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Chapter XIII

Computational Modelling in Shoulder Biomechanics

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ABSTRACT

The objectives of this chapter are as follows. First, a background in anatomy and biomechanics of the shoulder complex is presented to provide a brief review of the essential functions of the shoulder. Second, important features of practical shoulder models are discussed with reference to capabilities of current computational modelling techniques. Third, techniques in computational modelling of the shoulder complex are compared and contrasted for their effectiveness in representing shoulder biomechanics in situ, with some sample calculations included. Fourth, in vivo and in vitro techniques for verifying computational models will be briefly reviewed. Finally, a summary of emerging trends will indicate the clinical impact that computational modelling can be expected to have in progressing our understanding of shoulder complex movement and its fundamental biomechanics.

INTRODUCTION

Computer modelling and simulation of human body kinetics has advanced rapidly in recent years, as it is thought that this approach can provide more quantitative explanations of how the neuromuscular and musculoskeletal systems interact to produce movement. Modelling human pathological movement is also of interest, particularly to rehabilitation scientists in the research and development of musculoskeletal and neurological therapies (Zajac, 1993). Models of human movement have always been desirable due to the high cost of experiments with human cadavers and/or anthropomorphic dummies. Driven by ramping up of computer speed and performance, models of greater complexity are being used to study musculoskeletal function at levels much deeper than have been possible to date.

The study of biomechanics of the shoulder complex constitutes perhaps the most challenging and least successfully modelled regions of the musculoskeletal structure of the human body (Tumer & Engin, 1989). Lack of an appropriate biomechanical database and the inherent anatomical complexity of this region have led to much speculation over the role of musculoskeletal coordination in upper limb movement. This chapter seeks to show how the development of accurate mathematical models of the shoulder complex and simulations of shoulder movement kinematics can be used in elucidating the roles and interactions of specific muscles. Clarifying the complex nature of shoulder musculature function and control would directly enhance clinical predictions in shoulder stability treatment, joint replacement surgery, and rehabilitation.

Shoulder pain after exposure to high or sustained biomechanical strain in occupational situations has shown an increasing incidence in society (Hogfors, Karlsson, & Peterson, 1995). Common problems in assessing pain syndrome etiology in the human shoulder is that, due to the convoluted nature of the shoulder complex, it is often difficult to relate pain localised in certain structures to the actual loads applied to these structures in specific working conditions. For example, the case history of working with hands at or above shoulder level has been shown to constitute a significant occupational risk factor (Bjelle, Hagberg, & Michaelson, 1981). In order to identify occupational risk factors to prevent shoulder pains and the development of degenerative lesions, load distribution in the shoulder must be subject to comprehensive analysis. Such assessments are greatly enhanced with biomechanical models of the shoulder complex, particularly models embracing both the kinematics of the bones involved and the muscle forces between them.

To describe the mechanical behaviour of a musculoskeletal system such as the shoulder complex, and in developing a stable and manageable model of the system, many of its physiological characteristics must be considered. In particular, knowledge of musculoskeletal parameters is essential to understanding and modelling a muscle's force generating capability, for example, physiologic cross-sectional area (PCSA) relates directly to the maximum force a muscle can produce (Zajac, 1989). Anthropometric measurements and values of muscle-specific parameters are normally determined by cadaveric studies, through in vivo techniques such as MRI and fluoroscopic imaging, or computed using parameter estimation algorithms (Bao & Willems, 1999). This chapter reveals how studies of musculoskeletal parameters become essential in providing guidelines and limitations in computational simulations of shoulder movement.

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