [5].

In Fig. 1(a) the rotation sequence *YZX* has been chosen. It was selected so that the magnitude of the 'coupling' was similar to that reported in [1]. They did not report the sequence for their representation. In the case of their goniometer device (C6000 Spine Motion Analyzer) the sequence is determined by the construction of the goniometer, although the angles can be converted from one angular convention to another.

By trial and error Euler sequences have been found which show the cross-talk effect least, but it could not completely be abolished. For the flexion + axial rotation in our example the sequence *XYZ*, Fig. 1(b) performed best. Recently some new methods for angular representation of 3-D orientations have been proposed: the tilt/twist method [6] and the two-step method [7]. Both methods have been tried, but it turned out that neither solved the problem in question any better than the *XZY* Euler decomposition.

In our opinion the following conclusions can be drawn.

1. In reporting angles of three-dimensional rotations the Euler sequence should always be reported.
2. One representation that always gives the correct angles does not seem to exist at present. The 'best' solution should be searched for every experimental situation. Standardisation is badly needed.
3. As long as no solution is available that can exclude cross-talk effects, any reported coupling effect in cervical spine motion should be interpreted with extreme caution. This is unfortunate, because if such an effect would exist, it might be highly informative on pathological changes in the mobility of the cervical spine.

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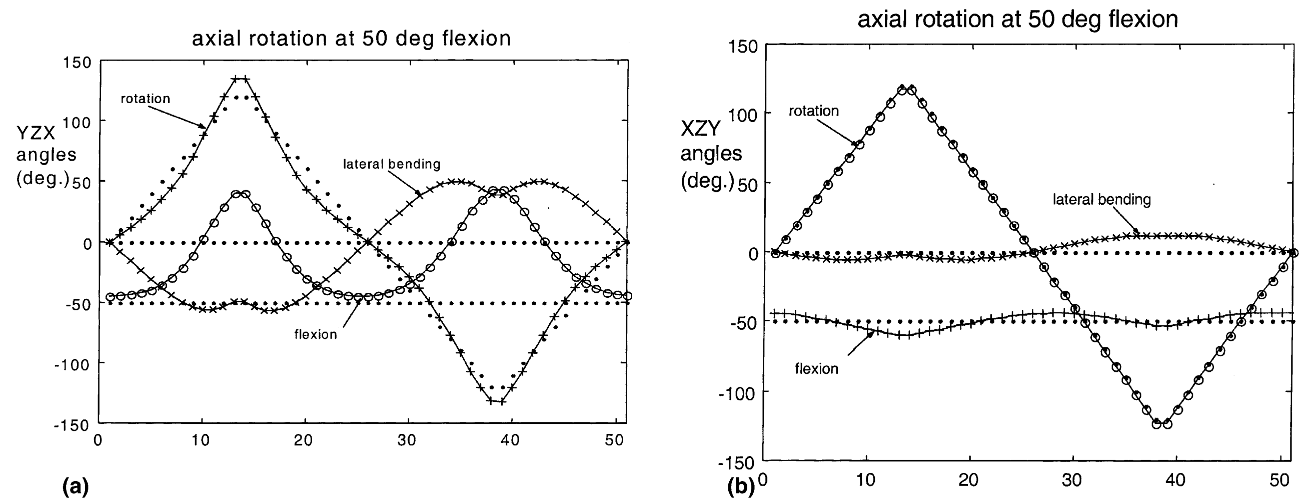

Fig. 1. Measurements with a dummy set-up. The 'head' was axially rotated 120° to left and right in a 50° flexed position. Dotted: true angles. Symbols: measured data represented in (a) *YZX* Euler sequence, and (b) *XZY* Euler sequence, with *X*-axis = flexion/extension, *Y*-axis = axial rotation, and *Z*-axis = lateroflexion. It is seen (Fig. 1(a)) that, although the motion was a pure axial rotation, a considerable 'cross-talk' is recorded in the angles of flexion and lateral bending. When a more favourable Euler sequence *XZY* is chosen, Fig. 1(b), the effect is less, but still present. Positive angles represent rotation to the left, extension, and lateral bending to the left, respectively.

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Response to letter to the editor

'Coupled motions' in cervical spine rotation can be misleading by A.L. Hof, C.L. Koerhuis and J.C. Winters

We would first of all like to thank Hof et al. for raising this issue to the scientific community. In particular, the importance of mentioning the sequence of Euler angles or any other method for representation of joint kinematics used when reporting three-dimensional motion ranges should be a major concern, and we acknowledge that this point is lacking in [1].

The rotation sequence chosen in our study for the processing and epresentation of rotation motion out of flexion was the (axial rotation–flexion–lateral bending sequence). We agree that for instance the (flexion–lateral bending–axial rotation) sequence presented by Hof et al. would have been more appropriate to minimize the cross-talk effects. Another point, related to the discussion raised by Hof et al., concerns the choice of location and orientation of the reference frame in which Euler angles are to be expressed. It would probably be more appropriate to use a reference system build on the

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