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ACTIVE-EXTENSION CAPACITY OF THE KNEE-JOINT IN THE HEALTHY SUBJECT

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It is usually assumed that a person in good sound health can actively extend the knee-joint through the full range, with the possible reservation of a slight resilience due to stretching of the posterior articular capsule if a powerful attempt is made to extend the joint passively. In earlier papers the authors have examined the forces acting in the knee-joint in active extension (2) and measured the force exerted by the quadriceps in the healthy subject (3). It was found that near full extension it was difficult, if not impossible, to obtain a reliable determination of the position of the knee-joint by ordinary clinical methods, and it was necessary to resort to radiographic examination.

In connection with these studies it was found, surprisingly enough, that healthy subjects in the supine position with the leg raised from the table were unable to extend the knee-joint fully. In passive extension with the foot supported and the leg hanging freely and relaxed there was a further 5° of extension, on average, and in some cases as much as 10°. With the object of further examining this active-extension defect we have carried out a more systematic study on a series of knee-joints.

MATERIAL

The study was performed on 52 subjects with sound knees, some of them hospital staff and others patients admitted for disorders not concerned with the lower extremities. The age and sex distribution is shown in Table 1. The term "sound knee" as used here implies that the knee-joint was clinically normal, that there were no symptoms associated with the knee and that a radiographic examination of the joint did not disclose pathologic alterations, apart from mild arthrosis.

A

B

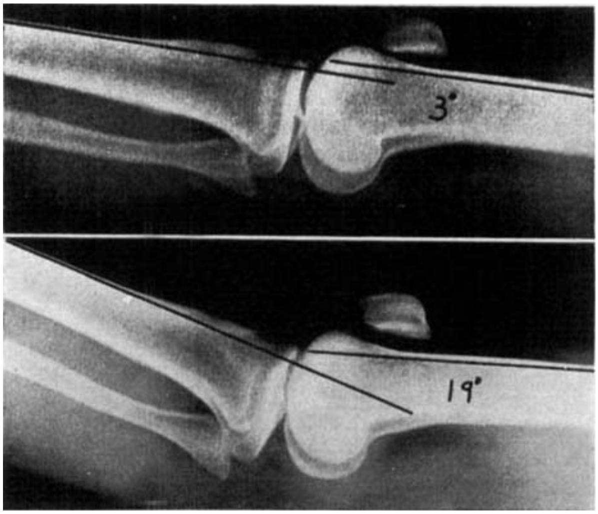

Figure 1. The knee-joint in lateral view. The reference lines for the femur and tibia are drawn in. A: Full passive extension (zero position). B: Full passive extension with the leg horizontal. In this case the active extension defect was unusually large (16°) and was obvious on clinical investigation.

METHODS

The extension position of the knee-joint was determined on X-ray films. Lateral projections were taken, with a focus-to-film distance of 100 cm. As a reference line the anterior contour of the femur or tibia was used (Figure 1). Maximum extension (the reference position) in this connection is defined as the position obtained with the patient supine and the leg horizontal, with a support under the foot and a load of 5 kg over the knee-joint. The degree of flexion was measured from this reference position.

The following positions of the knee-joint were examined.

(1) Supine with the leg relaxed and supported under the foot, with a load of 5 kg applied over the knee-joint (the weight was hung in a sling).
(2) Supine as in (1) but with a weight of 3 kg.
(3) Supine as in (1) but with a weight of 1 kg.
(4) Supine as in (1). Fully relaxed but with no load.
(5) Supine but with full active extension of the knee which, is raised from the table, unsupported. When the exposure was made the patient was asked to extend the knee-joint as much as possible.
(6) Standing with full active extension of the knee, unsupported.

In a further 14 subjects 7 and 9 kg loads were used to see whether there would be further extension beyond the reference position.

Table 1. Distribution of subjects with respect to age and sex.

Age	20-29	30-39	40-49	50-59	50-59	60-69	Total
Men	1	5	3	13	9	1	32
Women	1	5	2	5	2	5	20
Total	2	10	5	18	11	6	52

Table 2. Flexion of the knee-joint in various positions in a comparison with full extension, defined as the position with a load of 5 kg over the knee-joint and the muscles relaxed.

	Flexion (°)	
	Mean	Range
Supine, relaxed. Load 5 kg	0	
Supine, relaxed. Load 3 kg	0.6	—1 to +3
Supine, relaxed. Load 1 kg	1.1	—1 to +4
Supine, relaxed. Load 0 kg	2.4	+1 to +5
Active extension, standing	3.9	+1 to +7
Active extension, supine	5.1	0 to +19

RESULTS

The mean flexion and the ranges for the various positions are presented in Table 2. A reduction of the load on the knee from 5 to 3 kg gave extremely little flexion. The difference was not significant. With a load of 1 kg there was slight flexion that was significantly different from the reference position (***); the effect was still more pronounced with no load at all.

In the 10 cases loaded with 7 and 9 kg there was on average an extremely small additional extension (not significant).

In full active extension in the erect position there was a mean flexion of 3.9° and in full active extension in the supine position (when the weight of the lower leg contributes to the flexion), the flexion position was still greater—on average 5.1°; the differences were significant (***). It is remarkable that in several subjects the active extension defect in the supine position was more than 10°, and in one case as much as 19°; it was then possible, even with the ordinary clinical methods, to see that full active extension was not achieved.

DISCUSSION

The earlier observation that active extension of the knee could not always be achieved completely in the supine position with the leg raised was verified by this study. What are the causes of this relative insufficiency? In earlier studies by *Lindahl & Movin* (2) and *Hallén & Lindahl* (1) on the forces acting in the knee-joint in extension, and on the causes of active-extension defects in various knee injuries, it was found that the lever action of quadriceps at terminal extension became increasing less favourable. As it is known that a muscle exerts a lower force within its inner path of contraction (von Schwanns's law), these two facts would explain the difficulty of obtaining full active extension. In active extension in the supine position with the leg raised from the table the weight of the lower leg acts in the direction of flexion, and this may contribute to the extension defect. In the same test in the vertical position this weight does not act, and the tone and elasticity of the flexor muscles will then possibly be the only residual factor that counteracts full extension. An impression of the magnitude of this flexing force is obtained from the change in extension achieved with different loads in the supine position with the knee supported but relaxed; practically full extension could be obtained with as small a load as 3 kg, while a load of 1 kg did not suffice to overcome the resistance due to the tone and elasticity of the flexors.

The difference of 2 kg is enough to overcome the tone and elasticity of the flexors and represents a supplementary force of the order of 40 kgf cm[1] acting as a moment (the distance from the knee to the points of support in the proximal and distal direction is assumed to be about 40 cm). The difference in the moment required to obtain full active extension in the horizontal and erect positions is, for a normal person, on average, 100 kgf cm; this value, which may be ascribed to the weight of the lower leg, gives an impression of the magnitude of the force that the quadriceps can *not* exert in extension. With, for instance, a flexion of 120° the quadriceps in the sound knee develops, on average, a moment of 2200 kgf cm; from these measurements it may be concluded that the muscular power of the quadriceps in extension is about one twentieth of that in flexion; and if account is taken of the unfavourable lever action in extension, the absolute force for the quadriceps in extension will be only about one fifteenth of that in the 120° position.

There were large individual differences in the recorded values; for 9

[1] Kgf = Kp = 9.81 newtons = 2.2 pounds weight.

out of 52 subjects the active extension defect was only 1 or 0°. In these cases there was thus no active-extension defect of practical significance, and then the power exerted by the quadriceps in extension is presumably much greater. This individual variation may account for the relative ease with which some subjects could perform full extension in quadriceps exercise after knee injuries or operations.

SUMMARY

Fifty-two normal knee joints were examined by radiography to determine accurately the position of the joint *in full active extension* compared with various positions of passive extension. There was a mean of active-extension defect of 5.1° in the knee-joint compared with a passive extension obtained by loading the joint with 3–5 kg and supporting the foot. It is concluded that the power of the quadriceps for further extension in positions of extension is too low (less than 100 kgf cm) to overcome the resistance presented by the tone and elasticity of the flexors.

RESUME

Clinquante-deux articulations normales du genou ont été examinées par radiographie pour déterminer avec précision la position de l'articulation *en pleine extension active* par comparaison avec des positions variées d'extension passive. Il y avait une extension active défectueuse de 5,1° en moyenne dans l'articulation du genou comparée à l'extension passive obtenue par une charge de 3 à 5 kg sur l'articulation ayant aussi à supporter le poids du pied. On en conclut que la puissance du quadriceps pour une plus grande extension dans les positions d'extension est trop faible (inférieure à 100 kgf cm[1]) pour affronter la résistance opposée par le tonus et l'élasticité des fléchisseurs.

ZUSAMMENFASSUNG

Zweiunfünfzig normale Kniegelenke wurden mittels Röntgenstrahlen untersucht um die genaue Position des Gelenkes *bei voller aktiver Streckung,* verglichen mit verschiedenen Positionen bei passiver Streckung zu vergleichen. Man fandt einen durchschnittlichen aktiven Sreckdefekt von 5,1° im Vergleich mit einer passiven Streckung, die man erhielt wenn man das Gelenk mit 3–5 kg belastete und den Fuss unter-

[1] Kgf = Kp = 9,81 newtons = 2,2 pounds de poids.

stützte. Man schliesst, daraus dass die Kraft des Quadriceps für die weitere Streckung in Streckpositionen zu gering ist (weniger als 100 kgf cm[1]) um den Widerstand, der wom Tonus und der Elastizitet der Flexoren ausgeübt wird, zu überwinden.

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[1] Kgf = Kp = 9.81 Newtons =2,2 Pfund Gewicht.