KNEE EFFUSION AND REFLEX INHIBITION OF THE QUADRICEPS

A BAR TO EFFECTIVE RETRAINING

H. FAHRER, H. U. RENTSCH, N. J. GERBER, Ch. BEYELER, Ch. W. HESS, B. GRÜNIG

From the University of Bern, Switzerland

In order to investigate the difficulty of quadriceps training in the presence of an effusion into the knee we examined 13 patients with chronic effusions by recording isometric muscle strength. Maximal strength was markedly lower in the presence of an effusion, and aspiration of the effusion produced a 13.6% increase in strength (p < 0.01). A further, small increase of 8% was recorded after intra-articular lignocaine injection. Isometric strength and surface integrated EMG correlated well in six patients.

Two reflex mechanisms seem to inhibit quadriceps innervation in the presence of a persistent knee effusion, one mediated by pressure sensitive receptors, the other still unknown. Joint aspiration and systemic or intra-articular anti-inflammatory drug treatments are advised before any programme of quadriceps training to allow maximum effects to be achieved.

Wasting of the quadriceps due to chronic knee disease is a common problem in rheumatology, orthopaedic surgery and sports medicine. Both immobilisation and inflammation of the joint are considered to contribute (Harding 1929; Staudte 1981).

Earlier workers have demonstrated a near-linear relationship between volume and pressure of intra-articular fluid under experimental and pathophysiological conditions (Jayson and Dixon 1970; Gerber and Dixon 1974; McCarty 1980; Levick 1983). The reflex inhibition of the quadriceps due to joint effusion was first demonstrated experimentally by de Andrade, Grant and Dixon (1965). In 1984 Spencer, Hayes and Alexander demonstrated a linear decrease of Hoffman’s reflex in proportion to intra-articular fluid volumes in healthy subjects. Hoffman’s reflex is an electrically evoked monosynaptic stretch reflex of the quadriceps, produced by low voltage stimulation of the femoral nerve. The threshold for inhibition was 20 to 30 ml of experimental joint effusion. Intra-articular lignocaine abolished this decrease.

Both intra-articular fluid volume and joint angle influence intra-articular pressure. The capacity of a joint, as with a rubber balloon, can be defined by a pressure/volume relationship. This is least in a position of partial flexion, that is, from 30 to 60° (Eyring and Murray 1964; Stratford 1981; Levick 1983; Machan 1983). Quadriceps exercises, however, are usually done in full extension, when the pressure/volume relationship is raised (Basmajian 1970; Andrews 1982; Levick 1983).

It has been shown in experimental and postoperative effusions that the removal of fluid is followed by a fall in intra-articular pressure and a rise in the strength of quadriceps contraction (Bittscheidt, Hofmann and Schumpe 1978; Kennedy, Alexander and Hayes 1982). One recent study concluded that this phenomenon occurs only in cases of acute, but not chronic effusion (Jones, Jones and Newham 1987).

In our study we tested the hypotheses that effusions caused by arthritis inhibit quadriceps strength, that their removal increases quadriceps strength, and that physio-therapeutic exercises without prior removal of fluid are of doubtful value.

PATIENTS AND METHODS

We studied 13 patients (12 of them men) with a mean age of 31.3 years (range 16 to 57 years). In nine cases one knee was affected and in four cases, both knees. The diagnosis was rheumatoid arthritis in three, Reiter’s
syndrome in two, undefined monarthritis in four and degenerative joint disease in four. The effusions were all chronic.

**Muscle strength measurements.** These were recorded using a Cybex II dynamometer (Cybex, Division of Lumex, Inc., New York, USA). The patients were sitting with their abdomens and thighs tightly attached to the chair and the knee fixed to the dynamometer in 60° of flexion. This angle was chosen because it gives a lower intra-articular pressure than further flexion or extension (Levick 1983). The strength of isometric extension was first recorded on the healthy or less affected side. Patients were asked to push with maximal strength for eight seconds against the padded and blocked lever of the dynamometer. Results were recorded in Newton seconds (Nsec), that is the product of strength and recording time.

**Electromyography.** In six patients an electromyogram (EMG) of the medial vastus muscle was recorded on both sides in addition to the muscle strength. Two surface electrodes were taped 6 cm apart over the belly and near the tendon of the muscle, and the EMG signal was amplified by a DISA 1500 System (bandpass 10 Hz to 10 kHz) and subsequently processed by a DISA Mean Voltage Unit Type 14C 20 to give a continuous plot of the numerical mean voltage.

**Joint aspiration.** This was performed after the initial set of measurements. A sterile 18 G single way needle (0.8 mm lumen) was inserted under the upper medial pole of the patella without local anaesthesia. The mean volume aspirated was 52.5 ± 25.6 ml (range 25 to 110 ml). In six subjects 5 ml of 2% lignocaine was injected at the same site after the second and before a third set of measurements. We did not use an indwelling plastic vein catheter since, in a preceding pilot study of one patient, it irritated the knee and inhibited full muscle contraction. To allow the patients to adapt to the procedure, two recordings of eight seconds were made from the control leg during maximal voluntary contraction. Recordings were then made from the affected leg, before and after fluid aspiration and, in six patients, after intra-articular lignocaine.

**Evaluation.** Planimetry was performed on the isometric strength curves, using a Digiplan (Kontron Inc.); the integral under the curve was determined for contraction times of one and three seconds. The amplitude was measured after one and three seconds and at the maximal peak. Statistical evaluation of the strength changes was made by a paired two tailed t-test, with p<0.05 as the significance threshold. The linear correlation coefficient (r) and Spearman’s rank significance correlation coefficient (RS) were calculated.

**RESULTS**

Of the various parameters of the strength curve, the integral area over three seconds (S3s) proved to be the most informative and this alone is reported as the parameter for maximal strength of contraction (Fig. 1).

**Isometric strength on affected and unaffected or less affected side.** The two consecutive recordings of maximal isometric strength in the healthy or “better” leg showed identical results, the mean S3s values being 478 ± 148 Nsec (Mean ± SD) for the first set of measurements and 482 ± 174 Nsec for the second one, showing satisfactory reproducibility and excluding a significant learning or training effect (Fig. 2, left). As expected, the maximal strength of the affected leg was significantly lower 301 ± 203 Nsec, p<0.05.

![Fig. 1](image)

Recordings from a typical subject, before and after aspiration of 80 ml of fluid, showing mean voltage and integral of the EMG of vastus medialis (above) and isometric strength (below). Maximal strength is usually reached within three seconds of maximum voluntary activity.
Joint aspiration and intra-articular anaesthesia. None of the patients experienced pain on quadriceps contraction either before or after aspiration. There was a significant increase of strength from 301 ± 203 to 342 ± 192 after aspiration (Fig. 2, right). This increase was in the order of 13.6%, the variability coefficient being 15%.

Six subjects who were given intra-articular anaesthesia immediately after the post-aspiration measurement, had a third recording done five minutes after injection of lignocaine. In all but one subject there was a further increase in strength. In Subject I, the exception, there was a significantly delayed increase in strength, with poor results after three seconds, but much better results after five seconds, of the same order as the three-second results in the other five subjects (see Fig. 2). The whole group evaluation, including Subject I, showed equal quadriceps strength before and after lignocaine, but, excluding Subject I, the other five showed a significant increase in strength of 8% (p<0.01). There was no clear correlation between strength changes and volume of joint fluid.

Maximal strength and surface EMG. The comparison of muscle strength and the mean voltage of the EMG recorded simultaneously in six patients showed a linear correlation between the two parameters when the integrated value of each was taken over one and three seconds (p<0.002). When an alteration of 10% or more of both the integrated strength and the EMG activity was seen after aspiration, it was always in the same sense for the two measurements. That is, when there was a clear-cut increase in muscle strength after aspiration, an increase in EMG voltage was also observed.

DISCUSSION

We measured quadriceps strength in patients with clinical effusion before and after aspiration of joint fluid. The results have a bearing on why quadriceps training is often ineffective where there is a persistent effusion. Our results were reproducible and demonstrated a mean increase in strength of 13.6% after aspiration of about 50 ml of fluid, with a further mean increase of 8% after intra-articular lignocaine injection. The integrated surface EMG activity of the medial vastus, measured in some patients on both sides, correlated well with quadriceps strength, confirming previous findings that EMG gives a good estimate of muscle force, though it provides relative rather than absolute values (de Vries 1968; Moritani and de Vries 1978; Stratford 1981; Soderberg and Cook 1983). The fact that EMG activity also increased when there was a clear-cut gain in muscle strength after aspiration supports neurogenic rather than experimental explanation.

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Fig. 2

Maximal isometric strength of quadriceps. On the left, values for the first and second attempts with the normal or less affected leg are given. On the right are values before aspiration ● after aspiration ○ and, for six subjects, after the injection of lignocaine ▲.
mechanical joint inhibition. Thus, our observations confirm and quantify the postulate of an inhibitory reflex mechanism blocking voluntary quadriceps innervation (de Andrade et al. 1965).

Conclusions. Our experiments seem to demonstrate that at least two different sorts of afferent impulses are the cause of this muscle inhibition:

1. Those caused by raised intra-articular joint pressure (de Andrade et al. 1965).
2. Other impulses, non-pressure-mediated, shown by a further increment of strength after intra-articular anesthesia. It is not clear whether these afferents are related to the pain of inflammation.

Both mechanisms seem to work through other than ordinary pain reflexes, since none of our patients had pain on muscle contraction before aspiration or anesthesia (Dee 1978; Eriksson 1981; Newton 1982; Wood and Ferrel 1984). This has been confirmed by studies on the reflex inhibition of quadriceps activity after meniscectomy and arthroscopy (Stokes and Young 1984; Shakespeare et al. 1985).

Our results correlate well with the earlier findings of Spencer et al. (1984) in healthy volunteers when simulated effusions of comparable volume (60 ml) inhibited the H-Reflex by 31 to 44%, corresponding to an estimated 8.5% of the total pool of motor neurones. Unlike ours, their measurements were based on a neurophysiological reflex which was independent of conscious control. Our measurements depended entirely on our patients' motivation and the voluntary contraction of muscle.

The practical consequence of our observations is that the joint should be aspirated and systemic or intra-articular anti-inflammatory drugs be given before starting quadriceps exercises if maximal training effects are to be achieved.

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