

The effect of quadriceps contraction during weight-bearing on four patellar height indices

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The effect of weight-bearing on the height of the patellar using four radiological indices was studied in 25 healthy men using lateral radiographs of the knee in 30° of flexion non-weight-bearing and weight-bearing. The position of the patella was quantified using the Insall-Salvati, the modified Insall-Salvati, the Blackburne-Peel and the Caton indices. The contraction of the quadriceps on weight-bearing resulted in statistically significant proximal displacement of the patella with all four indices studied. The mean Insall-Salvati index was 0.919 (SD 0.063) before and 1.109 (SD 0.042) after weight-bearing ($p = 0.001$), while the mean modified Insall-Salvati index was 0.734 (SD 0.039) before and 0.896 (SD 0.029) after weight-bearing ($p = 0.041$). Similarly, the Blackburne-Peel index was 0.691 (SD 0.09) before and 0.807 (SD 0.137) after weight-bearing ($p = 0.012$). The mean Caton index was 0.861 (SD 0.09) before and 0.976 (SD 0.144) after weight-bearing ($p = 0.023$).

The effect of quadriceps contraction should be considered in clinical studies where the patellar position indices are reported.

The patella is the largest sesamoid bone in the human body and is at the centre of the extensor mechanism of the knee connecting the quadriceps tendon and the patellar ligament. The primary functional role of the patella is to increase the lever arm of the extensor mechanism, facilitating knee extension. Its position in the coronal and sagittal planes varies depending on the angle of flexion of the knee.¹ The patellar height can be reliably measured on lateral radiographs of the knee, on sagittal MR images or using ultrasound imaging.¹⁻⁷ However, plain radiography is the primary investigative tool in examining the height of the patella with several described radiological methods of measurement.²⁻⁵ In the studies where the height of the patella has been measured, the various indices have been calculated in various degrees of knee flexion without weight-bearing, with the patient lying on his side.¹⁻⁸ The most commonly-used indices are the Insall-Salvati,² the modified Insall-Salvati,³ the Blackburne-Peel⁴ and the Caton ratios.⁵

The most widely used is the Insall-Salvati index,² which compares the length of the patellar ligament measured on its deep posterior surface, from the lower pole of the patella to its insertion into the tibial tubercle to its greatest diagonal length. The accepted angle of knee flexion is 30° to 60°.² The length of the patella is usually slightly shorter than the patellar liga-

ment. In adults the normal range of the ratio is from 0.8 to 1.2.⁵

The modified Insall-Salvati index³ compares the length of the patellar ligament with the length of the articular surface of the patella, has an accepted angle of knee flexion of 30° to 60° and is considered useful in cases with a long distal (non-articulating) patellar articular facet. The cut-off point between a normal patellar height and patella alta is a ratio of 2.⁴

The Blackburne-Peel index⁴ is the ratio between the perpendicular distance from the lower articular margin of the patella to a line describing the tibial plateau and the length of articular surface of patella. The normal range for men is 0.805(SD 0.14) and for women 0.806 (SD 0.13).⁴

The Caton index⁵ compares the length of the patellar articular surface with the distance between the postero-inferior edge of the patella and the anterior border of the tibial plateau. The normal range is from 0.8 to 1.2.⁵

The purpose of this study was to evaluate the effect of quadriceps contraction during weight-bearing on the patellar height using standard radiological measurements.

Patients and Methods

The height of the patella was measured using lateral radiographs of the dominant knee of 25 young men with a mean age of 21.8 years (19

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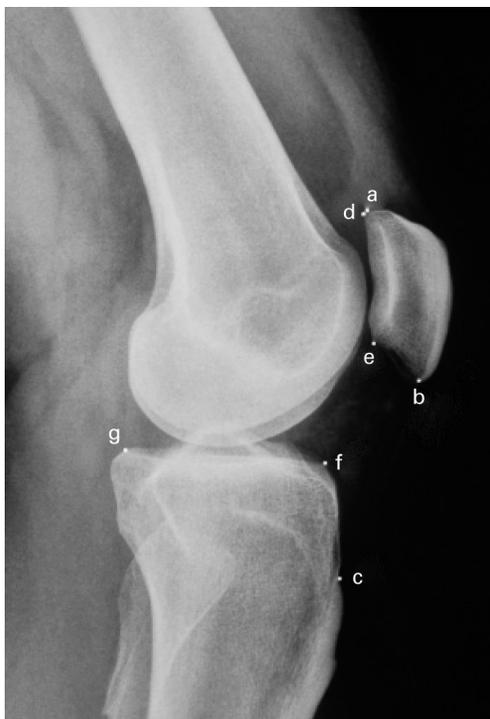


Fig. 1

Radiograph showing the seven landmarks on each knee. a, the upper and b, the lower pole of patella; c, the patellar tendon attachment at the tibial tubercle; d, the upper and e, lower patellar surface; f, the anterior and g, the posterior edge of the tibial plateau.

to 25). No participant had a history of knee injury or a disorder of the knee. The study was approved by the Institutional Ethics Committee, and all participants provided written consent. A true lateral radiograph of the knee in 30° of flexion to tension the patellar tendon was performed in all patients before (with the patient lying on their side) and after weight-bearing using fluoroscopy to assure superimposition of the femoral condyles for the exposure.

On each radiograph a total of seven landmarks were marked (Fig. 1). These included the upper and lower pole of patella (a and b), the patellar tendon attachment at the tibial tubercle (c), the upper and lower limit of the patellar articular surface (d and e) and the anterior and posterior edge of the tibial plateau (f and g).

From these points the patellar height was measured using four accepted ratios which were calculated as follows: the Insall-Salvati index² (bc/ab), the modified Insall-Salvati index³ (ec/de), the Blackburne-Peel index⁴ (perpendicular distance from e to a point crossing an extrapolation of the line de) and the Caton index⁵ (ef/de). Each index was measured on the radiographs, using a ruler, three times by the same reader (CKY) and the mean value of the three measurements used.

Statistical analysis. Statistical analysis was performed using Student's paired *t*-test to evaluate the change in the patellar height before and after weight-bearing, with $p < 0.05$ considered significant.

Results

The contraction of the quadriceps occurring on weight-bearing with the knee flexed to 30° resulted in significant proximal displacement of the patella compared with the non-weight-bearing radiographs. This change was statistically significant for all four patellar indices. The mean Insall-Salvati index was 0.919 (SD 0.063) before and 1.109 (SD 0.042) after weight-bearing ($p = 0.001$), while the mean modified Insall-Salvati index was 0.734 (SD 0.039) before and 0.896 (SD 0.029) after weight-bearing ($p = 0.041$). Similarly, the Blackburne-Peel index was 0.691 (SD 0.09) before and 0.807 (SD 0.137) after weight-bearing ($p = 0.012$). The mean Caton index was 0.861 (SD 0.09) before and 0.976 (SD 0.144) after weight-bearing ($p = 0.023$). Initially, all the indices were within the normal range for their method.

Discussion

The assessment of patellar height is clinically relevant, especially in the evaluation of patients with anterior knee symptoms. Radiological methods may produce inaccuracies, despite relying on standardised radiographs as they may be difficult to perform.

The position of the patella may be described as normal, high (*alta*) or low (*infera*). Patella *infera* refers to an inferior vertical position of the patella in relation to the femoro-tibial articulation while patella *alta* refers to superior migration of the patella. Patellar *alta* may result in patellar subluxation or dislocation and is associated with chondromalacia and Osgood-Schlatter's disease.⁸ It is also an aetiological factor in the development of patellofemoral arthritis especially when associated with trochlear dysplasia.⁹ Patella *infera*, sometimes described colloquially as patellar *baja*, refers to an abnormally low patellar position following peri-articular soft-tissue or patellar ligament contraction secondary to surgery or trauma. Patellar *infera* is considered a risk factor for anterior cruciate ligament (ACL) injury¹⁰ and may cause stiffness and pain, leading eventually to patellofemoral osteoarthritis.¹¹ Shortening of the patellar ligament occurs following knee operations such as ACL reconstruction, knee replacement, tibial osteotomy, and after intra-articular, supracondylar and patellar fractures at the knee.¹²⁻¹⁴ Shortening of the patellar ligament following ACL reconstruction is gender-related and more pronounced in women.¹⁵

Our study showed that the effect of quadriceps contraction should be taken into account in clinical studies where indices of the patellar position are evaluated. A drawback of this study is that it was performed on young, healthy individuals. The results of the study can be expanded repeating the protocol in patients with ACL reconstruction, osteotomy or knee replacement. In the post-operative or

Table I. The results of the four methods for defining patellar height

Patellar index	Normal values	Mean value (SD)	SEM	p-value (t-test)
Insall-Salvati				
Non-weight-bearing	0.8 to 1.2	0.919 (0.063)	0.022	0.001
Weight-bearing		1.109 (0.042)	0.015	
Modified Insall-Salvati				
Non-weight-bearing	The cut-off point between normal patella and patellar alta is 2	0.734 (0.039)	0.014	0.041
Weight-bearing		0.896 (0.029)	0.01	
Blackburne-Peel				
Non-weight-bearing	Men, 0.805 (SD 0.14)	0.691 (0.09)	0.032	0.012
Weight-bearing	Women, 0.806 (SD 0.13)	0.807 (0.137)	0.048	
Caton				
Non-weight-bearing	0.8 to 1.2	0.861 (0.09)	0.032	0.023
Weight-bearing		0.976 (0.144)	0.051	



Fig. 2a



Fig. 2b

Lateral radiographs of the knee a) non-weight-bearing and b) weight-bearing showing the proximal displacement of the patella associated with weight-bearing.

injured knee the amount of proximal patellar translation on weight-bearing may be less pronounced due to the influence of scar tissue. The effect of quadriceps contraction on the patellar position may be more pronounced in patients with ligamentous or soft-tissue laxity.

The kinematics of the patellar ligament during *in vivo* weight-bearing flexion has been studied using MR imaging in normal subjects.¹⁶ The deformation of the patellar ligament is relatively uniform but its length increases signifi-

cantly between full extension and 30° flexion, and remains relatively constant between 30° and 110° of flexion. The length of the central part of the patellar ligament increases from a mean of 49.9 mm (SD 8.1) at full extension to 56 mm (SD 5.3) at 30° of flexion. Using cine-phase contrast MRI to study the patellar ligament during flexion from 0° to 35° to 45°, average maximum strains of 6.6% were found for a low load extension task at relatively small angles of knee flexion.¹⁷

Weight-bearing has been shown to increase the patellofemoral contact area. At 30° of knee flexion the mean patellofemoral contact area in the unloaded lower limb is 400 mm², while when the lower limb is loaded to 0.45 times bodyweight, the respective area is increased to 522 mm².¹⁸ With increasing flexion, the ratio between the patellar ligament and the quadriceps tensile force increases initially up to 30°, then progressively decreases up to 90°, to increase again beyond 90° of flexion. The decrease in the patellar ligament force with flexion is responsible for the reduction in the knee extensor moment with flexion.¹⁹ Additionally, at 30° of flexion the force ratio between the patellar ligament and the quadriceps tendon reaches its maximum value of 1.27.²⁰

In conclusion, this study shows that weight-bearing changes the patellar height measurements in radiological studies. Proximal patellar translation on weight-bearing has to be taken into account when the patellar height is measured.

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