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THE MECHANICS OF THE TWO-JOINT MUSCLES RECTUS FEMORIS, SARTORIUS AND TENSOR FASCIAE LATAE IN RELATION TO THEIR ACTIVITY

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ABSTRACT. A functional study of the two-joint muscles on the front of the thigh, i.e. rectus femoris, tensor fasciae latae and sartorius has been performed with electromyographic technique. The investigation concerned engagement in ceratin isolated voluntary joint movements, simple and complex, as well as in habitual gait.

Two earlier papers (1, 2) have dealt with the mechanics of the hamstrings and the true extent of their active engagement in movements of the hip and knee joints. The present report concerns a functional study of the two-joint muscles that pass the knee as well as the hip joint on the front of the thigh, i.e. rectus femoris, tensor fasciae latae and sartorius. Unlike the hamstrings, the mechanics of these muscles are the same in an open muscular chain as in a closed, i.e. irrespective of whether the leg hangs free or the foot is on the ground.

Rectus femoris, sartorius and tensor fasciae latae all have the mechanics for flexion as well as abduction of the hip. The first two are also in a position to achieve outward rotation, while tensor fasciae latae is in a position to produce inward rotation of the hip. Rectus femoris and tensor fasciae latae are anatomically able to extend and sartorius to flex the knee. Furthermore, when the knee is flexed, tensor fasciae latae can produce outward rotation and sartorius inward rotation of the crus.

In the present study, electromyographic techniques were used to investigate the active engagement of these muscles in various positions and movements. The subjects were a couple of students and some of the laboratory staff (6 persons altogether). The investigation concerned engagement in certain isolated voluntary joint movements, simple and complex, as well as in habitual gait. The movements were performed in several different positions—standing, sitting, lying and walking—in order to ensure that the activity recorded in the muscle really was connected with its engagement in the movement being investigated. Isolated knee movements were performed in the prone and sitting positions. Outward and inward rotation at the hip were achieved with the leg hanging free, the subject standing on the other leg on a stool and balancing with the hands against a pillar. The same position was used for flexion at the hip, with the crus hanging relaxed, as well as for such flexion combined with inward and outward rotation at the hip. Abduction movements alone and combined with inward and outward rotation were also performed in this standing position. Similarly, it was used for flexion and extension at the knee with the thigh hanging vertically as well as with the hip joint flexed approximately 45°. Outward and inward rotation of crus were performed with the thigh vertical and the knee joint flexed 45°. The supine position was used for flexion as well as outward and inward rotation at the hip.

The action of the muscles during habitual gait was investigated while the subjects walked along a walking way about ten metres long, fitted with two force plates (3).

Wire electrodes were used in general, supplemented with concentric needle electrodes. The writer was a Honeywell Visicorder type 1508.

RESULTS

No activity could as a rule be detected in the standing symmetrical resting position (standing at

Table I. *Isolated hip movements*

	Rectus femoris	Tensor fasciae latae	Sartorius
Flexion	Activity	Activity	Activity
Extension	No activity	No activity	No activity
Outward rotation	Activity	No activity	Activity
Inward rotation	No activity	Activity	No activity
Flexion + outward rotation	Activity	Decreased activity or no activity	Increased activity
Flexion + inward rotation	Activity	Increased activity	Decreased activity or no activity
Abduction	Activity	Activity	Activity
Abduction + outward rotation	Increased activity	Decreased activity	Activity
Abduction + inward rotation	Decreased activity	Activity	Decreased activity or no activity

Table II. *Isolated knee movements*

	Rectus femoris	Tensor fasciae latae	Sartorius
Flexion	No activity	No activity	Activity
Extension	Activity	Activity	No activity
Outward rotation of the crus with the knee joint flexed 90°	No activity	No activity	No activity
Inward rotation of the crus with the knee joint flexed 90°	No activity	No activity	No activity

ease) in any of the muscles investigated. The results for isolated joint movements are given in Tables I and II. No quantitative grading of the activity has been given in the case of simple movements but relative comparisons are made in the results for composite movements. Thus, "decreased activity", for instance, implies that the activity in the combined movement is substantially less than in the isolated simple but equally large flexion or abduction.

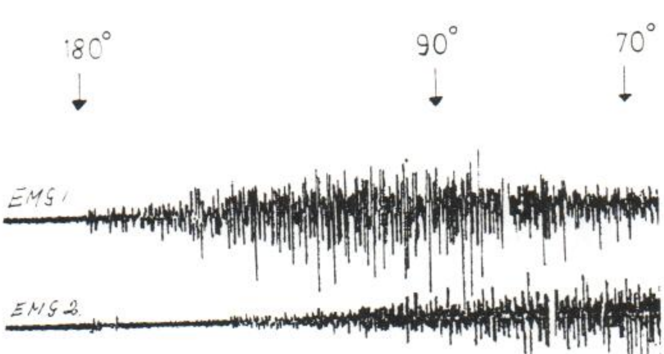

Fig. 1. Activity in tensor fasciae latae, EMG 1, and rectus femoris, EMG 2, during full flexion in the hip joint. The arrows indicate the angle of flexion at the hip joint.

As will be seen from Table I, all three muscles are active during hip flexion. Tensor fasciae latae and sartorius are active throughout the movement but rectus femoris only during the latter part. In many cases, in fact, rectus femoris did not become active until the hip had been flexed about 40°, i.e. when the angle at he hip joint was *c.* 140°. The activity in sartorius increased throughout the movement, being greatest at maximal flexion of the hip. The greatest activity in rectus femoris was usually observed with the hip joint at approximately 90° and there was little change during further flexion. Tensor fasciae latae, on the other hand, was most active at about 90° flexion of the hip but the activity decreased substantially on further flexion, though it did not disappear entirely (Fig. 1). This decrease in activity is not to be confused with that which occurs when hip flexion is combined with outward rotation in

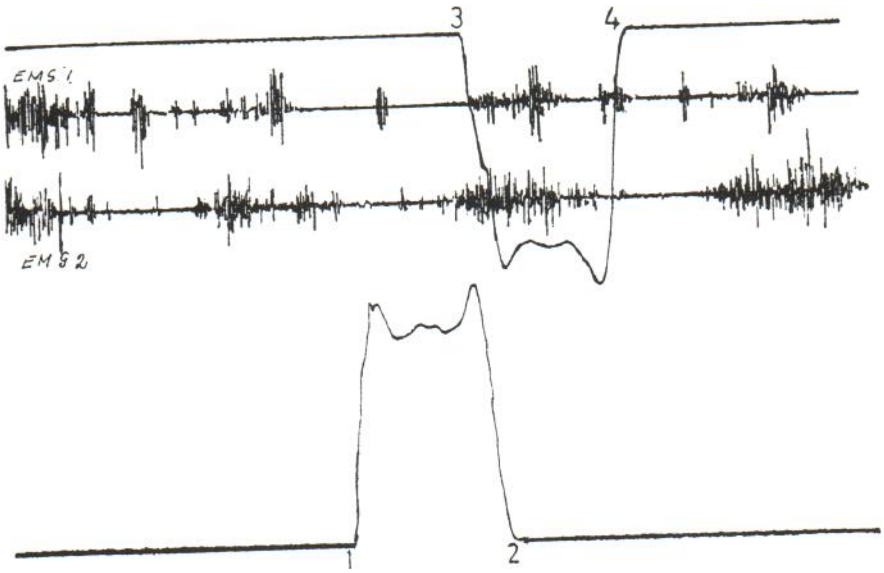

Fig. 2. Activity in right tensor fasciae latae, EMG 1, and right rectus femoris, EMG 2, during walking. The supporting phase of the right leg continues between mom. 3 and 4 (*upper curve*) and the supporting phase of the left leg between mom. 1 and 2 (*lower curve*). The curves are recorded from the force-plates.

the hip joint. In order to prevent involuntary outward rotation that might escape notice, a supplementary series of experiments was made in which the lateral aspect of the leg followed a vertical surface. Even when the hip was flexed in this way, the greatest activity in tensor fasciae latae occurred at a hip angle about 90°.

Sartorius appears to be of secondary importance as a knee flexor, no activity being registered as a rule until the knee had been flexed 70° to 80°. In some cases the muscle remained entirely silent.

The active engagement of these muscles in the habitual gait varies partly from case to case. Rectus femoris remained entirely passive in one case; in the others, activity was observed in the final part of the swinging phase as well as the first part of the supporting phase (Fig. 2). Tensor fasciae latae was active during the greater part of the supporting phase and remained active in some cases during the first part of the swinging phase. Sartorius sometimes had a brief period of activity in the latter part of the swinging phase.

DISCUSSION

Rectus femoris, sartorius and tensor fasciae latae are all actively engaged to a greater or less extent in all the hip movements for which their anatomical mechanics permit their participation, assuming that each movement is performed singly and in isolation. During a complex movement made up of two simple movements (e.g. simultaneous flexion and outward rotation, or simultaneous abduction and inward rotation), each of which engages the muscle in question when performed separately, the muscle displays greater activity than when only one of the simple movements is performed. In the case of complex movements having only one component that the muscle can perform, however, participation varies somewhat between the three muscles. The activity in tensor fasciae latae during hip flexion, for instance, is decreased or even entirely absent when this movement is combined with outward rotation (Fig. 3). The same applies to the activity in sartorius when hip flexion is combined with inward rotation. In the case of rectus femoris, on

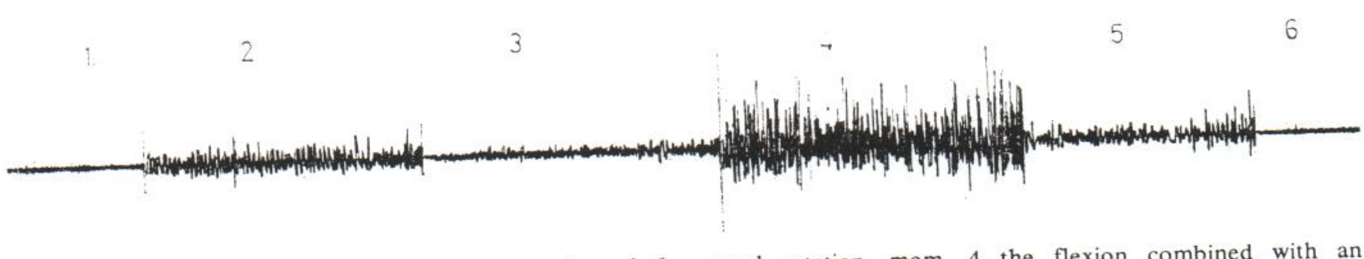

Fig. 3. Activity in tensor fasciae latae; mom. 1 and 6 the leg hanging free, mom. 2 and 5 the hip joint flexed about 45°, mom. 3 the flexion combined with an outward rotation, mom. 4 the flexion combined with an inward rotation.

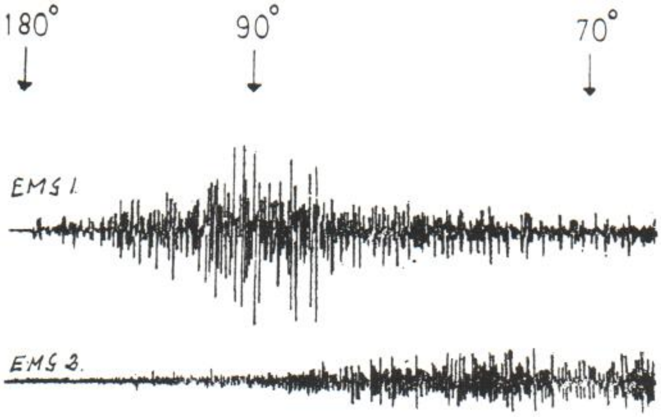

Fig. 4. Activity in tensor fasciae latae, EMG 1, and gluteus maximus, EMG 2, during full flexion in the hip joint. The arrows indicate the angle of flexion at the hip joint.

the other hand, the activity observed during hip flexion alone is affected to only a minor degree by the addition of outward rotation and usually not at all with inward rotation. Sartorius and tensor fasciae latae display a kind of reciprocal inhibition during outward and inward rotation of the hip and this reciprocity is decisive in its turn for these muscles' engagement in hip flexion, a movement in which they are synergists.

The muscles do not become activated synchronously on hip flexion. As a rule, rectus femoris is not active in the initial phase. The activity in tensor fasciae latae is greatest at a hip angle of about 90°. This may be because the weight arm, i.e. the resistance arm of the leg about the hip joint, is greatest in this position and so, consequently, is the torque of the leg. This torque decreases as the hip joint is flexed still further, which should reduce the load on the musculature. On the other hand, the muscles also shorten during flexion and hence their force potential is reduced as well. Tensor fasciae latae displays a marked decline in activity during the latter phase of hip flexion, i.e. when the angle of the hip becomes acute. An approximate calculation shows that the force arm of this muscle about the hip joint is greatest at roughly 90° hip flexion. Tensor fasciae latae is a short muscle compared with rectus femoris and sartorius, so that after this point it may not be able to shorten further and consequently exerts no contraction force. Moreover, flexion beyond 90° makes the muscle's force arm still shorter. It therefore seems appropriate that further flexion is left to other muscles with better mechanical qualifications.

The decrease of activity in tensor fasciae latae may be the result of reciprocal inhibition, being accompanied as it is by activation of the hip extensor gluteus maximus. A similar reciprocal inhibition can be observed during inward rotation of the hip joint (Fig. 4).

All three muscles are active during an isolated abduction of the hip. If this is combined with outward rotation, the activity increases somewhat in sartorius and rectus femoris and decreases in tensor fasciae latae. The addition of inward rotation to abduction has hardly any effect on the activity in tesnor fasciae latae, while that in sartorius and rectus femoris decreases.

The ability of sartorius and tensor fasciae latae to engage in movements of the knee joint is utilized only under special circumstances. The activity displayed by tensor fasciae latae during isolated knee extension is relatively slight and disappears at once if knee extension is combined with outward rotation of the hip. Standing symmetrically "at attention", which involes extension of the knee joint, activates tensor fasciae latae only if the feet are parallel in the sagittal plane or the toes are turned in. It is not engaged when standing ordinarily "at attention", i.e. with the feet pointing outward, which involves slight outward rotation of the hip. In other words, the muscle's effect on the knee joint is determined by the position of the hip. Sartorius' engagement in flexion of the knee is of subordinate importance but when this movement is combined with outward rotation of the hip, the muscle displays great activity. As in the case of tensor fasciae latae, the position of the hip determines whether or not sartorius participates in movements of the knee.

Although rectus femoris is a potential hip flexor, the muscle is not active during that part of the swinging phase of walking when a movement of flexion occures in the hip joint, presumably because the hip flexion involved in this movement is too slight. The activity observed in rectus femoris in some cases at the end of the swinging phase and in beginning of the supporting phase ad at the moment of propulsion probably reflects a need to stabilize and extend the knee joint.

The swinging phase of walking sometimes engages tensor fasciae latae and occasionally sartorius. The swinging phase involves flexion of the hip but this flexion is combined with some inward rotation initially and some outward rotation towards the end and it is precisely at the beginning of the swinging phase that tensor fasciae latae may be active and sartorius towards the end. The degree of these rotations varies from case to case and with the gait. So, consequently, does the presence and degree of activity, which is obviously correlated to the rotation and not to the flexion of the hip.

The engagement of tensor fasciae latae during the supporting phase reflects its function as an abductor, preventing contralateral dropping of the pelvis, in which respect it acts as a synergist to gluteus medius.

It is not always to grade the functions of a muscle into primary and secondary but it does seem clear from the present study that tensor fasciae latae is chiefly an abductor and inward rotator of the hip and sartorius an outward rotator, while the main function of rectus femoris seems to be extensor of the knee.

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