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MUSCLE FUNCTION IN KNEE EXTENSION

An EMG Study

By

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In clinical orthopaedic work one often encounters problems concerning the function and exercise of the quadriceps. After traumata in the knee region, including surgical trauma, it is important that the function of this muscle should be recovered rapidly and completely. During its exercise there is not infrequently a residual active-extension defect in the knee-joint, although there is no interference with full passive extension. Even after properly planned and executed exercise of the quadriceps and maximum effort, the patient is unable to perform the last 10–15° of the extension. In the present study the part played by the various portions of quadriceps during extension was examined by electromyography under normal and pathologic conditions. The study is a continuation of a series on the function and mobility of the knee-joint (4–8).

MATERIAL AND METHODS[1]

A six-channel EMG apparatus was used (Grass, Polygraph model 5). Synchronous recordings were obtained with surface or needle electrodes from the vastus lateralis, rectus femoris and vastus medialis muscles. They were performed during maximum isometric contractions of the quadriceps in the recumbent and seated positions, and with the knee-joint in different positions between 90° and extension—that is, the position where a firm resistance is encountered, whether at 180, 185 or 190°.

Fifteen normal subjects were examined in this way. Special attention was given to the following points: (1) Whether there was any difference in the activity from the three muscles, (2) whether there was any interval between the onset of activity in the different portions of the quadriceps muscle, and (3) the difference in these

[1] The study was planned in consultation with L. E. Larsson, M.D., former head of the Department of Neurophysiology, Umeå.

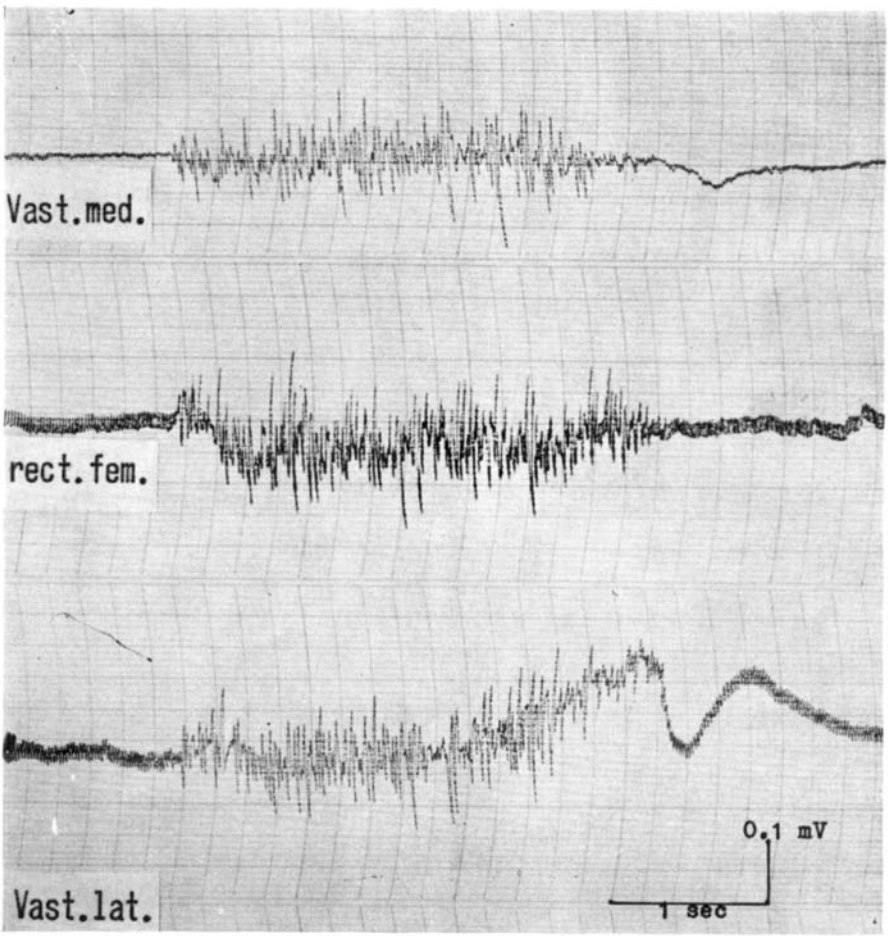

Figure 1 A. EMG with simultaneous recording from different portions of the quadri ceps muscle (surface electrodes). Healthy man aged 19 years. Recumbent with knee flexed 90°. Powerful activity was obtained.

two respects for various angles of the knee-joint, in the seated and recumbent positions.

The examination was also performed on 8 patients that had recently undergone knee operations, and who, probably owing to pain, had not been able to raise the leg from the horizontal, and on 7 patients who had older lesions in or near the knee-joint. A few months after the lesion these still had an active-extension defect of about 10° in the knee-joint. Finally, examinations were performed on 4 subjects in whom the vastus medialis had been blocked *in loco* with a local anaesthetic (Citanest, 0.5 per cent, 20–80 ml). EMG recordings were made at intervals of about 5 minutes before and after blocking, and with surface electrodes in place.

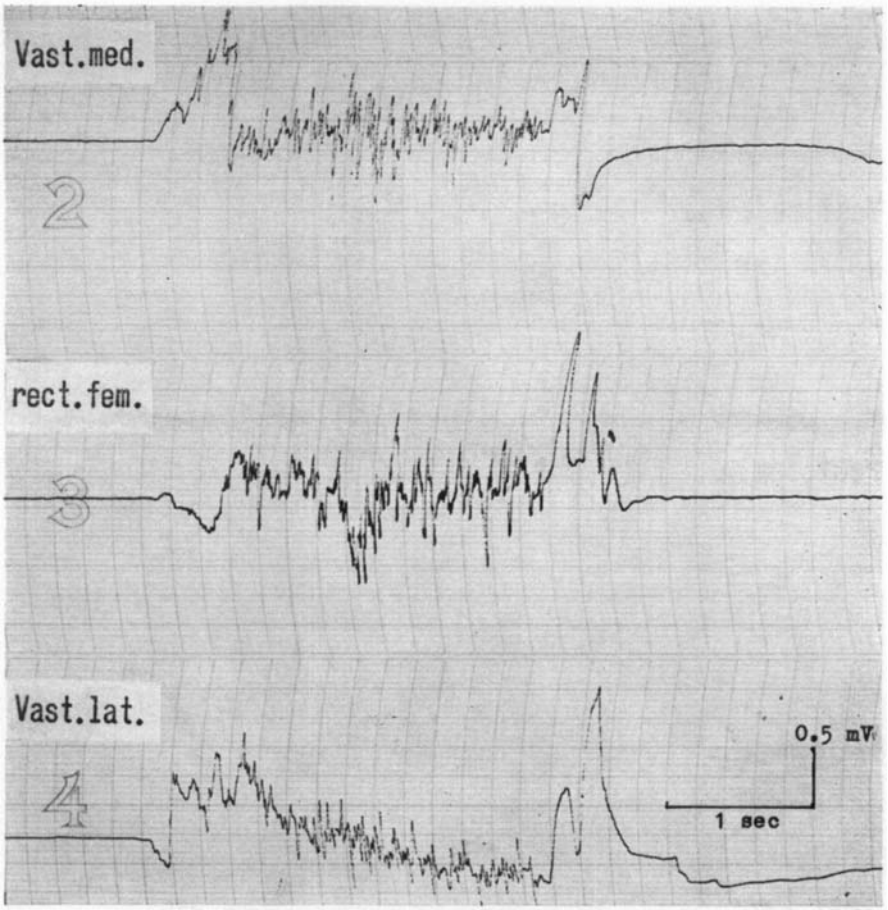

Figure 1 B. EMG with intramuscular needle electrodes. Healthy man aged 22 years. Recumbent with knee extended.

RESULTS

Where surface electrodes were used in normal subjects certain individual differences in the readings were found, as expected. Young, lean persons with powerfully developed muscles recorded higher activity (Figures 1 A and B). In older persons, with thick subcutaneous fat and less well developed muscles, the values were often lower (Figure 2).

As regards the three points specially mentioned above, no difference in the activity from the three muscles could be demonstrated, nor was there any clear difference as to the onset of the activity between the various portions of the muscles, with reservation for the possibility that

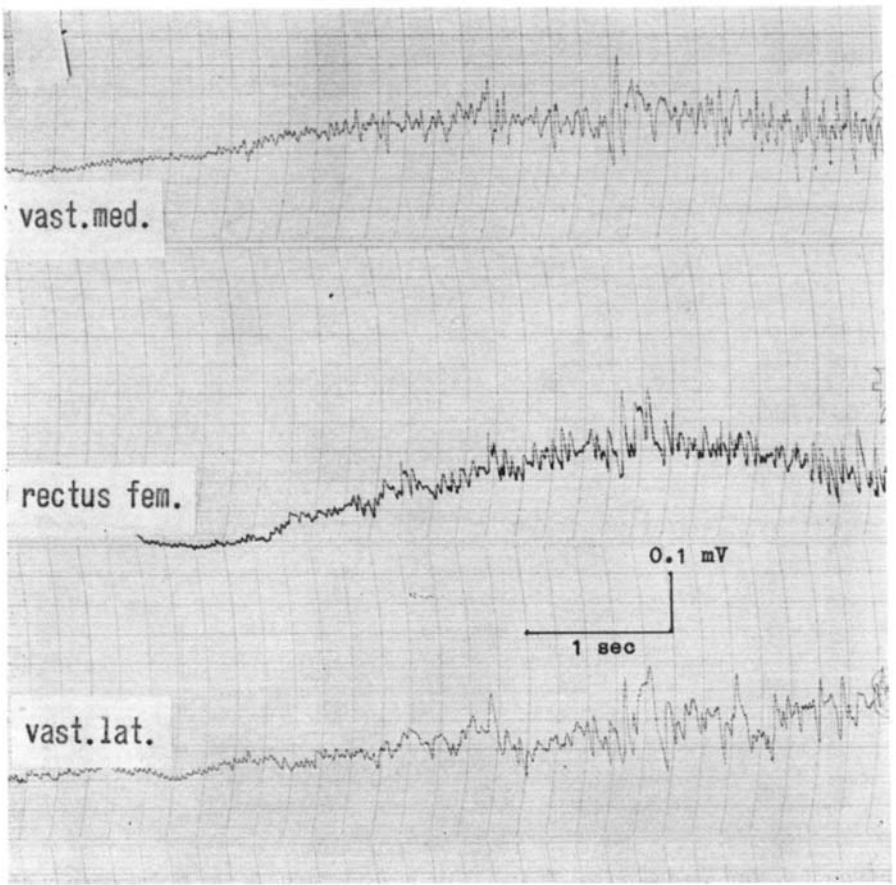

Figure 2. Healthy woman of 66 years with moderate subcutaneous fat. Recumbent with knee at 135°. Generally less activity than in Figure 1 (surface electrodes).

very small time differences could be masked by motion artefacts. As regards the third point there was no difference in activity between the portions during the various phases of extension. The same activity of the vastus medialis was found for both 90 and 135° in the recumbent and seated positions, as in extension. These findings were in agreement with those of *Close* (2).

The 8 patients that had recently undergone operations and that were unable to raise the extended leg owing to pain inhibition recorded extremely irregular and weak activity from all the muscles tested (Figures 3 A and B). No differences in respect of the above three points were found.

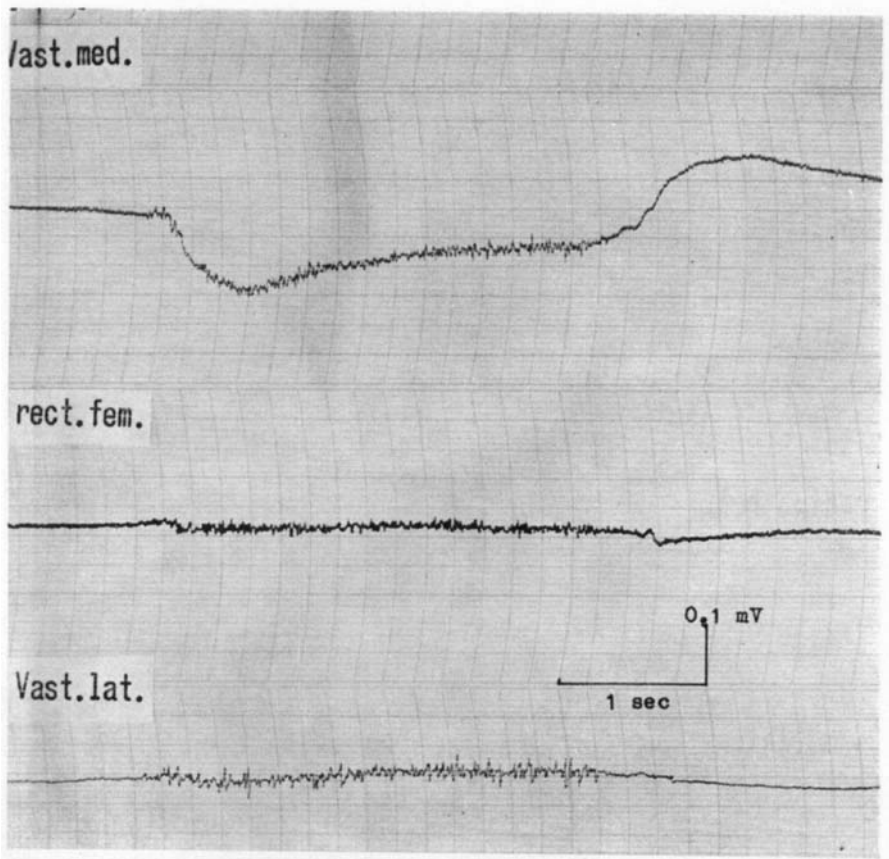

Figure 3 A. Man aged 47 years, 2 days after meniscectomy in the tested knee-joint. Could not raise the leg from the horizontal. Recumbent with knee extended. Weak, irregular activity (surface electrodes).

In the group of patients with older knee injuries and residual active-extension defect it was, of course, impossible to measure the muscle activity in extension, but in the other positions there was no difference in the action potentials from the 3 muscles as regards time or other properties, and in maximal extension for the individual case the activities were identical (Figure 4).

In the subjects in which the muscle activity was examined before and after infiltration of the vastus medialis with a local anaesthetic there was a clear reduction in the activity in the anaesthetized vastus medialis (Figures 5 and 6). It should be noted in this connection that the patient himself did not feel any appreciable difference in the power of exten-

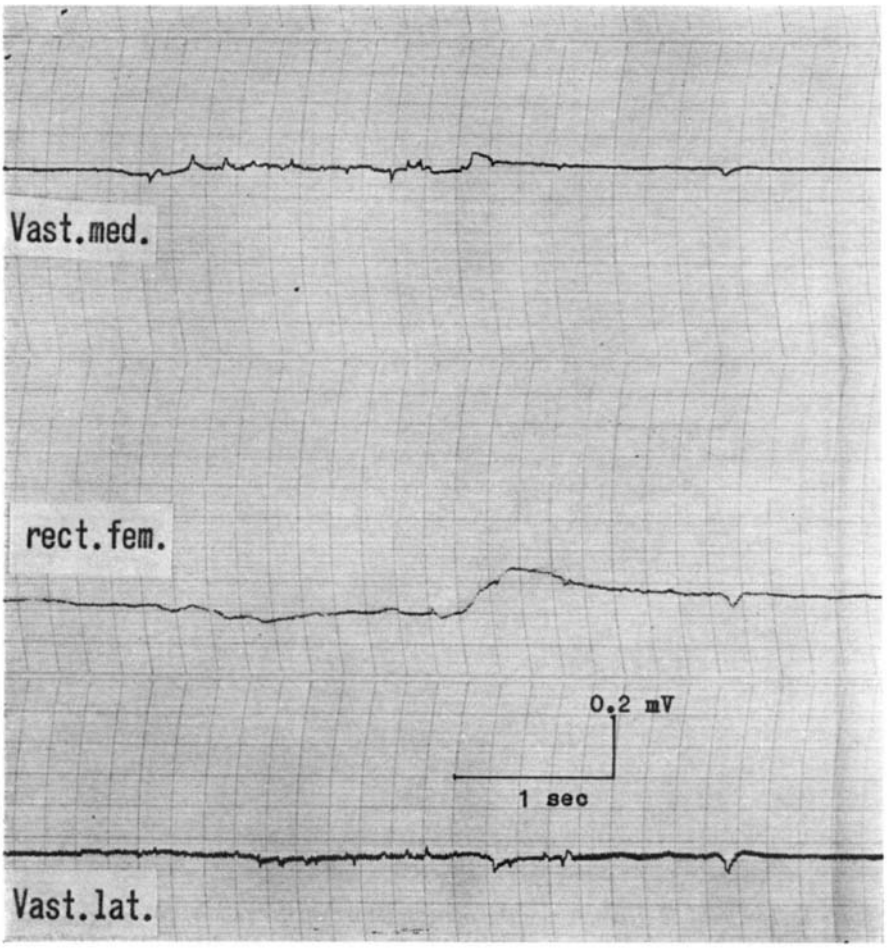

Figure 3 B. EMG with intramuscular needle electrodes. Woman aged 16 years 2 days after operation in the tested knee-joint. Could not raise the leg from the horizontal. Recumbant with knee extended. Weak, irregular activity.

sion, and that the knee could still be extended fully and to the same position as before infiltration. In one case in which an attempt was made to block the branches of the femoral nerve higher up where they entered the vastus medialis, no definite reduction in activity was recorded, although quite large volumes of anaesthetic were injected.

DISCUSSION

One object of this study of quadriceps function was to examine the causes of residual active-extension defect in the knee-joint, a familiar

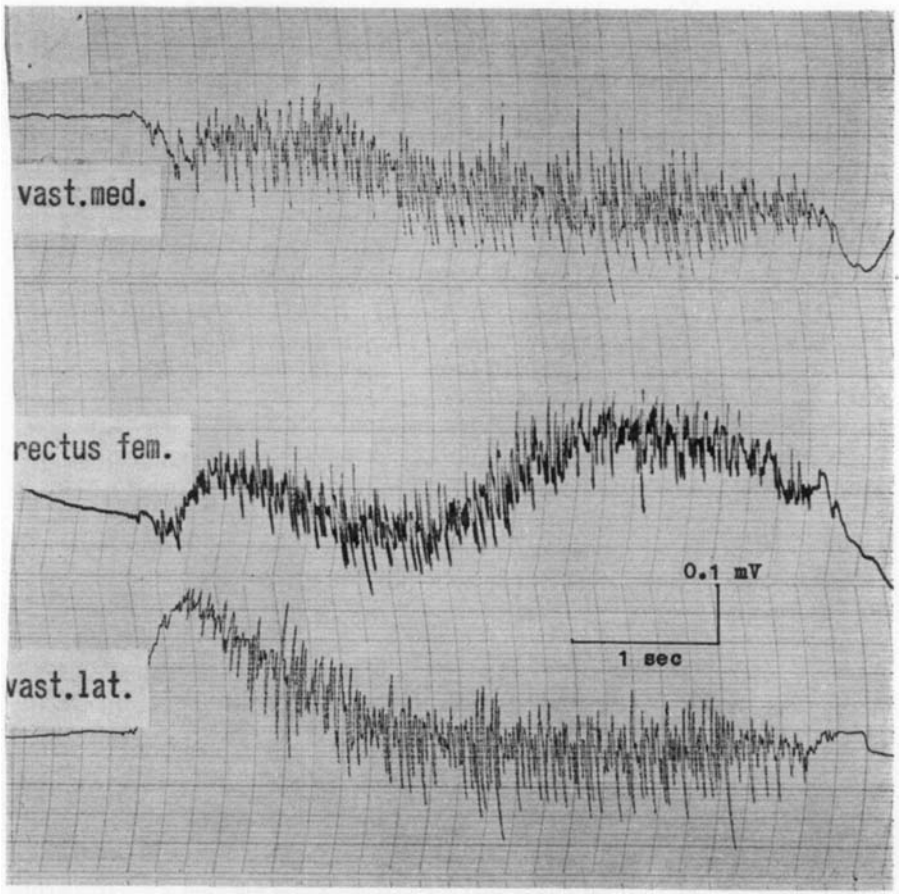

Figure 4. Man aged 56 years, 6 months after fracture of the femur. 10° active-extension defect in the knee. Recumbent with the knee at 170°. No difference in activity for the 3 portions of the muscle (surface electrodes).

condition that has been dealt with thoroughly by *De Palma* (3). In common with this author, *Smillie* (9) ascribes exceptionally great significance to the vastus medialis in the terminal extension of the knee. These workers base their views on the clinical observations that the belly of the vastus medialis is most prominent in full extension and that of all the portions of the quadriceps it is the one that is most severely atrophied after injury and is then the most difficult to exercise. *Smillie* closes his article with the statement "Vastus medialis is the key to the knee". The importance of this muscle is also stressed in the training of physiotherapists in Sweden (1).

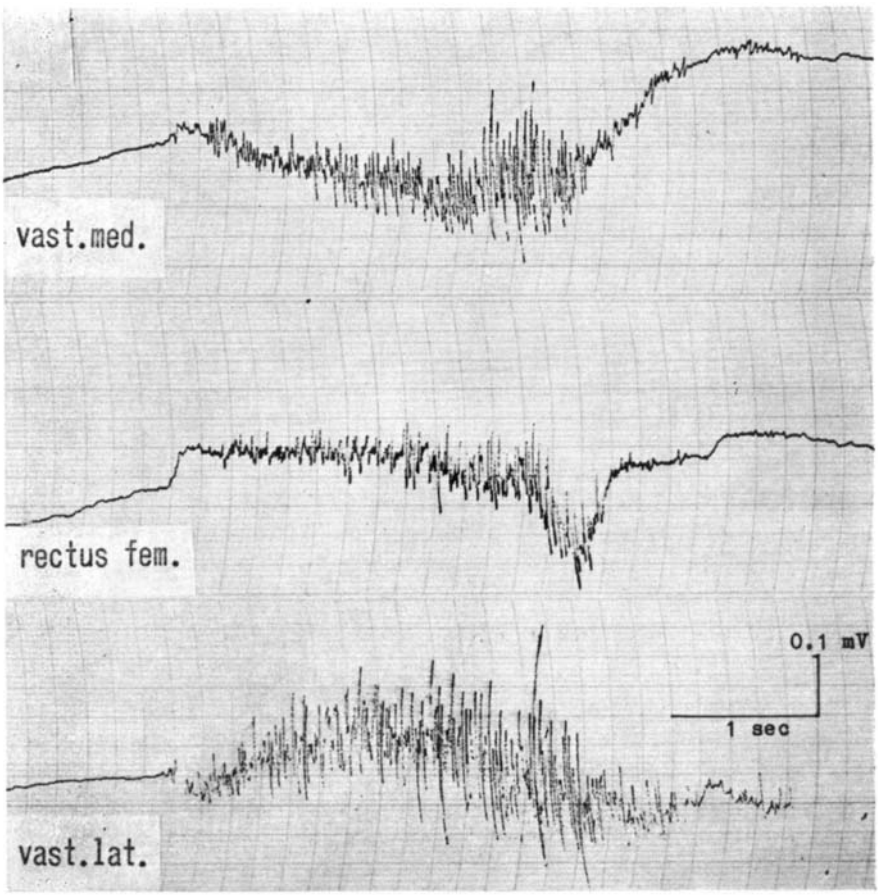

Figure 5. Healthy man aged 20 years. Recumbent with knee at 135°. Normal activity (surface electrodes).

The view that the vastus medialis functions only during the last 10–15° of extension and then assumes practically sole responsibility for the extension would seem *a priori* to be of doubtful validity if the quadriceps muscle is regarded as a unit consisting of four portions, all of which converge and are attached to the patella, the force then being transmitted to the tibia *via* the ligamentum patellae. That the muscle is most easily palpated and most prominent when the knee is fully extended is probably due to the fact that it is thickest when fully shortened; this would apply also to the other portions of the quadriceps, which, however, are not so visible. This phenomenon can also be seen in normal subjects when, with a flexion of 10–15°, the vastus medialis

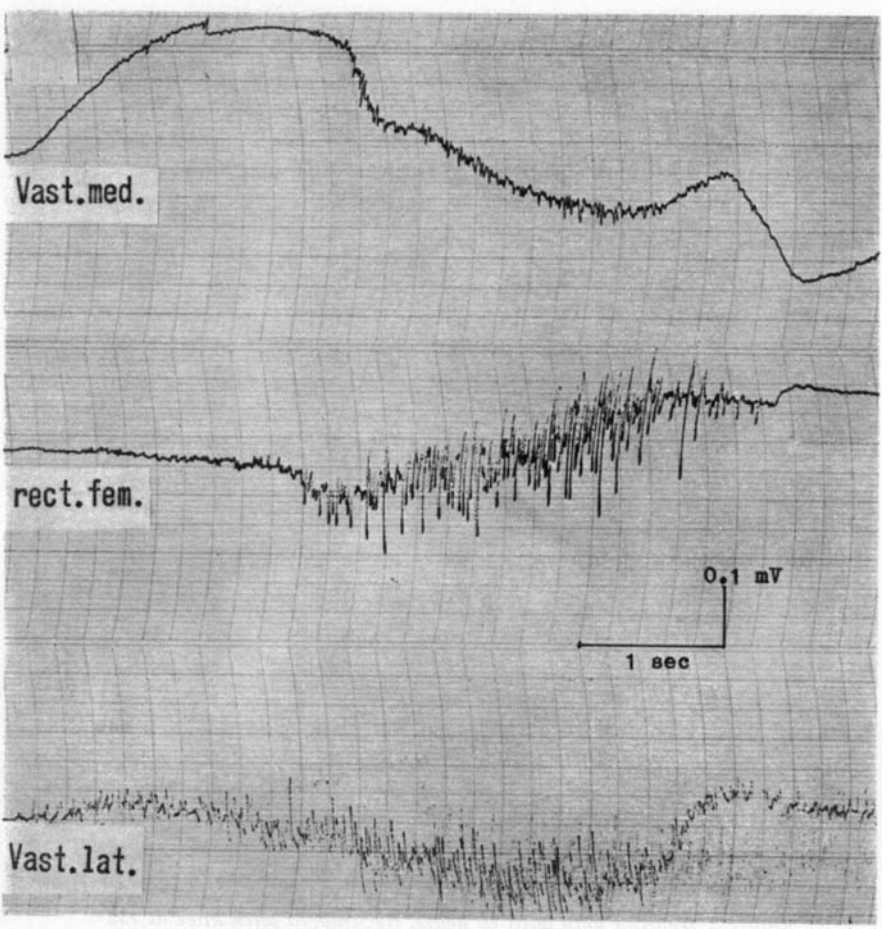

Figure 6. The same conditions as in Figure 5. Twenty millilitres of local anaesthetic were injected into the vastus medialis with the surface electrodes in place. Full active extension in the knee-joint. There was a clear reduction of the activity of the anaesthetized muscle.

is poorly outlined in spite of maximum tension. Only in full extension and powerful contraction, which after operation or other trauma often give rise to pain and are avoided, is the peripheral belly of the vastus medialis clearly seen and "normal" in appearance.

This EMG study thus provides no support for the view that in extension of the knee the vastus medialis differs from the other parts of the quadriceps muscle; in both the normal subjects and the patients the vastus medialis reacted throughout extension just as the other portions.

The activity recorded from the vastus medialis was normal even for the patients with residual active-extension defect. Elimination of the vastus medialis by infiltration with Citanest (Figure 6) did not prevent full extension of the knee joint.

If, then, the vastus medialis has no special function in the terminal extension of the knee-joint, how is the residual active-extension defect to be explained? There would seem to be four factors that suffice to account for the phenomenon:

1) In the actual terminal extension the lever action of the quadriceps is diminished (*Lindahl & Movin* (8)).
2) According to von Schwann's law a muscle exerts its greatest force when it is fully extended (though not ovestretched), the force decreasing as maximum shortening is approached.
3) Inhibition of pain, especially in acute cases.
4) Parapatellar shrinkage of the joint capsula and adhesions between the quadriceps and femur.

SUMMARY

The muscular activity in the quadriceps was studied electromyographically under normal conditions as well as in cases of the residual active-extension defect in the knee-joint often seen after traumatic knee lesions. In contradiction to the general opinion it was found that the vastus medialis did not assume any specific function in the terminal extension of the knee. The extension defects may be ascribed to the following four factors:

1) The quadriceps exerts the poorest leverage in the last 10° of extension.
2) In accordance with physiological laws the muscular power decreases as the muscle shortens.
3) Pain inhibition.
4) Adhesions.

RESUME

L'activité musculaire du quadriceps a été étudiée par électromyographie dans des conditions normales comme dans des cas de déficience résiduelle d'extension active de l'articulation du genou que l'on constate souvent après les lésions traumatiques du genou. En contradiction avec l'opinion générale, on a constaté que le vastus medialis n'assume pas

une foncsion spécifique dans l'extension terminale du genou. L'extension défectueuse peut être attribuée aux quatre facteurs suivants:

1) Le quadriceps fournit le moment le plus faible dans les derniers 10° de l'extension.
2) Conformément aux lois physiologiques, la force musculaire diminue lorsque le muscle est raccourci.
3) Inhibition par suite de douleurs.
4) Adhésions.

ZUSAMMENFASSUNG

Die muskuläre Aktivität des M. quadriceps wurde unter normalen Verhältnissen und in Fällen von zurückbleibendem, aktivem Streckeffekt des Kniegelenkes, der oft nach traumatischer Beschädigung des Knies gesehen wird, elektromyographisch untersucht. Im Gegensatz zur allgemeinen Auffassung wurde gefunden, dass der Vastus medialis keine besondere Funktion bei den Entstreckung des Knies übernimmt. Der Streckdefekt kann auf die folgenden vier Faktoren zurückgeführt werden:

1) Der Quadriceps übt die geringeste Hebelwirkung während der letzten 10° der Streckung aus.
2) In Übereinstimmung mit physiologischen Gesetzen nimmt die Muskelkraft mit der Verkürzung des Muskels ab.
3) Schmerzhemmung.
4) Adhæsionen.

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