### Introduction / Aim / Methods / Results / Conclusion / Acknowledgement

**Introduction**

In recent years, the advent of new tools for musculoskeletal simulation has increased the potential for significantly improving the ergonomic design process and ergonomic assessment of design. In this paper we investigate the use of one such tool, 'The AnyBody Modeling System', applied to solve a one-parameter and yet, complex ergonomic design problem. The aim of this paper is to investigate the potential of computer-aided musculoskeletal modelling in the ergonomic design process, in the same way as CAE technology has been applied to engineering design.

**Aim**

To demonstrate how advanced computer musculoskeletal modelling can nowadays be used to assist in the design process, a simulation of a sawing task involving the fish saw was performed using the AnyBody musculoskeletal modelling system. This simulation involved a simple sawing task in which the effects on muscular effort arising from small changes in the placement of the handle were investigated.

**Methods**

A musculoskeletal model of a human operator using a hand saw was constructed in the AnyBody Modeling System (ver. 4.1, AnyBody Technology A/S, Denmark). The AnyBody Modeling System uses recorded motion as input into the model. Inverse dynamics and a muscle recruitment algorithm, based on optimization, are then used to predict redundant muscle actions, and/or joint moments responsible for the motion. This entails solving a series of dynamic equilibrium equations within the biomechanical model which leads to the calculation of joint reaction forces, mechanical work and other properties that are useful to the assessment of human performance.
Results
Analyses were performed with variable handle offsets of -50, 0, 50, 100, 150, 200, 250 and 300 mm, where positive values designate handle positions above the blade. It becomes easier for the operator to advance the saw as the blade moves forward over the work piece. It can also be seen that the muscles are overloaded (i.e. above 100% relative muscle activity) at the beginning of the stroke for all handle positions. Under normal circumstances, the operator is likely to manage this situation by reducing the normal force acting on the saw in order to advance the saw. The analysis also reveals that the effort required to drive the movement forward depends on the height of the handle above or below the blade, and that an increase or reduction in relative muscle activity with handle displacement occurs across the entire movement. This means that the effort of driving the saw can be represented by the effort at a single point in the movement. This effect can be clearly seen by plotting the muscle activity envelope at the beginning of the stroke against the offset position of the handle. It appears that an optimum offset exists at a handle position of approximately 200 mm, and also that this optimum is rather flat in the sense that handle offsets between 150 mm and 250 mm result in almost similar levels of muscle activation.

Conclusion
The musculoskeletal modelling example of the sawing task suggests that it is advantageous from an ergonomic perspective to move the handle position of the saw upwards with respect to the blade, such that the blade is not directly extending the forearm, but located somewhat below it. Musculoskeletal simulation appears to offer the potential to substantially improve the field of ergonomic design and assessment in the same way that, for instance, finite element analysis has fundamentally changed the engineering design process.

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