The measurement of patellar height

A REVIEW OF THE METHODS OF IMAGING


From Department of Clinical Radiology and Department of Trauma and Orthopaedics, Royal Devon and Exeter Hospital, United Kingdom

Many radiographic techniques have been described for measuring patellar height. They can be divided into two groups: those that relate the position of the patella to the femur (direct) and those that relate it to the tibia (indirect). This article looks at the methods that have been described, the logic behind their conception and the critical analyses that have been performed to test them.

In 1938, Blumensaat described the first practical radiographic technique for measuring patellar height. Since then, many further attempts have been made to establish a simple, reliable and reproducible way of assessing the patella on standard imaging.

Knowledge of the anatomy and biomechanics of the patella is fundamental to understanding the different pathologies of the anterior knee. Abnormal patellar height is seen in many conditions that affect the patellofemoral joint. Patella alta, an abnormally high patella, is associated with anterior knee pain, patellar instability and Osgood-Schlatter’s disease, whereas patella baja or infera, an abnormally low patella, may be observed with anterior knee pain and limitation of knee flexion, mainly as a complication of surgery or trauma.

Since it was first described, the techniques devised to measure patellar height and the studies that test their validity have increased in number and complexity. Despite progression from a simple radiographic measurement to the most modern biomechanical and imaging technologies, the definition of patellar height and its causal relationship to the conditions commonly associated with anterior knee pain remains controversial. We have yet to devise a truly foolproof method that has all the necessary criteria for a universally accepted system providing accurate structural information for use in a clinical environment.

Methods of measurement of patellar height

Many methods have been described with only two specifically relating to children and only one applied to a specific racial group. These are summarised in Tables I and II and can be divided into two groups, those that relate the position of the patella to the femur (direct) and those that relate it to the tibia (indirect). The terms ‘direct’ and ‘indirect’ have been applied more latterly, following the realisation that the quantitative relationship between the patella and the femur is most important, as the patellofemoral biomechanics hold the key to explaining anterior knee pathology.

Indirect methods. The most widely accepted radiographic techniques used to measure patellar height are indirect, perhaps influenced by the pioneering method of Insall and Salvati, published in 1971 with the development of a simple ratio between the length of the patellar tendon and that of the patella. It proved easy to measure on lateral radiographs, not requiring a fixed-flexion angle, and the mean normal ratio of 1.0 (0.8 to 1.2) is easy to remember. It remains the most popular method, although the bony landmarks are not always easy to identify, the size of the patella can vary and pathological bony overgrowth can distort the native anatomy. The method also assumes that the tibial tubercle is at a constant distance below the tibial plateau. These drawbacks can lead to both intra- and interobserver error. However, modern digital radiographs have such good soft-tissue definition that the patellar tendon itself is usually visible, making accurate identification of the tibial tubercle obsolete. Furthermore, a cadaveric study by Schlenzka and Schwesinger demonstrated that absolute anatomical measurements and the resultant Insall-Salvati ratios correlated well with ratios measured on lateral radiographs.

Using a more modern approach, Miller, Staron and Feldman showed that Insall-Salvati ratios can also be applied to MR images but require a slight change in the normal range of values in order to be valid. In order to
### Table I. Summary of methods of indirect patellar height measurement in chronological order

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study population*</th>
<th>Imaging method†</th>
<th>Indirect method of measurement‡</th>
<th>Interpretation§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insall and Salvati¹²</td>
<td>114: ‘Normal’ subjects: Meniscectomies</td>
<td>Lateral XR 20° to 70° flexion</td>
<td>Length of patellar tendon (LT); Length of patella (LP)</td>
<td>LT:LP ratios: PA &gt; 1.2; N: 0.8 to 1.2; PI: &lt; 0.8</td>
</tr>
<tr>
<td></td>
<td>No demographics given</td>
<td></td>
<td>Ratio = LT:LP</td>
<td></td>
</tr>
<tr>
<td>Blackburne and Peel²¹</td>
<td>269: 171 ‘Normal’ subjects: Meniscal pathology or contralateral knees (121M; 50F); SS Subluxera (25M; 33F); 40 CMP (10M; 20F)</td>
<td>Lateral XR ≥ 30° flexion to tension the patellar tendon</td>
<td>Horizontal line projected anteriorly from the tibial plateau. Height from line to inferior edge of PAS (A); Length of PAS (B)</td>
<td>A:B ratios: PA: &gt; 1.0; N: 0.8 to 1.0; PI: &lt; 0.8</td>
</tr>
<tr>
<td>Caton et al²²</td>
<td>128: Clinical patella infera (70M; 58F; mean age 36 years); 141: Normal subjects - asymptomatic (80M; 61F; no age given)</td>
<td>Lateral XR 10° to 80° flexion</td>
<td>Distance between the inferior edge of PAS to the anterosuperior angle of the tibial plateau (AT); Length of PAS (AP)</td>
<td>AT: AP ratios: PA: &gt; 1.3; N: 0.6 to 1.3; PI: &lt; 0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ratio = AT:AP</td>
<td></td>
</tr>
<tr>
<td>deCarvalho et al²⁵</td>
<td>150: Normal subjects - asymptomatic (20 to 60 yrs; no gender given)</td>
<td>Lateral XR Approximately 30° flexion</td>
<td>Shortest distance between the inferior edge of PAS and the anterior tibial plateau (T); Length of PAS (P)</td>
<td>T:P ratio: PA: &gt; 1.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ratio = T:P</td>
<td></td>
</tr>
<tr>
<td>Micheli et al³</td>
<td>Paediatrics</td>
<td>AP XR 0° flexion</td>
<td>Distance from superior pole of patella to tibial plateau (A); Length of patella on AP film (B)</td>
<td>A-B distance: PA: &gt; 0 mm</td>
</tr>
<tr>
<td></td>
<td>10: Physseal plate fracture; contralateral knee used (12M; 7F; no ages given)</td>
<td>Serial XRs at 6 month to 1 yr intervals over 2 to 10 yrs</td>
<td>Distance = A-B</td>
<td></td>
</tr>
</tbody>
</table>
account for the potential errors arising from morphological variations in the patella, Grelsamer and Meadows developed the modified Insall-Salvati ratio, for which the length of the articular surface of the patella rather than that of the patella itself is used. However, the inferior margin of the articular surface is not easily identifiable and the inter-observer error of this method is higher than for the original ratio.15,16,20

Blackburne and Peel devised a technique that again used the length of the patellar articular surface for their ratio denominator, but exchanged the tibial tubercle for the tibial plateau as a landmark in order to avoid misidentification.

Table I. Summary of methods of indirect patellar height measurement in chronological order

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study population</th>
<th>Imaging method</th>
<th>Indirect method of measurement</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egund et al19</td>
<td>99:</td>
<td>Lateral XR 30° to 40° flexion</td>
<td>Distance from midpoint PAS (M) to tibial plateau, perpendicular to mechanical axis of tibia; Subject height (H); Tibial length (TL) Ratio = M:TL and M:H</td>
<td>No range of values given for PA, N or PI but: M = F for all absolute measurements; L = R; Young = Old</td>
</tr>
<tr>
<td>Koshino and Sugimoto10</td>
<td>Paediatric</td>
<td>Lateral XR 0°, 30°, 60°, 90°, 120° flexion</td>
<td>Lines drawn through distal femoral and proximal tibial physes; Midpoint of longest diagonal line of patella to midpoint of tibia phys (P-T) and line connecting midpoints of physes (FT) Ratio = P-T:FT at all angles Compared with IS and Blumensaat at 60°</td>
<td>0° to 30°: Ratio decreased from 1.31 to 0.9; 30° to 90°: Ratio static between 0.99 to 1.20 3.4% of subjects had PA with own method; 45.7% of subjects had PA with Blumensaat method; 66.7% had PA with IS method</td>
</tr>
<tr>
<td>Grelsamer and Meadows (modified Insall-Salvati method)</td>
<td>300: 100 ‘Normal’ subjects: no patellar pathology; 200 subjects with patellar pathology No demographics given</td>
<td>Lateral XR 20° to 70° flexion</td>
<td>The distance between the inferior PAS and the patellar tendon insertion (A); Length of the PAS (B). Ratio = A:B</td>
<td>A:B ratio: PA: &gt; 2.0</td>
</tr>
<tr>
<td>Leung et al11</td>
<td>Ethnic (S. Chinese) 290:</td>
<td>Lateral XR 30° to 70° flexion</td>
<td>Patellar tendon length (A1); Patellar length (A2); Length of PAS (B) Patellar alta index = Patellar alta Index = (A1 + A2)/B Compared with IS, MIS, BP and DeC</td>
<td>PAI ratios: PA: &gt; 3.4; N: 2.7 to 3.3; Pi &lt; 2.7 in Chinese population</td>
</tr>
</tbody>
</table>

* CMP, chondromalacia patellae; OS, Osgood-Schlatter
† XR, radiograph; AP, anteroposterior
‡ PAS, patella articular surface; IS, Insall-Salvati; MIS, modified Insall-Salvati; BP, Blackburne-Peel; DeC, deCarvalho
§ PI, patella infera
They did not describe how they arrived at the ‘tibial plateau line’ used. Is it perpendicular to the long axis of the tibia or, if simply estimated to run parallel to the plateau, which tibial condyle is used as a reference, bearing in mind that the two are significantly different in their morphology? It can only be assumed that the medial plateau is used, as the illustration implies this, together with the fact that it is concave and thus has better defined anterior and posterior margins. Seil et al. and Berg et al. both found this technique to be the most reproducible and accurate.

Caton et al. also modified the numerator by measuring the distance between the inferior margin of the articular surface of the patella and the anterosuperior angle of the tibial plateau. However, the problems associated with identifying the articular margin of the patella would apply similarly to the tibia. Despite this, Berg et al. found the Caton-Deschamps ratio to be very reproducible, closely behind that of Blackburne and Peel, when looking at the inter-observer error. This may in part be explained by the fact that the normal range of values is wide (0.6 to 1.3). They did, however, recognise that it was difficult to use in osteoarthritic knees.

These four methods are the most popular, owing partly to their relative simplicity. The lateral radiograph does not need to be taken with the knee at a fixed angle of flexion as long as the patellar tendon is under tension at 30° or more. These four are the ones most scrutinised in intra- and inter-observer variability studies that followed and utilised most often when comparing anterior knee pathologies. Further, less widely accepted and therefore relatively unknown, novel techniques were published in fairly quick succession during the 1980s and 1990s.

De Carvalho et al. developed a method in 1985 which is almost identical to that of Caton and Deschamps, but with a minor alteration in the tibial landmark. They measured the shortest distance between the inferior edge of the articular surface of the patellar and the anterior tibial plateau rather than its anterosuperior edge. Interestingly, the authors not only misquoted the methodology of Caton and Deschamps but also stated that, ‘this assessment never gained wide acceptance’, despite the close similarity to their own method.

Egund, Lundin and Wallengren published a method that is very similar to the Blackburne-Peel in that the patellar height is measured perpendicular to the tibial plateau. However, they defined the ‘condylar plane’ as being perpendicular to the true mechanical axis of the tibial shaft in order to eliminate variations in the inclination of the plateau. The lateral radiograph must be taken with the subject fully weight-bearing with the knee flexed in order to tension the patellar tendon and the tibia at 15° to the vertical. Although the authors recognised the problems associated with establishing a reliable way to measure patellar height, the solutions they introduced into their method have resulted in a complicated technique, making it impractical to use routinely; despite their claims. No range of values is given for the ratios calculated in the paper, which perhaps reflects the complexity of the method.

**Direct methods.** Relatively few publications describe and analyse methods of direct measurement of patellar height. Even the four most popular methods described above are indirect, once again raising the point about recognising the importance of the patellofemoral relationship in the aetiology of anterior knee pathology. Although Blumensaat is considered the pioneer of radiographic measurement of patellar height, an earlier method was described in 1930 by Boon-it. This assessed both patellofemoral and patellotibial relationships, but it required complicated geometrical calculations for each angle of flexion of the knee and proved too complex for routine use.

Blumensaat perhaps had early insight into the importance of the patellofemoral relationship, instead using the roof of the intercondylar notch as a reference line (the ‘Blumensaat line’) on the lateral radiograph of a knee flexed to 30°. The perpendicular height of the inferior pole of the patella above this line was measured, with normal being defined as a distance of zero. Any value greater than this was classified as patella alta. In 1955, Thestrup-Anderson applied this to a group of 286 subjects and found that 207 would be classified as having patella alta. He consequently moved the normal limit to 5 mm above the Blumensaat line. In 1970, Brattstrom pointed out the disadvantages of the Blumensaat method, indicating that this distance varies with knee flexion and also that the Blumensaat line does not form a fixed angle with the femoral axis, with variations up to 30°. In an attempt to rectify the latter problem, Seyahi et al. developed the intercondylar shelf angle (ISA)-corrected Blumensaat method, using a fixed ISA value of 147°, which was the mean angle between the femoral shaft axis and the Blumensaat line on 105 knees. The patellar height was determined using this fixed angle and a comparison was made with the original Blumensaat technique, but again moving the normal limit up to 10 mm above the line, and also with the Insall-Salvati, modified Insall-Salvati and Blackburne-Peel ratios. They showed that Blumensaat and the ISA-corrected methods showed similar but poor correlation with the three other methods, summarising ‘that the intercondylar notch cannot be a beneficial landmark alone’. This statement is likely to have prompted the idea of indirect methods that followed.

A further variation was developed by Hepp in 1984, whereby the perpendicular height of the superior pole of the patella above the Blumensaat line is measured, rather than the inferior pole. They also suggested using the ‘patellar height angle’, which is the angle subtended by the Blumensaat line and a line extending from the superior pole of the patella to the intersection with the posterior margin of the femoral condyles. Considering the variation in the position of the Blumensaat line, these methods do not appear to overcome this problem.

The next attempt at a direct method came from Labelle et al. However, this appears rather too simplistic and unusually requires a lateral radiograph of the knee flexed to 90°. If the superior pole of the patella lies above the
<table>
<thead>
<tr>
<th>Author/s</th>
<th>Study population*</th>
<th>Imaging method†</th>
<th>Direct method of measurement‡</th>
<th>Interpretation§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blumensaat3</td>
<td>No details available</td>
<td>Lateral XR 30° flexion</td>
<td>Perpendicular distance between the inferior pole of patella and the ‘Blumensaat’ line projected anteriorly through the roof of the femoral trochlea</td>
<td>Distance: PA &gt; 0 mm</td>
</tr>
<tr>
<td>Bernageau et al37</td>
<td>Normal subjects: No demographics given</td>
<td>Lateral XR Full extension</td>
<td>Distance between inferior edge of PAS (point R) and superior edge of femoral trochlea (point T) Distance = R to T</td>
<td>Distances R to T: PA: &gt; +6 mm (i.e. R higher than T); PI: &lt; -6 mm (i.e. R lower than T)</td>
</tr>
<tr>
<td>Labella et al31</td>
<td>No details available</td>
<td>Lateral XR 90° flexion</td>
<td>Height of the superior pole of patella above the tangent of the anterior cortical line of the femur</td>
<td>Distance: PA: &gt; 0 mm</td>
</tr>
<tr>
<td>Norman et al33</td>
<td>91: Meniscal pathology (57 M; 34 F; mean age 33 yrs)</td>
<td>Lateral XR 0° flexion 10° to 15° external rotation Quads contracted</td>
<td>Perpendicular distance from the distal edge of the PAS to the femoral condylar plane (line tangential to femoral condyles, perpendicular to anterior femoral cortex) (VP); Body height (H); Ratio = Vertical Index of the patella = VIP = VP:H</td>
<td>VIP ratio: 0.21 ± 0.02</td>
</tr>
<tr>
<td>Hepp23</td>
<td>560 knees No clinical or demographic details given</td>
<td>Lateral XRs at 5° incremental flexion from 25° to 60° flexion</td>
<td>2 methods: 1. Perpendicular distance between superior edge of PAS and the Blumensaat line; 2. Angle subtended by the Blumensaat line and the superior edge of the PAS to posterior femoral condyle margin</td>
<td>Linear decrease in both distance (58 to 37 mm) and angle (53° to 32°) with increasing knee flexion No range of values given for PA, N and PI</td>
</tr>
</tbody>
</table>
tangent of the anterior cortical line of the femur, patella alta is diagnosed. It is synonymous with the clinical evaluation, where alta is diagnosed if, with the knee in 90° of flexion, the patella points to the ceiling, rather than toward the torso. The fact the femur is curved makes the anterior cortical line difficult to position. Patella infera cannot be diagnosed using this method.

Norman et al developed a truly direct method, originally described in Swedish in 1976 and published in English in 1983, which assessed the height of the patella in its most proximal position, with the knee in full extension and the quadriceps contracted. The perpendicular distance between the inferior margin of the patellar articular surface and the distal aspect of the femoral condyles, expressed relative to

---

**Table II. Summary of methods of direct patellar height measurement in chronological order**

<table>
<thead>
<tr>
<th>Author/s</th>
<th>Study population*</th>
<th>Imaging method†</th>
<th>Direct method of measurement‡</th>
<th>Interpretation§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burgess¹⁰</td>
<td>'Normal' subjects: Meniscal/ACL injury (46 knees)</td>
<td>Lateral XR</td>
<td>Distance from midpoint of PAS to tibial plateau (A); AP width of femoral condyle (B) (perpendicular to femoral axis)</td>
<td>A:B ratio: Normal subjects: 0.56 to 0.76 (mean 0.66)</td>
</tr>
<tr>
<td>Miller et al¹⁸</td>
<td>'Normal' subjects: Meniscal/ACL injury (46 knees)</td>
<td>Lateral XR</td>
<td>Length of PAS (AS); Length of PAS at the level of anterior aspect of the distal femoral physeal scar (PH)</td>
<td>AS:PH ratios: 2.1 ± 0.8 (M) 2.9 ± 2.4 (F)</td>
</tr>
<tr>
<td>Seyahi et al³⁰</td>
<td>'Normal' subjects - no degenerative change on plain radiograph (77 knees)</td>
<td>Lateral XR</td>
<td>Perpendicular distance between the IPP and the 'intercondylar shelf angle' (ISA) corrected 'Blumensaat' line projected anteriorly through the roof of the femoral trochlea.</td>
<td>Distance: PA: &gt; 10 mm</td>
</tr>
<tr>
<td>Biedert and Albrecht³⁴</td>
<td>'Normal' subjects: Most had meniscal or ACL pathologies. No patellofemoral complaints; (66 knees)</td>
<td>MRI</td>
<td>Baseline patella (Bp) = vertical length of PAS; Baseline trochlea (Br) = vertical height of trochlear articular surface from most superior femoral aspect to most inferior aspect of PAS; Patellotrochlear index (%) = Br×Bp x 100</td>
<td>Patellotrochlear index: PA: ≤ 12.5% PI: ≥ 50% t-test showed 2nd observer intra-observer error; Inter-observer correlation high and significant</td>
</tr>
</tbody>
</table>

---

* ACL, anterior cruciate ligament  
† XR, radiographic  
‡ PAS, patella articular surface; IS, Insall-Salvati; BP, Blackburne-Peel  
§ PA, patella alta; PI, patella infera; N, normal; ISA, intercondylar shelf angle; MIS, modified Insall-Salvati  

---
body height rather than absolute measurements, is used because it was found that this ratio is equal in both males and females, unlike the absolute distances, thus requiring only one set of normal values. This gender difference was also observed by Egund et al.\textsuperscript{26} The biggest drawback is the fact that the height is measured parallel to the anterior cortex of the femur, which is curvilinear, allowing both intra- and inter-observer errors. No subsequent studies to test this possibility have been performed. Also, the use of a lateral radiograph of the knee in full extension, with the quadriceps fully contracted, is not part of the standard imaging technique, making it less practical.

It was not until 1989 that Burgess\textsuperscript{14} devised a method using lateral radiographs of the knee at any angle of flexion which produced tension in the patellar tendon. The direct ratio between the distance from the midpoint of the articular surface of the patella to the tibial joint line and the anteroposterior (AP) dimension of the femoral condyles perpendicular to the mechanical axis of the femoral shaft, was compared with the Insall-Salvati and Blackburne-Peel ratios. The direct method was deemed better at determining a normal range of values. However, although Burgess applied the problem of variation in patellar size and the position of the tibial tubercle to recognise the inaccuracies of indirect methods, he did not acknowledge that the femoral condyles could also vary in size. In addition, he did not identify which condylar width is used in the calculation: the lateral condyle usually has a greater AP dimension.

The most recent technique was described by Biedert and Albrecht in 2006\textsuperscript{34} as the ‘patellotrochlear index’. This involves MRI rather than radiographs and uses chondral landmarks rather than bony ones. This is logical, because patellofemoral biomechanics relates to articular surface interaction. Both Staeubli et al\textsuperscript{15} and van Huyssteen et al\textsuperscript{16} have shown a morphological difference between the articular cartilage and the underlying subchondral osseous anatomy of the patella and the femoral trochlea. Biedert and Albrecht\textsuperscript{34} adapted a radiographic technique, first described in 1969 by Bernageau et al,\textsuperscript{37} where the relationship between the superior line of the trochlea and the inferior edge of the patella is applied to articular cartilaginous landmarks rather than the corresponding bony ones. The original technique of Bernageau resulted in a large range of normal values from -6 to +6 mm. It was also criticised by Caton\textsuperscript{38} as not being useful when planning surgery in patients with patella alta or infera, and almost impossible to use in patients with severe trochlear dysplasia. The need to change the imaging modality from plain film radiography to MRI does not make the technique less practical, as most patients with anterior knee pain will undergo an MR scan as part of their management. A similar MRI method was described by Miller et al,\textsuperscript{39} who calculated the ratio between the patellar articular surface and the anterior femoral physeal height on sagittal MR scans, and tested the accuracy of the standard Insall-Salvati ratio when using MRI. Unfortunately, the correlation between the two methods was only fair. Biedert\textsuperscript{34} deemed the use of the physeal scar as the upper articular landmark to be inaccurate when developing the patellotrochlear index, subsequently finding that with the new adjustments, the intra-observer error was low and the inter-observer correlation was significantly high. It was also acknowledged that the effects of a tensed quadriceps, a change in the flexion angle and weight-bearing on this technique were not addressed. Biedert and Albrecht’s\textsuperscript{34} method has recently been tested by Barnett et al,\textsuperscript{39} who compared it to the Insall-Salvati, Blackburne-Peel and Caton-Deschamps ratios in subjects with patellofemoral dysplasia, and found that the patellotrochlear index does not correlate well with the other ratios for patella alta, although all had good intra- and inter-observer reliability. This supported the theory that chondral rather than osseous relationships are more important and clinically relevant.

**Paediatric studies.** Micheli et al\textsuperscript{9} described a method of measuring patellar height in children. This study is the only one identified, where the authors have acknowledged that adult ratios cannot be applied accurately to the paediatric population (anterior knee pain is common in adolescents) due to lack of ossification and subsequently developed a new method. They investigated how the growth spurt can affect the development of patella alta by performing serial radiographs at six- to 12-month intervals over a period of up to ten years. Because only a single AP view was used to assess growth in the lower limb, they adapted the principles of Brattström\textsuperscript{11} to fit the radiograph, thus evolving a new technique, but failed to recognise the significance of skeletal maturity. The length of the patellar tendon was calculated as the difference between the inferior pole of the patella and the tibial plateau. This differed from Brattström, who used the approximate joint line as his reference point. If this was greater than zero, then patella alta was diagnosed. However, not surprisingly, all of the 19 children studied had a positive value, although they found that patella alta is more likely to develop in girls than in boys during the adolescent growth spurt. The omission of the ages of the subjects is an important error, as full ossification may not have occurred and would in part explain why all subjects had positive values. Walker, Harris and Leicester\textsuperscript{40} also showed that young children all have a high Insall-Salvati ratio, which decreased with age and became the same as the adult values at approximately ten years in girls and 12 in boys. Full ossification occurred at 15 and 17 years of age, respectively.

Koshino and Sugimoto\textsuperscript{10} described a novel technique that uses the midpoints of the femoral and tibial physeal to calculate a ratio between the patellofemoral distance and the tibiofemoral distance, thereby eliminating the need to adjust for the extent of epiphyseal ossification. Although only a small series of 59 knees in 36 children, the method produced stable values for all angles of flexion between 30° and 90°, making it practical to perform in children, 3.4% of whom had patella alta using their calculations. The authors also determined both Blumensaat and Insall-Salvati ratios using the same radiographs and found that 46% and 67% of the subjects, respectively, would have been classified as having
patella alta, thus emphasising how adult ratios cannot be applied to children. They recognised that one drawback with this method was that cautious line-drawing through the physes is required, owing to their irregular morphology. Aparcio et al\(^\text{41}\) compared this with the Blackburne-Peel and Caton-Deschamps methods and found that, although all three had low inter-observer variability, Koshino’s was not as reproducible as the Caton-Deschamps ratio, with the latter also not being affected by skeletal maturity.

**Method limitations.** A review of all the methods that have been devised to assess patellar height has demonstrated that, although the patellofemoral relationship is the most important aspect of understanding the causes of anterior knee pain, most techniques are indirect. The last to be developed, by Biedert and Albrecht in 2006,\(^\text{34}\) is probably the closest to perfect, to date, as it uses MRI, relates the patella directly to the femur, and uses cartilaginous landmarks, thereby eliminating osseous variation, which is possibly the greatest cause of error in measuring patellar height accurately.

Of the studies that resulted in the description of the four most established methods, Insall-Salvati,\(^\text{12}\) Blackburne-Peel,\(^\text{21}\) Caton-Deschamps,\(^\text{22}\) and the modified Insall-Salvati\(^\text{19}\), only the Caton-Deschamp included knees that were asymptomatic, in an endeavour to establish a normal range of values. The subjects included in the remaining three studies had either meniscal or cruciate ligament pathology, which was deemed acceptable by the authors on the assumption that these soft-tissue problems have no effect on the patellofemoral relationship. This has been shown to be incorrect,\(^\text{42,43}\) and any proposed method should ideally be tested using only subjects with clinically and radiologically normal knees, before applying it to patients with anterior knee pathology. Of the less well-known methods, only Egund et al,\(^\text{26}\) Koshino and Sugimoto,\(^\text{10}\) Bernageau et al\(^\text{37}\) and de Carvalho et al\(^\text{25}\) managed to use normal knees, but even then, normality was only defined as being ‘subjects with no previous knee symptoms’. They did not undergo a clinical examination and none were excluded on the basis of the subsequent radiographic appearance.

Furthermore, little reference is made to the inherent anatomical differences between men and women, and only two studies look at ethnic diversity,\(^\text{11,44}\) where both showed that there are significant differences between Europeans and Arabs, Africans and Chinese, with the non-European populations having a much higher rate of patella alta. Leung et al\(^\text{11}\) developed the ‘patella alta index’ as the ratio of the sum of patellar length and patellar tendon length, to the length of the patellar articular surface, with a much higher range of normal values to better suit the Southern Chinese population.

Accuracy also seems to be a problem, with few studies looking at the inter- and intra-observer errors of any method, even the four most popular ones. Only three publications can be identified that compare the Insall-Salvati, the modified Insall-Salvati, the Blackburne-Peel and Caton-Deschamps methods, and even then abnormal knees were used.\(^\text{15,16,45}\) Blackburne-Peel and Caton-Deschamps seem to have better accuracy and reproducibility, but in the absence of any studies using normal knees, these cannot be deemed as fully reliable.

As Biedert\(^\text{34}\) has noted, no study where a new technique has been described has looked at how quadriceps tension, the angle of flexion and weight-bearing influences patellar height. These issues have been looked at separately, but not in the same study.\(^\text{6,7,10,18,46}\) The only way to solve this problem is to use dynamic MRI, but at present this is only practical for research purposes to define what is normal. Yiannakopoulos et al\(^\text{46}\) have recently shown that in normal knees the height of the patella changes significantly on weight-bearing through the effect of quadriceps contraction, regardless of which of the four most common ratios is used to calculate this. Although they gave no absolute measurements, there was a significant mean difference between the ratios calculated for the non-weight-bearing and fully weight-bearing groups of 0.2 (\(p < 0.05\)).\(^\text{46}\)

Having reviewed the extensive literature on this controversial subject, it appears that only the passing of time has led to acceptance of the most common methods for measuring patellar height. Not only is there little concrete evidence to support the accuracy and validity of these methods, but none has proved to be suitable for universal application, although both the Blackburne-Peel and Caton-Deschamps methods may be the most reliable indirect plain-film radiographic techniques. Direct methods have either proved too complex or too novel to be adopted regularly. MRI is currently underused in the assessment of patellar height and undoubtedly has great potential for use in further research. It would require a very large study with a truly population comprising all ages, genders and ethnicities to determine a truly normal range of values for any technique. However, before this vast undertaking can be considered, a method that accurately reflects the patellofemoral relationship and can also be used routinely and repeatedly in a clinical situation needs to be established. Ideally this should be able to demonstrate the patellofemoral relationship under physiological loading conditions in the symptomatic knee. Nonetheless, until dynamic imaging techniques become standardised and routinely available, we need to identify the best method of imaging and measuring patellar height from those currently available. From the limitations described above, there is clearly significant scope for improving the methods designed to date, insofar as to say that it is still very much an ‘evolving’ project, even after nearly eight decades.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

**References**