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Antagonistic activity of one-joint muscles in three-dimensions using non-linear optimisation.

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Summary: Nonlinear optimisation, such as the type presented by *R. D. Crowninshield* and *R. A. Brand* [The prediction of forces in joint structures: Distribution of intersegmental resultants. Exercise Sports Sci. Rev. 9, 159 ff (1981)], has been frequently used to obtain a unique set of muscle forces during human or animal movements. In the past, analytical solutions of this optimisation problem have been presented for single degree-of-freedom models, and planar models with a specific number of muscles and a defined musculoskeletal geometry. Results of these studies have been generalised to three-dimensional problems and for general formulations of the musculoskeletal geometry without corresponding proofs.

We extend the general solution of the above nonlinear, constrained, planar optimisation problem to three-dimensional systems of arbitrary geometry. We show that there always exists a set of intersegmental moments for which the given static optimisation formulation will predict co-contraction of a pair of antagonistic muscles unless they are exact antagonists. Furthermore, we provide, for a given three-dimensional system consisting of single joint muscles, a method that describes all the possible joint moments that give co-contraction for a given pair of antagonistic muscles.

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