Reporting net moments about the lumbar spine [letter]

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Letter to the editor

Reporting net moments about the lumbar spine

In their recent paper in Clinical Biomechanics entitled "Strategies of load tilt and shoulder positioning in asymmetrical lifting. A concomitant evaluation of the reference systems of axes", Gagnon et al. encourage the reader to pick up the debate on reporting net moments about the lumbar spine (Clinical Biomechanics 15 (2000) 478–488). This debate was opened or perhaps better reawakened in two recent letters to the Journal of Biomechanics [1,2]. In our response letter we argued for reporting net moments around the lumbar spine in a reference system derived from markers on the pelvis rather than from markers on the thorax as used by Gagnon et al. Mathematically the choice is arbitrary, but as we argued previously anatomical interpretation of the data may depend on the choice of axis system. For this reason, we favoured a pelvis-based system, the arguments for which have been given previously. Nevertheless, we do feel that it is important to react to the present paper, since it contains new elements for the discussion. In the present paper, Gagnon et al. take this debate one step further by directly comparing the results for these two reference systems and in addition by adding a third option, a joint reference system.

Although it may be feasible for an experienced biomechanist to keep in mind the limitations to interpretation resulting from the reference system chosen and if necessary to convert results from one reference system to another, this is certainly not straightforward for the end-user of our results. The results presented by Gagnon et al. nicely point out the importance of the choice of a reference system with respect to the inferences one might arrive at. Presenting the net moment in one axis system or another could result in a different advice with respect to the optimal lifting technique. In other words, the net moments do not provide unambiguous information with respect to low back load for someone not familiar with this type of analysis.

Although the use of a joint axis system is new in this paper, previously raised objections with respect to the trunk axis system do hold for the present version of the joint axis system. In our view the axis system can be connected both to the proximal member at a joint, or the distal member, or a system can be based on the orientation of both members, although non-orthogonal axes systems, such as the joint co-ordinate system make the interpretation of moments even more complicated. However, when considering the load on the L5-S1 joint, the proximal member is L5. The orientation of L5 can in our view not be determined accurately from markers at the level of C7. Had the orientation of the proximal member in the study of Gagnon et al. been derived from markers at L5, then the differences between the three axis systems would have been limited because of the relatively small excursions of L5 with respect to S1.

Is the problem solved then by choosing a reference system based on S1 orientation, on L5 orientation or both, as we have previously argued [2]? We now think not. As Gagnon et al. correctly point out, such a reference system may show an absence of asymmetrical moments while considerable asymmetry of posture is present. Obviously, the net moment is a result of the forces produced by the trunk musculature and the geometry of this musculature is affected by the asymmetry of posture. Consequently, asymmetrical activation of muscles will underlie this symmetric moment and very likely asymmetric loading of the L5-S1 joint (or any other lumbar joint) will occur. This problem can be solved in an obvious way. Quantification of back load in terms of compression and shear forces acting on the joint dictates an unambiguous choice of reference system, i.e., a reference system directly connected to the anatomical structure studied. In the case of the lumbar intervertebral joints, this leaves a choice between a system connected to, for instance, the upper endplate of the lower vertebra, or the lower endplate of the upper vertebra at one joint level, but this will entail only small differences. In conclusion, we would therefore suggest that the analysis of tasks involving asymmetric loads requires us to make the step from quantifying back load in terms of net moments to quantify back load in terms of the forces acting on the spine.

One could take this argument even further considering that the asymmetry of posture will also entail deformation of, for instance, the intervertebral disc, which would affect the tissue loads resulting from these forces [3]. The obvious disadvantage of quantifying back loads in terms of spinal forces is the fact that the number of assumptions in the modelling required increases and the validity thereof is unsure. This problem further increases when quantifying tissue loads. Obviously, part of our

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efforts should be aimed at validating and improving the models used, but in applied studies we need to make a reasonable choice between the methods available at present. With the end-user of our results in mind, it seems pragmatic (and feasible) to extend our analyses of spinal loads (in asymmetric tasks) to the level of forces acting on the intervertebral joints. In view of the assumptions involved in the estimation of these forces, it is our contention that the best report of results also contains information on the underlying net moments and (asymmetry) of posture. Evidently, presenting these net moments in the axis system of the spinal forces will facilitate interpretation. When forces on L5-S1 are reported this axis system would closely follow a conventional pelvis axis system, but it would be inclined with respect to the pelvis axis system, since the latter is usually defined as vertical in upright stance. For reporting of posture a thorax-based reference system as used by Gagnon et al. is needed, since the position of the thorax with respect to the pelvis largely defines the geometry of the musculature.

References

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Reply by authors

Joint coordinate systems of axes for coherence in reporting kinematic and kinetic data

It is with great interest that we read the letter to the editor by Dr. van Dieën and Dr. Kingma about our paper ‘Strategies of load tilts and shoulders positioning in asymmetrical lifting. A concomitant evaluation of the reference systems of axes’. The authors seem to discourage the users from adopting a joint system of axes on the ground that it is not straightforward and somewhat complicated because it is a non-orthogonal system. We do not agree with this position as our paper is addressed to scholars in biomechanics; some researchers in biomechanics may not be familiar with this approach, but the developments have been nicely presented by Fujie et al. [1], and the mathematics can be grasped by researchers with a solid formation in mechanics. They have described mathematically the six-degree-of-freedom forces and moments with respect to a commonly used knee joint coordinate system (namely the joint system described by Grood and Suntay [2]) by performing a $[6 \times 6]$ Jacobian matrix, and they stressed that it is critical to describe the kinematic and kinetic information with respect to the same coordinate system. At this point, it is important to mention that the problem addressed here refers to a 3D representation of moments not different from the problem of 3D representation of angles. We therefore support the view of Fujie et al., especially in studies dealing with the description of asymmetries of posture and efforts. However, this does not eliminate the problem of selecting the axes, one on each segment forming the joint.

Drs van Dieën and Kingma suggested to go one step further and quantify back load in terms of the forces acting on the spine rather than only net moments using one of the two vertebrae; they further suggested the use of the thorax to represent the geometry of the musculature. We believe that to pass from a model representing net moments to a model representing internal forces does not per se represent a solution, since it does not remove the problem of defining axes in any case. Moreover, even if we agree that the use of a small element characterised by L5 could probably reflect better what is actually occurring at this level as compared to larger segments, the sensitivity to torsion would probably be lost due to the very narrow distances (heights) between markers required to define the longitudinal axis of this small element and hence, torsion. As Kingma et al. [3] pointed out, our trunk reference system will not be sensitive to torsion in certain postures. We have also demonstrated at the ISB conference in 1999 in Calgary that the reciprocal can also be ap-

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