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Morphology and Mechanics of Muscle: Two or One?

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The present issue of *European Journal of Morphology* is devoted to a multidisciplinary workshop organised by the Biomechanics Section of the Netherlands Organisation of Scientific Research. Aim of the workshop was to generate a dialogue between engineers, morphologists and physiologists around the theme "striated muscle". The complexity of muscle architecture on the one hand and the fast growing technological development both on the level of computer facilities for modelling and on the level of advanced experimental techniques has turned of muscle research into a subject involving many disciplines. In order to offer to the international scientific community easy access to the developments discussed during the workshop each author has taken time to contribute to this special issue.

The life of any building in the world usually goes through four distinct phases : (1) a phase of design by an architect, (2) a phase of construction, (3) a phase of use and (4) a phase of dismantling. Usually only limited excursions from this scheme are admissible. In the case of biological tissues and more particularly muscle tissue, scientists are faced with a very complex structure which is continually reshaping itself according to the needs of its function. Design, construction, use and dismantling are simultaneously present on all levels of the structure and all phases of its existence. So many aspects of the design seem inextricably linked to the function of the organ. Studying the design without thorough understanding of the function is like studying a road infrastructure without knowledge of traffic. Therefore, the design of the workshop, reported here in this issue, is willingly involving a myriad of disciplines engaged into muscle research. This has been done nonobstant the language barriers between the different disciplines. The authors and the reviewers of the articles have done their utmost best to avoid the jargon of their specific discipline as much as possible. We hope the reader will show indulgence for shortcomings in some aspects of this endeavour.

Today we see a remarkable upsurge of interest for muscle mechanics in the Netherlands. No less than three authors present muscle models trying to abondon limitations of classical mathematical models which reduce muscles to contracting strings or parallellograms. Including more realistic morphology is a target which numerous morphologists will support. Huijing presents on the basis of own experimental data and data from the literature a plea in favour of including initial non-homogeneity of sarcomere length distributions as well as changes in sarcomere length distributions during deformation.

Advanced experimental techniques are required both for the quantification of morphological and physiological input parameters and for validation c.q. falsification of the model predictions. Magnetic Resonance Imaging of water diffusivity is used by van Doorn et al. for 3D reconstruction of muscle fiber orientation. This promising technique is still under investigation and requires testing of accuracy. If successful, it offers a perspective of a fast and non-invasive method of reconstruction of muscle fiber architecture. Considering the high sensitivity of models to chosen fiber orientations (Huyghe et al., 1992, Bovendeerd et al., 1992), the predicting capability of muscle models might be greatly enhanced by this method. Heslinga et al. measures intramyocardial pressure in a contracting papillary muscle using the servo-nulling micropipette technique. Pressure is probably the only stress measure which at persent is experimentally quantifiable inside muscle tissue and is an important determinant of regional blood perfusion.

Recent porous media models (Vankan et al) , inspired by the impressive work done in the field of soil mechanics in civil and petroleum engineering, are extending mechanical modelling beyond the traditional fields of stress and deformation, to blood perfusion and blood pressure distributions. Koolstra et al. present a model of the masticatory muscles coupled to a maxillomandibular joint model. The senstivity of the model to the shape of the joint surface indicates that muscle models work only when coupled to accurate joint models.

The traditional approach to muscle modelling is the forward analysis. From morphological and physiological data of the muscle and its external loading, predictions are made with respect to deformation and stress. The formidable task of providing the correct input data to these models has hampered a detailed experimental verification of these models. This gap between the experimental and analytical field is addressed in this issue both from the experimental as from the modelling side. From the experimental side, van Donkelaar et al. present a three-dimensional reconstruction of the rat triceps surae muscle and translate their data directly into a finite element mesh which is used by Vankan et al. for subsequent modelling. From the modelling side, the approach of Rijcken et al is an interesting one. Rijcken et al. use optimisation techniques to reconstruct the morphology of a muscle from hypothetised design criteria. In this way they perform a reversed analysis in which the input data are highly reduced. The philosophy behind this idea is that the rules underlying muscle architecture should be far more simple than the architecture itself. It is hardly conceivable that the genetic information encoded in the DNA molecule could contain every detail of the musculoskeletal system as a separate item of information. It seems more plausible to assume that the genetic code contains a limited number of rules which results in the construction of the system as it appears to us. In this approach the optimisation criteria are the input and the morphology the output. Morphologic measurements serve as a reference to check the plausibility of the optimisation criteria.

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