SUMMARY

The electromyogram (EMG) is the electrical signal which can be led off by means of electrodes from active skeletal muscles. In this thesis we describe how to determine the muscle force from this signal for any kind of contraction. Starting point is the assumption that the intensity of the EMG signal is a measure of the activity, more specific: of the active state, of the muscle. Apart from its activity, the force developed by the muscle is also dependent on its length and shortening velocity. Mechanical properties of muscle have been extensively studied in physiology. They can be described by means of muscle models, of which the Hill muscle model is one of the best known.

The essential part of the EMG to force processor is an electrical analogue of the Hill muscle model. Input signals of this analogue are the rectified EMG and the angle of the joint moved by the muscle, which is a measure of the muscle length. Output signals of the analogue are the torque of the muscle force around the joint and the work of the muscle.

The parameters of the muscle model have been determined for the human calf muscles, M.M. soleus and gastrocnemius, plantar flexors of the foot. This has been done with experiments in which the subjects had to perform contractions on instruments with which the muscle torque could be measured. This measured torque could then be compared to the torque computed by the processor in some series of contractions of various types.

The purpose of the processing method is the assessment of muscle torque and work in movement studies, e.g. in walking.

The thesis has been arranged as follows. After a general introduction (Chapter I) Chapter II considers in some more detail both input signals of the analogue: the EMG and the ankle joint angle. The physiological background of the EMG is dealt with and its electronic preprocessing (amplification, rectifying, filtering). An electrogoniometer for the ankle is described.

In Chapter III the relation between EMG and muscle torque is investigated for the simplest case, i.e. quasi-static isometric contractions. It appears that in this case there is a linear relationship between the mean rectified EMG and the ankle torque, provided that the EMGs of soleus and gastrocnemius are recorded
separately and properly weighted. This chapter has been published previously (J. Biomechan. 10 (1977): 529-539).

Chapter IV presents a description of the muscle model and the construction of the analogue. The Hill model consists of three components: the contractile component (CC), the series elastic component (SEC) and the parallel elastic component (PEC). Moreover the rectified EMG must be converted to the 'active state', one of the input variables of the CC.

The next chapters are devoted to results of experiments with dynamic contractions. The aim was twofold: estimating the parameters (Chapters V and VI) and testing the processing method in some types of contractions which cover essentially the whole range of possible muscular activity. (Chapters VI and VII).

Chapter V describes experiments with isotonic contractions on a calf ergometer. This enabled us to determine most parameters of the CC and the PEC.

Chapter VI deals with experiments on a torque plate. The remaining parameters, of the active state and the SEC, could be determined in this way. Moreover the accuracy of the EMG processor was investigated with experiments in which the subject tilted on his toes. As measures the work and the integrated torque were used. For positive work, negative work as well as integrated torque a relative error of \( \pm 6\% \pm 14\% \) (mean \( \pm \) s.d.) was found.

Finally in Chapter VII experiments are described with contractions on a modified bicycle ergometer, in which, in contrast to the tilting experiments of Chapter VI, an eccentric contraction (muscle stretching) precedes the concentric contraction (muscle shortening). It turned out that the processor performance was comparable for both cases.

The results suggest that EMG to force processing can be a useful tool in biomechanics.