Comments on 'Estimation of instantaneous moment arms of lower-leg muscles' - reply

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LETTERS TO THE EDITOR

COMMENTS ON 'ESTIMATION OF INSTANTANEOUS MOMENT ARMS OF LOWER-LEG MUSCLES'

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The authors of the above paper (*J. Biomechanics* **23**, 1247–1259) have conducted a kinematic assessment of joints in the leg to assess the values of moment arms. Generally, moment arms of muscles and ligaments are of use to infer loads in the relevant structures from calculated values of moments due to external and mass related forces. This procedure is valid, provided the resultant joint force vector intersects the axis of rotation. This patently is the case if the bearing surfaces are cylindrical and friction is negligible. It is suggested by various authors that the lever arms should be measured from the instantaneous axis of rotation of the joint. This is realistic for the hip, but in the knee the relative rotational movements are complex and three-dimensional. It is suggested by others that the knee as a four-bar linkage allows the definition of an instantaneous centre of rotation and that moments should be taken about axes through this centre. Conceptually, this is ideal if the resultant joint force vector intersects this axis. This may well be the case for surfaces developed from four-bar linkage analyses if the contact is presumed to be over an infinitely small area. However, in actual joints this cannot be the case and depending on the compliance of the articular surfaces and the regime of lubrication present, pressure will be developed over a finite area on surfaces which are of complex geometry.

It would be interesting if Dr Spoor and his co-workers or other analysts could determine whether the vector of the resultant joint force passes through any of the defined axes systems in this situation.

AUTHORS' RESPONSE

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In the calculation of muscle and ligament forces from a given resultant joint moment, one can discern two stages. First, the joint moment must be distributed over various components, and second, the moment and moment arm of each component are used to calculate the force. The first stage becomes complicated if the joint reaction force does not intersect the instantaneous motion axis, since this quality of the joint force introduces an unknown contribution embedded in the total joint moment. However, there are no direct consequences for the moment arms of the muscles: they can still be defined relative to the instantaneous axis. In this respect, the complexity of the motion is not relevant, whether it is two- or three-dimensional, or whether the axis is fixed or controlled by a four-bar system.

When a joint force does not intersect the instantaneous axis, the joint either dissipates, accumulates or releases energy during motion. Causal phenomena are friction, ligament strain and cartilage compliance. These will generally also influence the position of the instantaneous axis. Non-intersection of the joint reaction force with the instantaneous axis will affect the values of the moment arms through the axis position, but the definition of the moment arm remains the same.

Calculating the moment arms from tendon travel and joint angulation, as in our study, has the important advantage over direct measurements that no axis position and no muscle line of pull are required. Axis positions and joint forces were not determined, as they were not needed. Since reversing the motion resulted in different moment arm curves (maximum difference 2.6 mm, see Fig. 6a), we must assume that friction was present and that the joint reaction force did not exactly intersect the instantaneous motion axis.