The degree of patella alta in newborns shows strong correlations with patellofemoral parameters and is influenced by the intrauterine position – an ultrasound-based correlation study

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Angaben zur Veröffentlichung / Publication details:

Röttinger, Timon, Kurt Vollert, Stefanie Tüchert, Leonard Lisitano, Khaled Salama, Heinz Röttinger, Christian Dannecker, Edgar Mayr, and Johanna Abelmann-Brockmann. 2025. "The degree of patella alta in newborns shows strong correlations with patellofemoral parameters and is influenced by the intrauterine position – an ultrasound-based correlation study." The Knee 54: 222–29. https://doi.org/10.1016/j.knee.2025.01.011.

The Knee 54 (2025) 222–229

Contents lists available at ScienceDirect

The Knee

journal homepage: www.elsevier.com/locate/thekne

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ARTICLE INFO

Article history:
Received 1 September 2024
Revised 5 January 2025
Accepted 27 January 2025

Keywords:
Patella
Patellofemoral joint
Breech position
Patella alta
Newborns

ABSTRACT

Background: Studies suggest that the development of a suitable patellar groove is highly dependent on a regular patellar position imprinting the patellofemoral joint. Furthermore, previous studies have shown that breech position also has an influence on the patellofemoral joint shape. The aim of this study is to exploratively analyze influences on patellar sagittal height in newborns.

Methods: In this ultrasound-based study, parameters influencing patellar height will be exploratively examined (i.e. patellofemoral joint parameters, hip dysplasia, sex, body and age characteristics of the parents and the newborn, intrauterine position). 98 newborns born between June 2023 and November 2023 at the University Hospital receiving an ultrasound hip screening examination received additional standardized ultrasounds of their knees.

Results: For all 3 measured patellar height indices patellar height was lower for newborns after breech positions. For one of the measured indices this result was significant ($p = 0.018$). Patellofemoral trochlear configuration also showed significant relationships to patellar height. A high sulcus angle and a lower internal rotation of the trochlea are significantly related to lower patellar heights (multiple linear regression model, model fit: $p = 0.002$, Coefficients: Sulcus angle $p = 0.007$, Trochlea angle $p = 0.028$).

Conclusions: Breech position, high sulcus angle and lower internal rotation of the trochlea are significantly related to lower patellar heights. This is the first study to describe these relationships in newborns and increases clinical awareness. As the exact nature of the relationships remains unclear further research should be conducted.

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https://doi.org/10.1016/j.knee.2025.01.011
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1. Introduction

Ultrasound has proven to be a reliable tool for visualization of the newborn femoral trochlea and the position of the patella [1]. An ultrasound-based analysis showed that the cartilaginous trochlear configuration was similar from birth to 18 years of age, suggesting that the trochlea is already well-developed in newborns [2].

There are reports of significant correlations between the degree of patella alta and patellofemoral alignment [3], while there are no significant correlations between patellar height and trochlear morphology [4]. People with a patella alta suffer from a reduced contact area [3] and increased patellar stress during brisk walking [5]. Studies have shown that the degree of patella alta in patients with a history of patella dislocation does not change with age and the authors suggest that patella alta is prevalent as a biomechanical conflict at a young age rather than developing in adolescence [6].

Past experiments showed that the patellofemoral trochlea flattened in rabbits with surgically induced inadequate patellar positions, performed by a medial soft-tissue release [7]. The same effect could be shown for surgically induced patella alta using a patellar tendon z-plastic on rabbit knees [8]. Supporting these interrelationships, patellectomy in rats leads to trochlear dysplasia [9]. This suggests that developing a suitable patellar groove depends on a regular patellar position imprinting the patellofemoral joint.

Previous studies have shown that breech positions influence the patellofemoral joint shape [10,11]. Because of the biomechanical relevance, it is necessary to examine whether breech positions also influence the degree of congenital sagittal patellar height.

The study aimed to detect significant influences on sagittal patellar height in newborns.

2. Materials and methods

2.1. Ethical approval

The study design was presented to the local Ethics Committee, which approved the study protocol in advance of the study. The study was carried out in accordance to the Declaration of Helsinki of the World Medical Association as amended by the 64th General Assembly in Fortaleza in 2013.

2.2. Setting and patients

In this ultrasound-based study, newborns born at the University Hospital between June 2023 and November 2023 who had planned in-house ultrasound screening examinations of the hip joints as part of the German U2-Health-Examination were included. The U2-Health-Examination is performed between the 3rd and 10th day of living. We excluded newborns who were born prematurely or who suffered from obvious malformations or were missing a lower extremity.

2.3. Data collection

A supplementary questionnaire was handed out to the child's parents during the informative talk to collect data from both parents concerning height, body weight, previous illnesses, medical history and risk factors for the presence of hip dysplasia. The parents of the patients were informed verbally and in writing by member of the orthopaedic and trauma surgery department before the ultrasound examination.

The prebirth intrauterine position, week of birth and Body Mass Index (BMI) was determined via patient's files. If a breech position was reported, the patients file often did not determine the exact nature of the breech position. Thus, the presence of a breech position was not divided into subtypes and included all types (incomplete, Frank and complete).

2.4. Ultrasound procedure and technique

As part of the routine screening examination for hip joint dysplasia in infancy, we carried out an ultrasound-based analysis of the characteristics of the femoropatellar joint. As a result, the examination took a few minutes longer for the patients. Apart from this, there were no additional burdens or stress for the patients. The examinations were carried out by two pediatric radiologists experienced in pediatric orthopaedic radiology.

The ultrasound examinations were performed with the newborn in a comfortable position besides the mother, father or guardian. During the procedure, the examiner flexed the knee. We standardized two ultrasound planes (axial and sagittal) of both knees to perform the examination as accurately as possible. Axial cross-sectional images were taken with the knee joint flexed at approx. 90° to visualize the bone core of the distal femur and the unossified femoral condyles. The alignment of the transducer was 90° to the femoral shaft axis. The axial plane was chosen so that the cut allowed ideal visualization of the posterior condylar axis.

For the sagittal plane the femorotibial joint had to be flexed by 30°, in accordance and adopted from established clinical practice in x-ray diagnostics [12]. This was because the patellar tendon was often not taut when the knee joint was in extension and the tendon fibers were therefore not aligned linearly. In those cases, the patellar tendon length/patellar height would have been underestimated with extended knee joints and thus measured inaccurately.

The hip joints were examined in the standardized way according to the Graf classification [13].

2.5. Language

Fluent English-speaking authors wrote this text. This process was also supported by DeepL Translator (https://www.DeepL.com/Translator (free version)) and Grammarly App (premiun update version, Grammarly Corporation, San Francisco).

2.6. Checklists

We used the STROBE cross sectional checklist when writing our report [14].

3. Theory and calculation

The hip joints were measured according to the Graf-classification [13]. The sulcus angle, the lateral trochlea inclination (LTI), the trochlea angle (TA), the sulcus angle (SA) of the patellar groove was measured to characterize the trochlea or as a measure of possible dysplasia (Figure 1).

All measured values referenced to the posterior condylar axis were determined using the axial plane of the knee joint. The posterior condylar axis was measured at the point where the posterior condyles extended the furthest dorsally.

To calculate the Patellar Height Index 1 (PHI1), the distance from the distal end of the retropatellar cartilage to the anterior proximal edge of the tibial head is first measured in a sagittal plane (E) (Figure 2) and then indexed using the epicondyle distance (D) (Figure 1):

$$PHI1 = E / D$$

With the Caton-Deschamps index (CDI), the same measurement distance is set in relation to the joint length on the posterior surface of the patella (G) [19,20] (Figure 2):

$$CDI = E / G$$

The Patellar Height Index 2 (PHI2) uses the patellar tendon length (F) (Figure 2) from its origin at the inferior patellar pole to the center of its insertion at the tibial tuberosity tibiae and is then set in relation to the epicondyle distance (D) (Figure 1):

$$PHI2 = F / D$$

Using the epicondylar distance as an indexing parameter for patellar height showed significant relationships with patellar tracking parameters in a previous study [21]. Therefore, using the epicondyle distance for indexing was also adopted in this study in addition to CDI.

The standardized sonographic pictures of the knee joints were measured. For all measurements an average of the left and right knee measurements was calculated and used for further statistical analysis. The measurements were collected in a table and were supplemented with the data from the questionnaires; if the questionnaires were incomplete, the remaining data from the digital patient file ORBIS® (Agfa Health Care) was added, if available. The data was pseudonymized.

The data listed in Table 1 were collected from the patient files, the questionnaires and the ultrasound images.

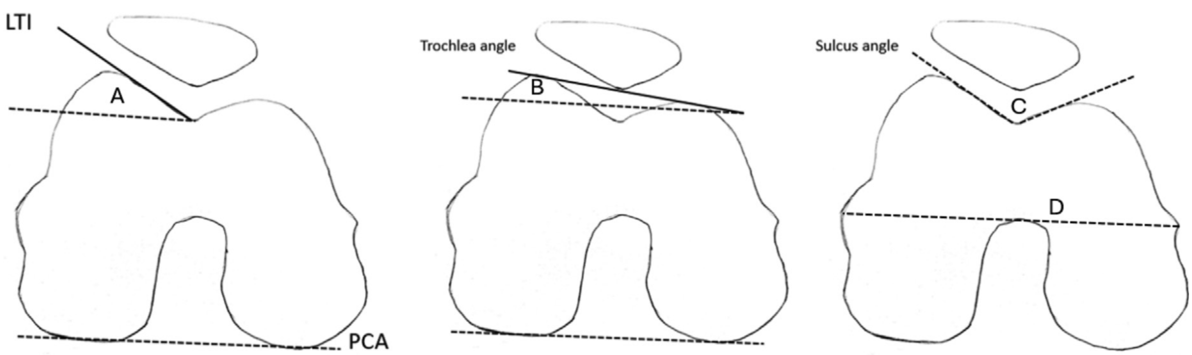

Figure 1. Collected newborn's patellofemoral parameters. left: Lateral trochlea inclination (LTI) (A), middle: Trochlea angle (TA) (B), right: sulcus angle (SA) (C) and epicondylar distance (D). The lateral trochlear inclination (LTI) is the angle between the lateral trochlear inclination and the posterior condylar axis [15–18]. To determine the trochlear angle (TA), a line is drawn from the most anterior point of the medial condyle to the anterior point of the lateral condyle. The angle is then formed with the straight line of the posterior condylar axis [18]. The sulcus angle (SA) is the angle between the lateral and medial facet [17,18].

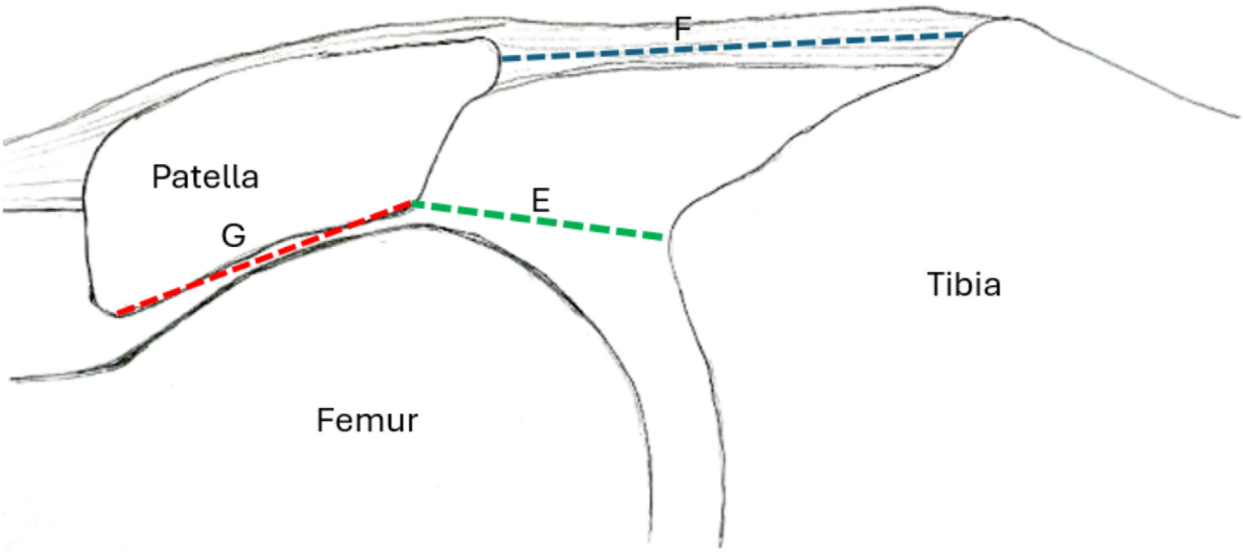

Figure 2. Measurement of patellar height. Green line (E): distance from the distal end of the retropatellar cartilage to the anterior proximal edge of the tibial head is first measured in a sagittal plane, blue line (F): Patellar tendon length from its origin at the inferior patellar pole to the center of its insertion at the tibial tuberosity, red line (G): joint length on the posterior surface of the patella.

Table 1
Overview of the analyzed variables.

General newborn's characteristics	Newborn's patellofemoral parameters	Newborn's patellar height	Parent characteristics
Week of Birth	Trochlea Angle (TA)	Patellar Height Index 1 (PHI1)	Age
Sex	Sulcus Angle (SA)	Patellar Height Index 2 (PHI2)	Sex
Body Mass Index (BMI)	Lateral Trochlea Inclination (LTI)	Caton Deschamps Index (CDI)	Weight
Prebirth intrauterine Position	**Newborn's Hip parameters**		Height
	Alpha Angle		BMI
	Beta Angle		

3.1. Statistical analysis

Correlations were used to check whether a linear relationship existed between the predictors and the dependent variables. Pearson correlation coefficients were calculated for normally distributed predictors. For non-normally distributed variables, Kendall-Tau correlations as a non-parametric alternative were established. Furthermore, the study investigated whether sex or breech position influences the patellar height parameters. When independent samples were normally distributed, a T-test for independent samples was carried out.

All predictors that are linearly related to the dependent variable and show significant correlations were tested in a multivariate linear regression with backward elimination and corresponding models are created for further evaluation. In addition, possible multicollinearity of the predictors was checked before multiple linear regression models were performed. Multicollinearity is not assumed for correlation coefficients of < 0.7 between the independent variables. The residuals of all regressions after completion were checked both graphically and analytically for independence (Durbin-Watson test), homoscedasticity (Breusch-Pagan test) and normal distribution (Shapiro-Wilk test). For all tests performed in this study, alpha was set to $p < 0.05$.

We used Jamovi (The jamovi project (2020), Version 2.3 for Windows) and SPSS (SPSS Statistics 28.0.0.0, IBM, Armon; NY, USA) to carry out the statistical tests.

4. Results

4.1. Patellar height and intrauterine position

For all measured indices the mean patellar height is lower for breech positions. PHI2 is significantly lower for breech positions ($p = 0.018$). No significant influence was found for PHI 1 and CDI.

4.2. Patellar height and trochlea characteristics

PHI 1 and PHI 2 showed significant correlations with patellofemoral parameters. PHI 1 significantly correlated with SA (Pearson-correlation −0.301, p = 0.006) and almost significantly correlated with TA (Kendall Tau-coefficient 0.145, p = 0.053), while PHI 2 correlated significantly with SA (Pearson-correlation −0.223, p = 0.043). Patellar height does not correlate with the remaining metric variables of Table 1.

As mentioned above, PHI1 showed stronger correlations with patellofemoral parameters. Therefore, a multiple linear regression model was built to test SA und TA as predictors of patellar height (PHI 1). The Model was highly significant (p = 0,002) and suggests that the tested patellofemoral characteristics can predict 12.8% (adjusted r2 of 0.128) of the patellar height variance. Breech position was eliminated by backward elimination.

CDI does not correlate with the patellofemoral parameters.

For all statistical tests reported, the necessary assumptions (see *Statistical Analysis*) tested for were met.

4.3. Patellar height and the remaining variables of Table 1

Patellar height does not correlate with the remaining variables of Table 1.

5. Discussion

According to our results, the patellofemoral morphology, as well as the intrauterine position, are significantly related to the patellar height (Table 2) in newborns. The lower the SA, the higher patellar height (PHI 1) (Table 3) and vice versa, meaning flatter trochlea morphologies show significantly decreased patellar heights (using PHI1 and PHI2) in newborns. The exact nature of this significant interaction remains unclear. This study does not contradict past paradigms but outlines significant interrelationships between patellar height and anatomic trochlea configuration in newborns. To understand this, it is necessary to differentiate between patellar tracking parameters and anatomic trochlea configuration, as they don't describe the exact same entity. However, these significant relationships could only be shown when not using traditional indexes to measure patellar height. Conry et al come up with similar results for adult patients, when analyzing two groups of adult patients in an 'alta group' and a 'non-alta group' and suggesting that in the 'non-alta group' the depth of the trochlea groove was lower than in the 'alta-group' [22]. Luczak at el states that CDI does not significantly correlate with the sulcus angle but does significantly correlate with LTI and reports corresponding p-values of this multivariate analysis [4]. The direction of the described significant relationship by Luczak at el remains unclear. Luczak et al concludes that these correlations were not strong and do not provide significant evidence that patellar position is intimately related to trochlear morphology.

In comparison to PHI1 and PHI2, CDI showed no significant relationships with trochlea shape parameters. This is in consensus to a study analyzing adult knees [4], which also found no significant association between CDI and patellofemoral alignment. The results resemble the findings of a previous doctoral thesis, using the epicondylar distance as an indexing parameter to evaluate patellar height, which also delivered significant correlations to patellofemoral alignment parameters in adults, while the traditional indices (CDI and Insall Salvati) did not [21]. Using the CDI to characterize patellar height seems to hide significant results, not only referring to trochlea configuration but also to patellar tracking parameters (as bisect offset and patellar tilt) in adults [15,22,23]. An the contrary using the epicondylar distance as a reference to index patellar height, significant influences of patellar height and tracking parameters can be detected [21].

One possible explanation for the statistical weakness of traditional indexing in adults (as in the CDI), would be that maltrackers tend to have a significantly longer patellofemoral sagittal joint length [17]. If an index is used that sets the sagittal

Table 2
Independent Sample T-Test (PHI1, PHI2, CDI) with Grouping Variable of intrauterine Position (cephalic and breech position) with different measurements of patellar height.

Independent Samples T-Test		Statistic	df	p
PHI1	Student's t	0.933	85.0	0.354
PHI2	Student's t	2.416	87.0	0.018
CDI	Student's t	0.177	83.0	0.860

Group Descriptives	Group	N	Mean	Median	SD	SE
PHI1	cephalic	59	0.317	0.314	0.0571	0.00744
	breech	28	0.305	0.308	0.0615	0.0116
PHI2	cephalic	62	0.603	0.598	0.0672	0.00854
	breech	27	0.566	0.575	0.0648	0.0125
CDI	cephalic	56	0.969	0.980	0.1953	0.02610
	breech	29	0.960	1.000	0.2305	0.0428

Table 3
Multiple linear regression model using backward elimation with the significantly correlating variables (SA, TA and Breech Position) and the Patellar Height Index 1 (PHI1).

Model Fit Measures

				Overall Model Test			
Model	**R**	**R^2**	**Adjusted R^2**	**F**	**df1**	**df2**	**p**
1	0.387	0.150	0.128	6.87	2	78	0.002

Model Coefficients – PHI1

Predictor	**Estimate**	**SE**	**t**	**p**	**Stand. Estimate**
Intercept	0.79229	0.18533	4.28	<.001	
SA	−0.00347	0.00124	−2.79	0.007	−0.292
TA	0.00574	0.00256	2.24	0.028	0.234

patellar height in relation to the length of the sagittal articular surface, a systematically underestimated index for patellar height in maltrackers is determined.

We could also show that a higher medial trochlea rotation, characterized by the TA, significantly positively correlates with patellar height (PHI 1) in newborns. As patella alta is known to be a major risk factor for patellar dislocation in skeletally immature [24] and skeletally mature individuals [25], this significant interaction could be a compensating attempt of the developing newborn's knee to stabilize patellar tracking of a 'high riding' patella. In this context it is interesting to note the skeletal maturity or lower age at the first-time dislocation seems to be a significant risk factor of recurring patellar dislocations itself [26,27], perhaps indicating the role of insufficient compensation mechanisms of the patellofemoral system in early life. Animal experiments also suggest that patellar height significantly influences the 'imprint' of the patellofemoral joint [8]. Notably, patella alta and dysplastic patellofemoral joint parameters are key risk factors for both primary [25] and recurrent patellar dislocations [27]. Since a flat trochlea profile seems to come along with a significantly higher patellar height (Table 3), our work suggests that these risk factors tend to be present solely and should not show a tendency for coexistence after birth.

Our study included no patients with congenital patellar dislocations, since this condition is rare. It is defined as lateral dislocation of the patella with unsuccessful closed reduction. Detection of this disorder is often delayed. Since ultrasound can detect congenital patellar dislocations [28], systematic ultrasound of newborn's knees after birth and knowledge of the risk factors associated with patellofemoral abnormalities of the knee could improve early diagnosis and access to early treatment. Congenital patellar dislocations seem to be influenced by genetic disorders [29]. Therefore, congenital patellar dislocations seem to have a different and complex developmental foundation. In contrast, habitual dislocations in later childhood and adolescence seem to be influenced by the interaction of multiple biomechanical patellar tracking parameters like patella alta, trochlea dysplasia and position of the tibial tuberosity [25].

According to our results breech positions lead to a significantly lower patellar height when characterized as PHI2. Previous studies have shown that the breech position with extended knees appears to be a risk factor for trochlea dysplasia [10,11]. This strengthens the assumption that intrauterine positions affect the intrauterine range of motions of the lower extremity and therefore influences the patellofemoral joint. Yet the exact mechanisms are yet unsolved and remain theoretical.

The limitations of our work are missing clinical parameters as well as no follow-up analysis of the investigated individuals. Also, patellar tracking and patellofemoral stability were not analyzed in this study.

5.1. Conclusion

Intrauterine position as well as patellofemoral trochlear morphology are significantly related to patellar height in newborns. This is the first study to describe the interrelation between patellar height and trochlea morphology in newborns, as well as the significant relationship between breech position and patellar height. In newborns a decreased sagittal patellar height shows a significant tendency towards increased sulcus angle, meaning a flatter trochlea morphology, and vice versa. Increased sagittal patellar height was significantly related to a higher medial trochlea rotation. Breech positions lead to a significantly lower patellar height when characterized with a patellar height index, using the epicondylar distance as a reference in indexing. Breech positions are known to be related to trochlea dysplasia [10,11] and showed lower patellar heights according to our results. Hence, lower patellar heights are also significantly correlated with trochlea morphology in the above manner. The exact nature of these significant interdependencies is still unsolved and should be subject to further studies.

Funding

Johanna Abelmann-Brockmann's doctoral studies, of which this paper is also part of, was funded by 'Intramurale Foschungsförderung', Medizinische Fakultät, University of Augsburg.

Author contributions

T.R. had the initial study idea, carried out the statistical evaluation, created graphs and tables, wrote this article, T.R. and J. A.B. developed the initial idea further towards a study design, planned and implemented the study, were responsible for surveying, organized and carried out the data collection and analysis, K.V., S.T., L.L., K.S., C.D., E.M. supported the implementation of the study and substantially assisted in the planning phase, K.V. and S.T. carried out the ultrasounds, K.V., S.T. and K.S. substantially helped in the data collection. In addition all authors made a substantial contribution to this paper by critically addressing problems and provided helpful feedback/corrections revising the manuscript. In addition, interim results were discussed with all authors so that further action could be planned.

Ethical approval

The study design was presented to the Ethics Committee of the Ludwig-Maximilan-Universität in Munich, who approved the study protocol in advance of the study (Project number: 22-0582).

Informed consent

Informed and written consent to participate in this study was obtained from the parents/guardians for all individuals participating in this study.

Consent to publish

The manuscript doesn't contain any individual person's data.

CRediT authorship contribution statement

Timon Röttinger: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Kurt Vollert:** Writing – review & editing, Project administration, Methodology, Investigation, Conceptualization. **Stefanie Tüchert:** Writing – review & editing, Project administration, Methodology, Investigation. **Leonard Lisitano:** Writing – review & editing, Conceptualization. **Khaled Salama:** Writing – review & editing, Project administration, Conceptualization. **Heinz Röttinger:** Writing – review & editing, Conceptualization. **Christian Dannecker:** Writing – review & editing, Resources, Conceptualization. **Edgar Mayr:** Writing – review & editing, Supervision, Resources, Methodology, Conceptualization. **Johanna Abelmann-Brockmann:** Writing – review & editing, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank all patients and their parents/guardians.

Additional information

Correspondence and request for materials should be addressed to T.R.

References

[1] Øye CR, Holen KJ, Foss OA. Mapping of the femoral trochlea in a newborn population: an ultrasonographic study. Acta Radiol 2015;56(2):234–43. doi: https://doi.org/10.1177/0284185114524391.
[2] Nietosvaara Y. The femoral sulcus in children. An ultrasonographic study. J Bone Joint Surg Br 1994;76(5):807–9.
[3] Ward SR, Terk MR, Powers CM. Patella alta: association with patellofemoral alignment and changes in contact area during weight-bearing. J Bone Joint Surg Am 2007;89(8):1749–55. doi: https://doi.org/10.2106/jbjs.F.00508.

[4] Luczak SB, Cheng C, Hedgecock JP, Brimacombe M, Pace JL. Patellar height correlates modestly with trochlear dysplasia: a magnetic resonance imaging analysis. Arthrosc Sports Med Rehabil 2022;4(3):e1031–7. doi: https://doi.org/10.1016/j.asmr.2022.02.009.
[5] Ward SR, Powers CM. The influence of patella alta on patellofemoral joint stress during normal and fast walking. Clin Biomech (Bristol, Avon) 2004;19(10):1040–7. doi: https://doi.org/10.1016/j.clinbiomech.2004.07.009.
[6] Patel NB, Oak SR, Rogers K, Crawford EA. The onset and development of patella alta in children with patellar instability. J Pediatr Orthop 2023;43(7):447–52. doi: https://doi.org/10.1097/bpo.0000000000002420.
[7] Huri G, Atay OA, Ergen B, Atesok K, Johnson DL, Doral MN. Development of femoral trochlear groove in growing rabbit after patellar instability. Knee Surg Sports Traumatol Arthrosc 2012;20(2):232–8. doi: https://doi.org/10.1007/s00167-011-1603-0.
[8] Kaymaz B, Atay OA, Ergen FB, Mermerkaya MU, Olgun ZD, Atesok K, et al. Development of the femoral trochlear groove in rabbits with patellar malposition. Knee Surg Sports Traumatol Arthrosc 2013;21(8):1841–8. doi: https://doi.org/10.1007/s00167-012-2163-7.
[9] Yang G, Li F, Lu J, Niu Y, Dai Y, Zuo L, et al. The dysplastic trochlear sulcus due to the insufficient patellar stress in growing rats. BMC Musculoskelet Disord 2019;20(1):411. doi: https://doi.org/10.1186/s12891-019-2802-y.
[10] Øye CR, Foss OA, Holen KJ. Breech presentation is a risk factor for dysplasia of the femoral trochlea. Acta Orthop 2016;87(1):17–21. doi: https://doi.org/10.3109/17453674.2015.1089023.
[11] Masquijo J, Bruno A, Warde A, Mónico C, Turazza F. Ultrasound evaluation of the femoral trochlea in newborns: incidence of trochlear dysplasia and associated risk factors. Journal of Pediatric Orthopaedics B 2024;33(6):519–23. doi: https://doi.org/10.1097/bpb.0000000000001141.
[12] Seil R, Rupp S, Kohn D. *Die Beurteilung der Patellahöhe*. In: Wirth CJ, Rudert M, editors. *Das patellofemorale Schmerzsyndrom*. Heidelberg: Steinkopff; 2000. p. 66–77.
[13] Graf R. The diagnosis of congenital hip-joint dislocation by the ultrasonic Combound treatment. Arch Orthop Trauma Surg 1978;97(2):117–33. doi: https://doi.org/10.1007/bf00450934.
[14] von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. Ann Intern Med 2007;147(8):573–7. doi: https://doi.org/10.7326/0003-4819-147-8-200710160-00010.
[15] Elias JJ, Soehnlen NT, Guseila LM, Cosgarea AJ. Dynamic tracking influenced by anatomy in patellar instability. Knee 2016;23(3):450–5. doi: https://doi.org/10.1016/j.knee.2016.01.021.
[16] Elias JJ, Jones KC, Cyrus Rezvanifar S, Gabra JN, Morscher MA, Cosgarea AJ. Dynamic tracking influenced by anatomy following medial patellofemoral ligament reconstruction: Computational simulation. Knee 2018;25(2):262–70. doi: https://doi.org/10.1016/j.knee.2018.02.002.
[17] Harbaugh CM, Wilson NA, Sheehan FT. Correlating femoral shape with patellar kinematics in patients with patellofemoral pain. J Orthop Res 2010;28(7):865–72. doi: https://doi.org/10.1002/jor.21101.
[18] Prakash J, Seon JK, Woo SH, Jin C, Song EK. Comparison of radiological parameters between normal and patellar dislocation groups in Korean population: a rotational profile CT-based study. Knee Surg Relat Res 2016;28(4):302–11. doi: https://doi.org/10.5792/ksrr.16.010.
[19] Caton J. Method of measuring the height of the patella. Acta Orthop Belg 1989;55(3):385–6.
[20] Caton J, Deschamps G, Chambat P, Lerat JL, Dejour H. [Patella infera. Apropos of 128 cases]. Rev Chir Orthop Reparatrice Appar Mot 1982;68(5):317–25.
[21] Röttinger TM. Gibt es einen Zusammenhang zwischen patientenspezifischen Formparametern des patellofemoralen Gleitlagers und den anatomisch spezifischen Patellapositionen? Dissertation, LMU München 2021. doi: https://doi.org/10.5282/edoc.27761.
[22] Conry KT, Cosgarea AJ, Tanaka MJ, Elias JJ. Influence of tibial tuberosity position and trochlear depth on patellar tracking in patellar instability: Variations with Patella Alta. Clin Biomech (Bristol) 2021;87:. doi: https://doi.org/10.1016/j.clinbiomech.2021.105406105406.
[23] Biyani R, Elias JJ, Saranathan A, Feng H, Guseila LM, Morscher MA, et al. Anatomical factors influencing patellar tracking in the unstable patellofemoral joint. Knee Surg Sports Traumatol Arthrosc 2014;22(10):2334–41. doi: https://doi.org/10.1007/s00167-014-3195-y.
[24] Askenberger M, Janarv PM, Finnbogason T, Arendt EA. Morphology and anatomic patellar instability risk factors in first-time traumatic lateral patellar dislocations: a prospective magnetic resonance imaging study in skeletally immature children. Am J Sports Med 2017;45(1):50–8. doi: https://doi.org/10.1177/0363546516663498.
[25] Arendt EA, England K, Agel J, Tompkins MA. An analysis of knee anatomic imaging factors associated with primary lateral patellar dislocations. Knee Surg Sports Traumatol Arthrosc 2017;25(10):3099–107. doi: https://doi.org/10.1007/s00167-016-4117-y.
[26] Jaquith BP, Parikh SN. Predictors of recurrent patellar instability in children and adolescents after first-time dislocation. J Pediatr Orthop 2017;37(7):484–90. doi: https://doi.org/10.1097/bpo.0000000000000674.
[27] Huntington LS, Webster KE, Devitt BM, Scanlon JP, Feller JA. Factors associated with an increased risk of recurrence after a first-time patellar dislocation: a systematic review and meta-analysis. Am J Sports Med 2020;48(10):2552–62. doi: https://doi.org/10.1177/0363546519888467.
[28] Koplewitz BZ, Babyn PS, Cole WG. Congenital dislocation of the patella. AJR Am J Roentgenol 2005;184(5):1640–6. doi: https://doi.org/10.2214/ajr.184.5.01841640.
[29] Sever R, Fishkin M, Hemo Y, Wientroub S, Yaniv M. Surgical treatment of congenital and obligatory dislocation of the patella in children. J Pediatr Orthop 2019;39(8):436–40. doi: https://doi.org/10.1097/bpo.0000000000000973.