Measurements on electrical and mechanical activity of the elbow flexors
Vredenbregt, J.; Koster, W.G.

Published in:
Biomechanics I, 1st international seminar, Zurich, 1967

Published: 01/01/1967

Publisher's Version
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:
• A submitted manuscript is the author's version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher’s website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):
Measurements on electrical and mechanical activity of the elbow flexors

J. VREDENBREGT and W.G. KOSTER

Most of the research in muscle has been carried out on isolated muscles. The information obtained under these conditions cannot often be used to predict muscle behaviour and limb movement, since the isolated muscle is not stimulated by its own nerve system. Moreover, its natural feedback loops are cut off.

The aim of our investigations is to find a description of the mechanical behaviour of muscle contraction in vivo under two conditions, namely the static condition, under which the muscle contracts at constant length, and the dynamic condition under which a muscle shortens during the contraction, causing a movement of the limb.

We have carried out extensive experiments, of some of which a short description is given.

The phenomena measured simultaneously at the wrist of the forearm are:

— the force, exerted by the muscle
— the acceleration
— the degree of shortening and
— the rate of shortening.

All these phenomena were measured parallel to the longitudinal direction of the biceps muscle. Moreover, during all experiments the electromyogram as well as the integrated electromyogram were determined by a specially designed high quality electromyograph.

These phenomena were visualized simultaneously by a recorder. Figure 1 shows the experimental set-up.

The framework consists of a support to keep the subject’s upperarm in a fixed horizontal position. A double segment, which can pivot in
the vertical plane, is fixed to this support. A metal cuff encloses the wrist, while the subject keeps his forearm within the two segments, causing the axis of rotation of the segments to coincide with that of the elbow joint.

To create the static situation the forearm can be set in any position by fixing the segments. For the dynamic situation the segments enable us to load the forearm by fastening various kinds of load to the segments.

The force exerted is measured by a dynamometer, suspended in the apparatus between two rigid horizontal metal strips and connected to the metal cuff by a pair of rods, so as to detect the force acting parallel to the longitudinal direction of the muscles. The position of the wrist, which is related to the muscle length, is determined by a displacement meter, while the rate of shortening as well as the acceleration are measured directly by a speedometer and an accelerometer respectively.

In the static experiments the forearm is fixed at different angles between forearm and upper arm. In this position the subject has also to contract his forearm flexors as fast as possible from zero to maximum effort. A comparison between the mechanical response and the EMG as well as the integrated EMG shows that: 1. the electromyographic activity is almost immediately at a constant value, 2. the force

![Diagram](image)

Fig. 1. General view of the apparatus for measuring simultaneously the degree and rate of contraction, the acceleration and the force of the muscle at the wrist.
builds up about twenty milliseconds later, compared with the EMG and rises slowly in contrast with the electromyographic activity.

The force-time curve is of the same shape as found by Hill (1949) and Wilkie (1950). The shape of the force-time curve clearly shows the existence of elastic and damping properties of the total system.

Comparing the results obtained at different muscle lengths, it appears that the maximum force exerted decreases with smaller muscle length, which is in agreement with data of Wilkie. Moreover, the rate of increase of the force is smaller for a shorter muscle. The EMG, however, shows under maximum effort the same value and shape, in spite of changes in muscle length.

In the dynamic experiments the forearm is moved during contraction.

It was found that the shape and value of the EMG do not differ from those under static conditions. However, by comparing the force-time curves obtained under static and dynamic conditions a great difference is found. Also a considerable difference remains between points on the dynamic force-time curve and those of the static one at corresponding muscle lengths and points of time. This is due to properties of the contracting mechanism. Among these an important one is the friction in the system itself. Besides we ascertain activity of the forearm extensors during their passive extension as a consequence of the contraction of the flexor muscles. This extension will produce a resistive force.

As pointed out already by Buchthal (1951) friction has to be taken into account. This friction is necessary for damping, and our investigations in this field, which are now in progress, give rise to the presumption that the system is nearly critical damped.

To evaluate the amount of resistive force from the electrical activity of the muscle the relation between force at the wrist and the value of the EMG has been determined for the flexor as well as for the extensor muscles under static conditions at steady state levels of activity and at different muscle lengths. Plotting the level of electrical activity as a function of the exerted force, different convex curves are found for different muscle lengths.

Plotting the electrical activity as a function of the ratio between the force exerted at different levels of activity and the maximum force at the same muscle length all these curves appear to coincide without increasing standard deviation. This shows again that the electrical activity is independent of the triceps sartorius values.

In contrast with linear one has been with those of Buchthal already mentioned on this subject expect the authors and the movement...
pared with the EMG graphic activity. 
found by Hill (1949) rve clearly shows the
sum with smaller muscle t. Moreover, the rate 
muscle. The EMG, value and shape, in
med during contrac-
EMG do not differ comparing the force-
conditions a great
 of the static one at me. This is due to
 these an important
we ascertain activity on as a consequence
sion will produce
iction has to be taken
and our investiga-
give rise to the pre-
the electrical activity
rist and the value of
as for the extensor
els of activity and at
ectrical activity as a
urses are found for
of the ratio between
l the maximum force 
 to coincide without
 that the electrical

activity is independent of the muscle length. The corresponding relation for the triceps muscles shows the same shape at different abso-
lupe values.

In contrast with a linear relation found by Lippold (1952), a non-linear one has been found. This non-linear relation is in agreement with those of Buchthal (1942) and Bottomly (1964). Beside the proper-
ties already mentioned, the elasticity behaviour is equally important. Also on this subject experiments are going on and maybe the results will con-
tribute to an understanding of the mechanical behaviour of the flexors and the movement pattern of the forearm.

References


Lippold, O.C.J.: The relation between integrated action potentials in a human muscle


Author’s address: J. Vredenbregt and W.G. Koster, Instituut voor Perceptie Onderzoek, Insulindelaan 2, Eindhoven (The Netherlands).