Novel method of measuring patellar height ratio using a distal femoral reference point

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Abstract

Purpose Patellar height is an important factor in patellar tracking and alters the force of the patellofemoral joint reaction. Several methods for measuring patellar height ratio have been described, with no single method recognised as a gold standard. This study developed a new measurement method using a distal femoral reference, where the normal values of measurement are unaffected by varying angles of knee flexion.

Methods Eighty-five volunteers had radiographs taken of their knees at 0°, 15°, 30°, 45° and 60° of flexion in a supine position. Patellar height was assessed by five different measurement methods: Insall-Salvati (IS), modified Insall-Salvati (MIS), Caton-Deschamps (CD), Blackburne-Peel (BP) and our new method. Three independent examiners sequentially conducted all measurements under identical conditions.

Results The normal value obtained with the method reported here was 1 ± 0.1 standard deviation (SD) (IS 1.1 ± 0.2 , MIS 1.8 ± 0.25 , CD 1.08 ± 0.2 , BP 0.9 ± 0.2). IS and the new method tended to have better reliability in the face of varying knee-flexion angles than did CD, BP or MIS. All methods had good to excellent levels of interobserver variation (IS 0.969, new method 0.811, MIS 0.768, CD 0.735, BP 0.708).

Conclusion The new patellar height ratio measurement method proved to be accurate and reproducible for evaluating a normal population. This method offered the benefit of using the distal femur as a reference landmark,

and, thus, the resulting measurements were not altered by varying degrees of knee flexion.

Introduction

The patellofemoral joint plays an important role in the knee's extensor mechanism. The patella acts as the lever arm in extensor arc motion and improves quadriceps strength by 30–50% [17]. Patella height alters the joint reaction force of the patellofemoral joint. Patella alta (a high-riding patella) is a condition associated with patellofemoral malalignment and a reduced area of patellofemoral contact, leading to patellofemoral pain or instability [8, 11, 14, 24]. Patella baja (a low-riding patella) is associated with limited knee range of motion (ROM), Osgood–Schlatter disease and patellofemoral arthritis [1]. Several patellar height-measurement methods have been described: Blumensaat [6], Insall-Salvati (IS) [14], modified Insall-Salvati (MIS) [12], Blackburne-Peel (BP) [5], Caton-Deschamps (CD) [7], De Carvalho (12) and Koshino (13). However, there is no consensus regarding the superiority of any one of these methods [2, 10, 22]. Most are based on the ratio of patellar length to the distance of the patella from the tibial reference point [5, 7, 9, 12, 14, 20]. Actually, the patellofemoral joint is defined by the patella's position relative to the distal femur. Therefore, it would be meaningful to use the distal femur as the reference point for measuring patellar height [23]. However, most methods that do use a distal femoral reference point, e.g. Blumensaat [6], Bernageau et al. [3], Biedert and Albrecht [4], are disadvantaged by the significant differences in the normal ratios they obtain at varying angles of knee flexion. Because measurement accuracy depends on the specific angle of knee flexion, these methods are not widely used clinically.

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Fig. 1 Adjustable knee support frame and goniometric ruler attached to a radiopaque iron bar guided volunteers' knee flexion at each angle

In this study, we developed a new patellar height ratio measurement method using the distal femur as a reference point. The principal aim was to validate the accuracy and reproducibility of the method. The secondary objective was to assess the influence of knee flexion angles on several previous methods of patellar height-measurement ratio. We hypothesised that the normal values of the new measurement method would be unaffected by varying degrees of knee-flexion angle.

Materials and methods

Eighty-five volunteers were recruited from the healthy population. Inclusion criteria for the study were: skeletal maturity (ranging in age from 20 to 45 years); no history of chronic knee pain, patellar instability, knee deformity, crystal-induced or rheumatoid arthritis and no past infection of the knee joint. All volunteers underwent lateral radiographs of their knees at 0°, 15°, 30°, 45°, and 60° of flexion in the supine position and with no quadriceps contraction. Each knee-flexion angle was standardised using a customised adjustable knee support frame to position the seated individual's leg. A goniometric ruler with a radiopaque iron bar was attached to an X-ray board and used to guide volunteers' knee flexion at each angle (Fig. 1). The greater trochanter, lateral femoral condyle and lateral malleolus

were used as reference points when aligning the goniometric ruler. Volunteers were then asked to relax their knees to eliminate quadriceps contraction. After fluoroscopy, we checked radiograph quality for control accuracy of the knee-flexion angle and condyle rotation, not to overlap more than three millimetres. If the quality of either radiograph was unacceptable, the procedure was repeated. All radiographs were recorded by a digital system.

The new method we developed determines the ratio of the distance from the posterior angle of the intercondylar roof to the tibial tubercle, with the distance from the midpoint of the patellar articular facet to the tibial tubercle (Fig. 2). Patellar height was measured by five methods: IS [14], MIS [12], CD [7], BP [5] and our measurement method (Fig. 3). Three independent examiners (all orthopaedic residents) conducted these measurements sequentially and under identical conditions for each volunteer. All examiners used the digital radiograph system for measuring patellar height ratios. Each examiner was blinded with regard to each volunteer's data and results of other examiners.

Statistical analysis

Normal values for patellar height ratios were described by mean $\pm$ standard deviation (SD). Variation in the values delivered by the different methods at varying angles of knee flexion was compared using one-way analysis of variance

Fig. 2 New patellar height-measurement ratio

Fig. 3 Reference points for patellar height-measurement methods

(ANOVA). Intra- and interobserver reliability were assessed with intraclass correlation coefficient (ICC) at a 95% confidence interval (CI).

Results

Eighty-five volunteers [42 men, 43 women; mean age 32 (range 22–44) years] participated in our study. Normal values for each method of measuring the patellar height ratio (mean $\pm$ SD) for overall knee flexion angles (0°, 15°, 30°, 45°, 60°) were: 1 ± 0.1 (new method), 1.1 ± 0.2 (IS), 1.8 ± 2.5 (MIS), 1.08 ± 0.2 (CD) and 0.9 ± 0.2 (BP). Normal values found at different knee-flexion angles were slightly different for each measurement method (Table 1). ANOVA showed no statistically significant difference between methods; however, the CD method tended to have the most variable results ($4,400 = 1.925$, $p=0.106$) when compared with other methods (Table 2). At 0° of flexion, the MIS and BP approaches had lower normal values (1.75 ± 0.25 and 0.87 ± 0.2 , respectively) than at other degrees of flexion. The CD method resulted in high normal values (1.12 ± 0.2) at 0° of flexion, which then decreased gradually as the angle of knee flexion increased, ending up with normal values of 1.0 ± 0.2 at 60° of flexion. In contrast, normal values given by the IS and our new method stayed constant at all knee-flexion angles.

These data indicate that the five methods show no significant difference in normal values when used between 0° and 60° of knee flexion. The IS and our novel method

delivered the most reliable results. CD produced the most variable results, suggesting that its normal values are particularly affected by the different degrees of knee flexion: CD normal values were high at 0° of flexion and decreased conversely to the angle of knee flexion. The MIS and BP methods resulted in lower normal values at 0° of flexion. Interobserver variation for the five methods, as analysed by the intraclass correlation coefficient (ICC) with a 95% CI had good to excellent reliability (Table 3). The IS method had the best results (95% CI >0.9). Our new method obtained excellent reliability (>0.8). The MIS, BP and CD methods had good to excellent reliability (0.7–0.8) but lower 95% CI (0.6–0.8) than the former two methods (0.7–0.9).

Discussion

Patellar height measurement is a valuable clinical tool for screening, diagnosing and planning treatment for many knee conditions. Several methods of measuring patellar height have been proposed, but no single method has yet been accepted as a gold standard [2, 10, 22]. Significantly, many studies have been unable to verify a correlation between abnormal patellar height and clinical symptoms [13, 15, 18, 19, 24]. Most existing measurement methods use lateral radiographs with the knee in varying degrees of flexion and calculate patellar height as an index ratio involving the patella's distance from different particular landmarks. Patellar height-measurement reference methods

Table 1 Normal values (mean $\pm$ standard deviation) of different patellar height-measurement methods at varying knee-flexion angles

Patella height index	0° Mean (SD)	15° Mean (SD)	30° Mean (SD)	45° Mean (SD)	60° Mean (SD)
Insall-Salvati	1.076 (0.25)	1.087 (0.18)	1.098 (0.17)	1.095 (0.16)	1.100 (0.17)
Modified Insall-Salvati	1.759 (0.25)	1.795 (0.25)	1.798 (0.25)	1.782 (0.27)	1.809 (0.27)
Caton-Deschamps	1.118 (0.22)	1.107 (0.21)	1.079 (0.20)	1.063 (0.23)	1.037 (0.20)
Blackburne-Peel	0.837 (0.21)	0.916 (0.21)	0.923 (0.19)	0.924 (0.19)	0.924 (0.20)
Novel method	0.981 (0.10)	0.968 (0.10)	0.974 (0.07)	0.970 (0.08)	0.987 (0.05)

SD standard deviation

Table 2 Differences between knee flexion angles by one-way analysis of variance (ANOVA)

	Degree of freedom	<i>F</i> ratio	<i>P</i> value
Insall-Salvati	4, 400	0.202	0.937
Modified Insall-Salvati	4, 400	0.467	0.760
Caton-Deschamps	4, 400	1.925	0.106
Blackburne-Peel	4, 400	0.973	0.422
Novel method	4, 400	0.686	0.602

can be categorised into two groups: (1) nondistal femoral and (2) distal femoral. Of the two approaches, nondistal methods are more widely reported in the literature and in research studies. These methods measure the ratio of the distance from the tibia reference landmark to the patella and the length of either the patella or the articular surface. The four most well-known methods are the IS [14], MIS [12], BP [5] and CD [7]. Most orthopaedic surgeons are familiar with these methods in clinical practice. The advantages of these methods are that it is easy to find the reference landmark on plain film, and normal values are relatively independent of variations in knee-flexion angle. However, they all have the same disadvantage: they do not represent the true relation of patellofemoral articulation but measure the position of the patella relative to the tibia. In theory, patellar height ratio measurement using a distal femoral reference point should be the ideal method for studying patellofemoral articulation. The important consideration for this reference point is that the distal femur rolls and glides throughout the knee's range of motion. Thus, it is difficult to find a single landmark to use for a range of different knee angles. Most existing methods can be used only at specific angles of knee flexion. Thus, such measurement methods are thought to be inaccurate and are not widely used in recent studies. In 1938, Blumensaat [6] described a measurement method that used a line projected from the intercondylar notch. In a normal state, the line should fall on or just above the lower pole of the patella. However, this method can be used only at precisely 30° of knee flexion. Koshino et al. [16] described an epiphyseal line method to calculate a ratio between the distance from the centre of the patella to the epiphyseal midpoint line in the proximal tibia

and the distance between the distal femur and the proximal tibia. The average ratio for this method is 1.31 ± 0.9 at full extension, and it gradually decreases to 0.99 ± 0.06 at 90° of flexion. This is a popular method used for children with a remaining epiphyseal line, and many studies using this method have found strong correlations between patellar height and clinical symptoms or pathology in children. However, the method cannot be used accurately in patients who have reached skeletal maturity, and its normal values still vary by knee-flexion angle. Most recently, Biedert and Albrecht [4] proposed a method called patellotrochlear index, which is performed using magnetic resonance imaging (MRI) at 0° of knee flexion. The authors claim the method can exactly measure true patellotrochlear articular congruence and eliminate errors induced by osseous variation in the patella. Although useful, MRI is not always available for routine use in clinical practice, and the requirement of 0° knee flexion cannot be met by many patients with knee-flexion contracture. To the best of our knowledge, those authors summarised the ideal characteristics of a patellar height measurement, including:

1. using a distal femoral reference point to represent true patellofemoral articulation;
2. maintaining accuracy in the face of varying degrees of knee flexion;
3. having a simple value of normal ratio that is easy to remember and calculate;
4. good intra- and interobserver variation;
5. ability to be measured with routine lateral radiographs, which lead to greater ease of screening and diagnosis;
6. high levels of correlation with clinical symptoms and knee pathology. However, at this time, there is no single available method that meets all of these criteria.

In the study reported here, we propose a new method of measuring the patellar height ratio that uses a distal femoral reference point. Analysing lateral radiographs taken at 0°, 15°, 30°, 45° and 60° of knee flexion, we compared the results of our method with those of the four most popular existing methods. The resulting normal value for our method was 1 ± 0.1 . This normal value is very easy to remember and to calculate. When analysing radiographs taken at different flexion angles, our novel method showed

Table 3 Intraclass correlation coefficient (ICC) with a 95% confidence interval (CI) for patellar height ratio

Patella height index	ICC	95% CI (lower-upper)	Significant
Insall-Salvati	0.969	0.957–0.978	<0.001
Modified Insall-Salvati	0.768	0.676–0.837	<0.001
Caton-Deschamps	0.735	0.628–0.814	<0.001
Blackburne-Peel	0.708	0.745–0.872	<0.001
Novel method	0.811	0.737–0.867	<0.001

good accuracy in the range of 0–60° flexion. The distal femoral reference point at the posterior angle of the intercondylar roof is closely related to the knee's centre of rotation axis. This means our method is unaffected by varying degrees of flexion.

The CD [11] method tends to find higher normal values at 0° of flexion and decreases as the degree of knee flexion increases. The MIS [12] and BP [5] methods find lower normal values at 0° of flexion. From the results of our study, evaluation of patellar height-measurement ratio at full knee extension without quadriceps contraction can be influenced by patellar tendon laxity. To avoid this factor, a little knee flexion at 10° to create tension of mechanical extensor apparatus is recommended. We emphasise these differences only for the purpose of added caution in clinical practice; however, we found differences between methods at varying degrees of knee flexion were not statistically significant.

Levels of interobserver variation, as measured by ICC, were good to excellent for all measurement methods. Our findings were better than those in previous studies [21, 22]. This was a prospective study in which all volunteers were recruited and underwent radiographic examination under identical conditions. All radiographs were taken with the same digital radiographic system, which was intended to reduce the chances of equipment error. All processes used led this study to be well standardised and created minimal interobserver variation.

In conclusion, our proposed novel patellar height-ratio measurement index is an accurate and promising method for evaluating patellar height in the normal population. This method has the benefits of using a distal femoral reference point and of giving consistent results during varying degrees of knee flexion. Furthermore, its normal value is easy to remember, and it has high interobserver reproducibility.

References

1. Aparicio G, Abril JC, Calvo E, Alvarez L (1997) Radiologic study of patellar height in Osgood-Schlatter disease. *J Pediatr Orthop* 17:63–66
2. Berg EE, Mason SL, Lucas MJ (1996) Patellar height ratios. A comparison of four measurement methods *Am J Sports Med* 24:218–221
3. Bernageau J, Goutallier D, Debeyre J, Ferrané J (1975) New exploration technic of the patellofemoral joint: relaxed axial

- quadriceps and contracted quadriceps. *Rev Chir Orthop Reparatrice Appar Mot* 61(Suppl 2):286–290 (in French)
4. Biedert RM, Albrecht S (2006) The patellotrochlear index: a new index for assessing patellar height. *Knee Surg Sports Traumatol Arthrosc* 14:707–712
5. Blackburne JS, Peel TE. (1977) A new method of measuring patellar height. *J Bone Joint Surg [Br]* 59-B:241–2.
6. Blumensaat C (1938) Die Lageabweichungen und Verrenkungen der Kniescheibe. *Ergebn Chir Orthop* 31:149–223 (in German)
7. Caton J, Deschamps G, Chambat P, et al. (1982) Patella infera: a propos of 128 cases. *Rev Chir Orthop Reparatrice Appar Mot*; 68:317–25 (in French).
8. Caton HJ, Dejour D (2010) Tibial tubercle osteotomy in patellofemoral instability and in patellar height abnormality. *Int Orthop* 34(2):305–309
9. de Carvalho A, Holst Andersen A, Topp S, Jurik AG (1985) A method for assessing the height of the patella. *Int Orthop* 9:195–197
10. Egund N, Lundin A, Wallengren NO (1988) The vertical position of the patella. A new radiographic method for routine use *Acta Radiol* 29:555–558
11. Grana WA, Kriegshauser LA (1985) Scientific basis of extensor mechanism disorders. *Clin Sports Med* 4:247–257
12. Grelsamer RP, Meadows S (1992) The modified Insall-Salvati ratio for assessment of patellar height. *Clin Orthop* 282:170–176
13. Haim A, Yaniv M, Dekel S, Amir H (2003) Patellofemoral Pain Syndrome. Validity of Clinical and Radiological Features *Clin Orthop Relat Res* 451:223–228
14. Insall J, Salvati E (1971) Patella position in the normal knee joint. *Radiology* 101:101–104
15. Kannus PA (1992) Long patellar tendon: radiographic sign of patellofemoral pain syndrome: a prospective study. *Radiology* 185:859–863
16. Koshino T, Sugimoto K (1989) New measurement of patellar height in the knees of children using the epiphyseal line midpoint. *J Pediatr Orthop* 9:216–218
17. Krevolin JL, Pandey MG, Pearce JC (2004) Moment arm of the patellar tendon in the human knee. *J Biomech* 37:785–788
18. Kujala UM, Osterman K, Kormanen M, Nelimarkka O, Hurme M, Taimela S (1989) Patellofemoral relationships in recurrent patellar dislocation. *J Bone Joint Surg Br* 71:788–792
19. Laprade J, Culham E (2003) Radiographic measures in subjects who are asymptomatic and subjects with patellofemoral pain syndrome. *Clin Orthop Relat Res* 414:172–182
20. Leung YF, Wai YL, Leung YC (1996) Patella alta in southern china: a new method of measurement. *Int Orthop* 20:305–310
21. Roger B.A., Thornton-Bott P., Cannon S.R., Briggs T.W.R. (2006) Interobserver variation in measurement of patellar height after total knee arthroplasty. *J Bone Joint Surg [Br]*; 88-B, 4:484–488
22. Seil R, Muller B, Georg T, Kohn D, Rupp S (2000) Reliability and interobserver variability in radiological patellar height ratios. *Knee Surg Sports Traumatol Arthrosc* 8:231–236
23. Seyahi A, Atalar AC, Koyuncu O, Cinar BM, Demirhan M (2006) Blumensaat line and patellar height. *Acta orthop Traumtol Turc* 40 (3):240–247
24. William R (2005) Anterior knee pain: diagnosis and treatment. *J Am Acad Orthop Surg* 13:534–543