CrossMark

ARTHROSCOPY AND SPORTS MEDICINE

Effect of patient position on measurement of patellar height ratio

Rapeepat Narkbunnam[1] · Keerati Chareancholvanich[1]

Abstract

Background Patient position is an important factor which can affect the accuracy of patellar height ratio measurement. Varying degree of knee flexion angles and action of quadriceps muscle while supine or standing positions are the most concerning factors.

Methods Forty healthy subjects had radiographs taken of their knees at 0°, 30°, and 60° of flexion in the supine (non-weight-bearing) and standing (weight-bearing) positions. Patellar height was assessed by five different measurement methods including Insall-Salvati (IS), Modified Insall-Salvati (MIS), Caton-Deschamps (CD), Blackburne-Peel (BP), and Knee triangular ratio (KT).

Results The mean and standard deviation (SD) in the supine/standing position of each method were IS 1.0 (0.1)/1.05 (0.1), MIS 1.6 (0.2)/1.8 (0.3), CD 1.0 (0.2)/1.2 (0.2), BP 0.9 (0.2)/1.0(0.2), and KT 1(0.1)/1(0.1). Significant differences were found between supine and standing positions using all of the methods except for KT ratio. Comparisons between the various knee flexion angles were found to be statistically significant by most of the measurement methods, although the differences between the means were less than their SD.

Conclusion Quadriceps action had a significant influence on the mean values obtained by the MIS, CD, and BP methods. In clinical practice, interpretation for patella alta or patella baja of these measurement methods should be normalized according to the patient position. Varying the degree of knee flexion did not produce clinically important effects in any of the five patellar height measurement methods.

Keywords Patellar height · Knee biomechanics · Patellofemoral instability · Patellofemoral pain syndrome

K. Charoencholvanich is the Co-author.

✉ Rapeepat Narkbunnam
  mai_parma@hotmail.com

  Keerati Chareancholvanich
  sikcr@mahidol.ac.th

[1] Department of Orthopaedics Surgery, Faculty of Medicine, Siriraj Hospital, Mahidol University, 2, Prannok Road Bangkoknoi, Bangkok 10700, Thailand

Introduction

The biomechanics of the patellofemoral joint are fundamental to understanding normal knee function and the pathologies of knee disorders [1–6]. Blumensaat [7] described the first technique for measuring patellar height in 1938. Since then, several methods [7–15] have been proposed; most of these methods utilize patellar height measurements to obtain the ratio of two reference lines and define the normal value as a range of the mean and standard deviation. Due to femoral roll-back and rotation, knee flexion causes of the relationship between the patella and femur to change accordingly. This effect interferes with the accuracy of the patellar height ratio measurement. Various methods have a pre-determined accepted measurement range of knee flexion, e.g., Insall-Salvati [8] 10°–70°, Modified Insall-Salvati [9] 20°–70°,Caton-Deschamp [10] 10°–0°, and Blackburne-Peel [11] >30°. However, methods that use the distal femur as a reference point require specific degrees for measurement, e.g., Blumensaat [7] 30°, Bernageau [12] full extension, Biedert and Albrecht [13] 0° flexion.

Another concerning factor is the effect of quadriceps action during supine non-weight-bearing and standing with weight-bearing positions. Yannakopoulos et al. [16] reported a radiographic study of knee joints at 30° flexion in 25 healthy subjects and compared the patellar height ratios in weight-bearing or non-weight-bearing positions by 4 methods. Significant differences were found using all of the methods. These factors can affect the accuracy and clinical interpretation of patellar height for diagnosis and treatment.

"Knee triangular ratio" is a new method for patellar height measurement that uses the distal femur as a reference point and was designed to eliminate the influences from the above-mentioned factors. This method was validated with regard to accuracy and reproducibility in our previously published study [17]. The aim of this study was to evaluate the influences of knee flexion angles and the action of quadriceps muscles on 5 measurement methods of patellar height ratios.

Materials and methods

Ethical committee approval for the study was obtained from the ethical review board of Siriraj hospital, Mahidol University, Bangkok, Thailand. Informed consent documentation was obtained from all participants after complete explanation of the study protocol.

In this study, we recruited 40 volunteers from the general population who had reached skeletal maturity with no current or past history of patellofemoral pain or instability. All subjects had lateral radiographs taken of their knees at 0°, 30°, and 60° of flexion in 2 positions. The first position was the supine position with no contraction of the quadriceps. In this condition, the knee flexion angle was standardized using a customized adjustable knee support frame to position the seated subject's leg. The second was the standing position with contraction of the quadriceps. A goniometric ruler with radiopaque-guided rods was attached to an X-ray board for controlling the subjects' knee flexion at each angle (Fig. 1). The greater trochanter, femoral lateral condyle, and lateral malleolus were used as the reference points when aligning the goniometric ruler. After fluoroscopy, we were able to check the quality of the radiographs for accuracy in the knee flexion angle and the rotation of the condyle to ensure that there were no overlaps greater than 3 mm. If the quality of any radiograph was unacceptable, the procedure was redone. All radiographs were recorded by a digital radiograph system.

The patellar height was measured by five different methods: Insall-Salvati [8], Modified Insall-Salvati [9], Caton-Deschamps [10], Blackburne-Peel [11], and Knee


Fig. 1 Lateral radiographs taken at 0°, 30°, and 60° of knee flexion in the supine and standing positions (*top row*). Goniometric rulers with radiopaque-guided rods were attached to an X-ray board for controlling the accuracy of each degree of knee flexion angle (*bottom row*)

triangular ratio (Fig. 2). The knee triangular ratio involves the measurement of the distance from the posterior angle of the intercondylar roof with the tibial tubercle ratio and the distance from the midpoint of the patellar articular facet to the tibial tubercle. Three independent examiners (all orthopedics residents) conducted these measurements sequentially and under identical conditions for each volunteer. All examiners used the digital radiograph system for measuring the patellar height ratios. Each examiner was blinded with regard to each volunteer's data, as well as to the results obtained by the other examiners.

Statistical analysis

Normal values for patellar height ratios were described in terms of the mean and standard deviation (SD). Differences between weight-bearing (supine) and non-weight-bearing (standing) conditions were compared using Student's t test. The alpha and beta values were preset to 0.05 and 0.20, respectively. Comparisons between the various angles of knee flexion were calculated by repeated ANOVA with Bonferroni method. Interobserver reliability was assessed with the intraclass correlation coefficient (ICC) at a 95 % confidence interval (CI).

Fig. 2 Patellar height was measured using five measurement methods: Insall-Salvati [8], Modified Insall-Salvati [9], Caton-Deschamps [10], Blackburne-Peel [11], and Knee triangular ratio

Insall-salvati   Modified Insall-salvati   Caton-Deschamp   Blackburne-Peel   Knee triangular
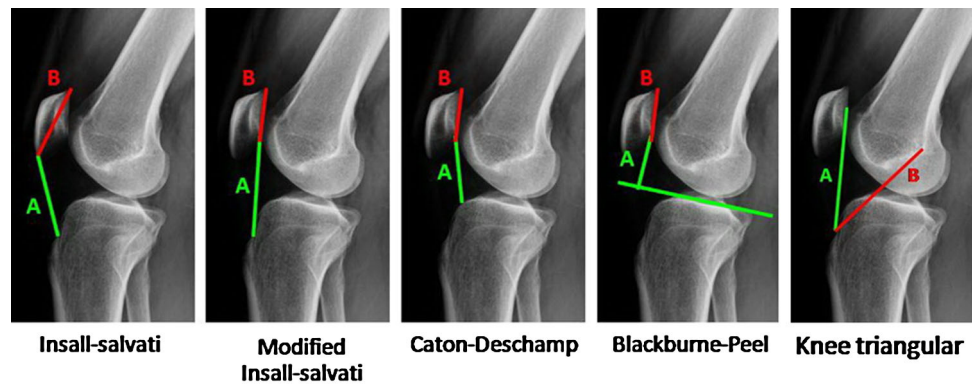
Results

Forty (20 male/20 female) healthy subjects were recruited. The average age was 37 years (range 21–55 years). The normal values for each method of measuring the patellar height ratio for overall knee flexion angles in the supine non-weight-bearing and standing with weight-bearing positions were as follows: Insall-Salvati [8] 1.002 (0.12)/1.051 (0.13), Modified Insall-Salvati [9] 1.593 (0.20)/1.862 (0.28), Caton-Deschamp [10] 1.033 (0.17)/1.197 (0.24), Blackburne-Peel [11] 0.865 (0.17)/1.002 (0.21) and Knee triangular ratio 0.968 (0.05)/0.978 (0.05) [Mean (SD): non-weight bearing/weight bearing].

Significant differences ($P < 0.05$) in the patellar height ratios between the supine non-weight-bearing position and upright weight-bearing position were found in all four of the previous methods. Conversely, no significant differences were found using the Knee triangular ratio method at any knee flexion angle ($P = 0.368$ at 0°, 0.088 at 30°, and 0.303 at 60°) (Table 1).

A comparison of patellar height ratios between knee flexion angles of 0°, 30°, and 60° revealed significant differences using all of the measurement methods except for the Modified Insall-Salvati [9] in both supine and standing positions ($P = 0.299, 0.111$, respectively) and Blackburne-Peel [11] in supine position ($P = 0.292$). The differences between the means of each flexion angle were less than the SD in all of the measurement methods. The Knee triangular ratio method produced the lowest standard deviation (SD = 0.004–0.008) among the tested methods. Thus, even very small differences in mean values (0.023, 95 % CI = 0.009–0.036) were statistically significant (Table 1).

Interobserver variation for the five methods, as analyzed by the ICC with a 95 % CI, had good-to-excellent reliability (ICC = 0.6–0.9).The Knee triangular ratio method had the best results, with excellent interobserver reliability at 0°, 30°, and 60° of knee flexion (ICC = 0.938, 0.941, and 0.850, respectively) (Table 2).

Discussion

Height of the patella affects 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 and instability [4–6, 18]. Patella baja (a low-riding patella) is associated with a limited range of knee motion, Osgood–Schlatter disease, and patellofemoral arthritis [19–21]. Several methods of measuring patellar height have been proposed, but no single method has yet been accepted as a gold standard [22–27].

Philips et al. [27] divided patellar height measurement methods into 2 groups: direct and indirect. Indirect methods are the most widely accepted for clinical use. These methods relate the patella to the tibia. Therefore, these methods do not require a fixed angle of knee flexion for radiographic studies. The four most popular methods (Insall-Salvati [8], Modified Insall-Salvati [9], Caton-Deschamps [10], and Blackburne-Peel [11]) were used in the present study. Direct methods reveal the true relationship of the patella to the femur, but their accuracy depends on fixed angles of knee flexion. Thus, the use of direct methods is limited in the clinic. "Knee triangular ratio" is a new direct method of patellar height measurement that is designed to eliminate the influence of knee flexion angle.

Knee flexion angles and quadricep action on weight-bearing position are important factors for the evaluation of patellar height, although there is no single previous study that has compared all of these factors [13, 27]. In the present study, we evaluated the influence of these factors on the patellar height ratios in a healthy knee population using standardized methods for radiographic study and data measurement.

In this study, quadriceps contraction in the standing, weight-bearing position created significantly influenced the patellar height ratio. Significant differences were found using all of the methods except for knee triangular ratio.

Table 1 Mean and standard deviation of patellar height ratios at 0°, 30°, and 60° of knee flexion and the difference between the supine non-weight-bearing position and the standing with weight-bearing position

Methods	Flexion degree	Supine mean (SD)[a]	Standing mean (SD)[a]	P-value***
Insall-Salvati	0	0.961 (0.14)	0.996 (0.14)	0.113
	30	1.032 (0.11)	1.079 (0.12)	<0.001
	60	1.014 (0.11)	1.077 (0.12)	<0.001
P-value**		<0.001[1,2,3]	<0.001[1,2]	
Modified Insall	0	1.598 (0.26)	1.817 (0.30)	<0.001
	30	1.603 (0.18)	1.896 (0.29)	<0.001
	60	1.576 (0.18)	1.874 (0.27)	<0.001
P-value**		0.299[n]	0.111[n]	
Caton-Deschamp	0	1.084 (0.20)	1.220 (0.25)	0.002
	30	1.037 (0.14)	1.215 (0.24)	<0.001
	60	0.978 (0.14)	1.156 (0.23)	<0.001
P-value**		<0.001[2,3]	<0.004[3]	
Blackburne-Peel	0	0.834 (0.22)	0.906 (0.23)	0.093
	30	0.884 (0.14)	1.042 (0.20)	<0.001
	60	0.878 (0.14)	1.056 (0.20)	<0.001
P-value**		0.292[n]	<0.001[1,2]	
Knee triangular	0	0.973 (0.08)	0.987 (0.07)	0.368
	30	0.975 (0.04)	0.985 (0.04)	0.088
	60	0.958 (0.04)	0.962 (0.05)	0.303
P-value**		<0.001[3]	0.001[3]	

** Repeated ANOVA with multiple comparisons: Bonferroni method

*** Student's t-test

[1] Significant difference ($P < 0.05$) between 0° and 30°, [2] Significant difference ($P < 0.05$) between 0° and 60°, [3] Significant difference ($P < 0.05$) between 30° and 30°, [n] No significant difference ($P < 0.05$)

[a] Standard deviation

Table 2 Intraclass correlation coefficient (ICC) with a 95 % confidence interval (CI) for the patellar height measurement methods at different degrees of knee flexion

Patella height method	Flexion degree	ICC	95 % CI lower–upper	Significance
Insall-Salvati	0	0.927	0.750–0.970	<0.001
	30	0.854	0.390–0.947	<0.001
	60	0.767	0.312–0.903	<0.001
Modified Insall	0	0.839	0.603–0.925	<0.001
	30	0.852	0.391–0.946	<0.001
	60	0.740	0.253–0.891	<0.001
Caton-Deschamp	0	0.825	0.518–0.924	<0.001
	30	0.705	0.474–0.839	<0.001
	60	0.653	0.386–0.809	<0.001
Blackburne-Peel	0	0.806	0.670–0.815	<0.001
	30	0.672	0.451–0.815	<0.001
	60	0.791	0.648–0.882	<0.001
Knee triangular	0	0.938	0.877–0.968	<0.001
	30	0.941	0.851–0.973	<0.001
	60	0.850	0.611–0.932	<0.001

The Modified Insall-Salvati [9], Caton-Deschamps [10], and Blackburne-Peel [11] methods had an especially significant effect in the clinical interpretation. Modified Insall-Salvati [9] was described by Grelsamer and Meadows, who defined the cut-point for the patella alta as >2.0; no accepted range of normal values was reported. Based on this study, we suggest using 1.6 ± 0.2 as the normal value for non-weight-bearing positions and 1.8 ± 0.3 for weight-

bearing positions. The original cut-point was only represented in the upper limit in the weight-bearing position, and thus, it should not be used when the quadriceps are relaxed. Caton-Deschamp [10] defined a wide range as their normal limit (0.6–1.3), making this value impractical and inaccurate for diagnostic purposes. The normal values should be divided by 1.0 ± 0.2 for non-weight-bearing and 1.2 ± 0.2 for weight-bearing positions. For the Blackburne-Peel method [11], the normal value was 0.8–1.0. This range was close to the normal value for non-weight-bearing positions obtained in the present study (0.9 ± 0.2). The normal value should be changed to 1.0 ± 0.2 when measuring in a weight-bearing position. The upper limit of the original cut-point was equal to the mean value in the weight-bearing position; this difference can create false-positive patella alta.

Conversely, a statistically significant difference was found by the Insall-Salvati method [8], but it was not clinically significant. The difference was <0.05, which did not affect the normal value. Based on the results of the present study, the normal value was used as the original cut-point (1.0 ± 0.2) in both the weight and non-weight-bearing positions (Table 3).

Another factor that was evaluated in this study was the influence of varying degrees of knee flexion. At 0°, 30°, and 60° of knee flexion, statistical significance was found using most of the measurement methods. However, the differences of the means were less than their standard deviations; thus, these results did not support changing the normal values from their accepted range for each method. The results from this study showed that differences in knee flexion angles from 0° to 60° were not clinically significant for any of the patellar height measurement methods.

Levels of variation, as measured by ICC (intraclass correlation coefficient), were good-to-excellent for all of the measurement methods. These findings were improved relative to those found in the previous studies [25, 28, 29]. This improvement may be due to good standardization of the materials and methods in this study. First, this study

was a prospective study in which all volunteers were recruited and subjected to radiographic examination under identical conditions. Second, all of the examiners were orthopedic residents. Each of the examiners received the same instructions regarding the methods and reference points used for the measurements. Third, all of the radiographs were taken with a digital radiographic system, which may have reduced the chances of equipment error. Altogether, these precautions ensure that this study was well-standardized and suffered from minimal interobserver variation.

Knee triangular ratio was the only method in which there were no significant differences between weight- and non-weight-bearing positions at any knee flexion angle. It is easy to use the normal value (1.0 ± 0.1) in clinical practice. This method references the true relationship of the patella to the distal femur and tibia, which involves triangular movement. The reference point at the posterior angle of the intercondylar notch is close to the instantaneous axis of rotation of the knee joint. Thus, this method is not influenced by the knee flexion angle. The midpoint of the patellar articular surface represents the true patellofemoral articulation and eliminates errors from variations of the patellar shape. Moreover, the reproducibility of the Knee triangular ratio method was excellent (ICC > 0.8), and compared to the other methods, the Knee triangular ratio method produced the best interobserver variation.

In conclusion, knee flexion angle and quadriceps action in supine non-weight-bearing or standing with weight-bearing position are the key factors of concern during the evaluation of patellar height ratios. Varying knee flexion at 0°, 30°, and 60° was not clinically important for patellar height ratio measurement by any of the five methods in this study. However, the cut-point value for the diagnosis of patella alta or baja should be adjusted following quadriceps action in 3 measurement methods including Modified Insall-Salvati [9], Caton-Deschamps [10], and Blackburne-Peel [11] methods.

Table 3 Comparison between reference value from original studies of patellar height measurement ratio to normal value from supine and weight-bearing positions in this study

Measurement methods	Original imaging method	Original reference value	Supine position normal value[a]	Standing position normal value[a]
Insall-Salvati	20°–70° flexion	0.8–1.2	0.8–1.2	0.8–1.2
Modified Insall-Salvati	20°–70° flexion	PA: >2.0	1.4–1.8	1.5–2.1
Caton-Deschamp	10°–80° flexion	0.6–1.3	0.8–1.2	1.0–1.4
Blackburne-Peel	≥30° flexion	0.8–1.0	0.7–1.1	0.8–1.2
Knee triangular	0°–60° flexion	0.9–1.1	0.9–1.1	0.9–1.1

The lower value interpret to patellar infera and the upper value interpret to patellar alta

PA Patellar alta

[a] Normal value = mean ± standard deviation

References

1. Krevolin JL, Pandy MG, Pearce JC (2004) Moment arm of the patellar tendon in the human knee. J Biomech 37:785–788
2. Wahrenberg H, Lindbeck L, Ekholm J (1978) Knee muscular moment, tendon tensionforce and EMG during a vigorous movement in man. Scand J Rehabil Med 10:99–106
3. William R (2005) Anterior knee pain: diagnosis and treatment. J Am Acad Orthop Surg 13:534–543
4. Grana WA, Kriegshauser LA (1985) Scientific basis of extensor mechanism disorders. Clin Sports Med 4:247–257
5. Ward SR, Powers CM (2004) The influence of patella alta on patellofemoral joint stress during normal and fast walking. Clin Biomech (Bristol, Avon) 19:1040–1047
6. Ward SR, Terk MR, Powers CM (2007) Patella alta: association with patellofemoral alignment and changes in contact area during weight-bearing. J Bone Joint Surg (Am) 89-A:1749–1755
7. Blumensaat C (1938) Die lageabweichungen und verrenkungen der kniescheibe. Ergeb Chir Orthop 31:149
8. Insall J, Salvati E (1971) Patella position in the normal knee joint. Radiology 101:101–104
9. Grelsamer RP, Meadows S (1992) The modified Insall-Salvati ratio for assessment of patellar height. Clin Orthop 282:170–176
10. Caton J, Deschamps G, Chambat P et al (1982) Patella infera: a propos of 128 cases. Rev Chir Orthop Reparatrice Appar Mot 68:317–325 **(in French)**
11. Blackburne JS, Peel TE (1977) A new method of measuring patellar height. J Bone Joint Surg (Br) 59-B:241–242
12. 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)**
13. Biedert RM, Albrecht S (2006) The patellotrochlear index: a new index for assessing patellar height. Knee Surg Sports Traumatol Arthrosc 14:707–712
14. 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
15. Ellington M, Robin B, Jupiter D, Allen B (2014) Plateau-patella angle in evaluation of patellar height in osteoarthritis. Knee 21(3):699–702
16. Yiannakopoulos CK, Mataragas E, Antonogiannakis E (2008) The effect of quadriceps contraction during weight-bearing on four patellar height indices. J Bone Joint Surg (Br) 90-B:870–873
17. Chareancholvanich K, Narkbunnam R (2012) Novel method of measuring patellar height ratio using a distal femoral reference point. Int Orthop 36(4):749–753
18. Pal S, Besier TF, Beaupre GS, Fredericson M, Delp SL, Gold GE (2013) Patellar maltracking is prevalent among patellofemoral pain subjects with patella alta: an upright, weightbearing MRI study. J Orthop Res 31(3):448–457
19. Aparicio G, Abril JC, Calvo E, Alvarez L (1997) Radiologic study of patellar height in Osgood-Schlatter disease. J Pediatr Orthop 17:63–66
20. Neogi DS, Bae JH, Seok CW, Lim HC (2014) Impact of patellar height on unicompartment knee arthroplasty: does patella baja lead to an inferior outcome? J Orthop Traumatol. 15(1):47–54
21. Chen AF, Tetreault MW, Levicoff EA, Fedorka CJ, Rothenberg AC, Klatt BA (2014) Increased incidence of patella baja after total knee arthroplasty revision for infection. Am J Orthop (Belle Mead NJ). 43(12):562–566
22. Seil R, Muller B, Georg T, Kohn D, Rupp S (2000) Reliability and interobserver variability in radiological patellar height ratios. Knee Surg Sports TraumatolArthrosc 8:231–236
23. Carson WG Jr, James SL, Larson RL, Singer KM, Winternitz WW (1984) Patellofemoral disorders: physical and radiographic evaluation. Part II: radiographic examination. Clin Orthop Relat Res 185:178–186
24. Math KR, Ghelman B, Potte HG (1995) Imaging of the patello-femoral joint. In: Scuderi GR (ed) The patella. Springer, New York, pp 83–125
25. Berg EE, Mason SL, Lucas MJ (1996) Patellar height ratios. A comparison of four measurement methods. Am J Sports Med 24:218–221
26. 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
27. Phillips CL, Silver DAT, Schranz PJ, Mandalia V (2010) The measurement of patellar height: a review of the methods of imaging. J Bone Joint Surg Br 92-B:1045–1053
28. Roger BA, Thornton-Bott P, Cannon SR, Briggs TWR (2006) Interobserver variation in measurement of patellar height after total knee arthroplasty. J Bone Joint Surg (Br) 88-B(4):484–488
29. Seil R, Muller B, Georg T, Kohn D, Rupp S (2000) Reliability and interobserver variabilityin radiological patellar height ratios. Knee Surg Sports Traumatol Arthrosc 8:231–236