**The relationship between joint hypermobility and patellar instability: A systematic review**

RUNNING TITLE: hypermobility and patellar instability

Libbi Anne Heighesa, Diego Agustín Abelleyra Lastoriaa, Rebecca Benia, Ahsan Iftikhara, Caroline Blanca Hingb

aSt George’s, University of London, London, SW17 0RE, United Kingdom

bSt George’s University Hospitals NHS Foundation Trust, London, SW17 0RE, United Kingdom

Corresponding author:

Diego A Abelleyra Lastoria

St George’s, University of London

Cranmer Terrace, London, SW17 0RE

United Kingdom

m1800817@sgul.ac.uk

Disclosure statements:

Acknowledgement: none

Conflict of interest: none

Funding/sponsorship: this research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

Informed consent: not applicable

Institutional Ethical Committee Approval: not applicable

**Abbreviations:**

MPFLR: Medial patellofemoral ligament reconstruction

EDS: Ehlers Danlos syndrome

MPFL: Medial patellofemoral ligament

LAX: ligamentous laxity

NLX: No ligamentous laxity

IKDC: International knee documentation committee

BANFF: Banff instability instrument 2.0

OKS: Oxford Knee Score

Pedi-FABS: Pediatric functional activity brief scale

WOMAC: Western Ontario and McMaster University Osteoarthritis index

SF-12MCS: 12-item short form survey mental component summary

SF-12PCS: 12-item short form survey physical component summary

**Abstract**

*Introduction:* Hypermobility describes the movement of joints beyond normal limits. Whether hypermobility predisposes to patellar instability is yet to be established. We aimed to determine if joint hypermobility leads to an increased risk of patellar instability, and to evaluate outcomes of treatment for patellar instability in those who exhibit hypermobility.

*Methods:* Published and unpublished literature databases were searched to the 7th of September 2023. Studies comparing prevalence of patellar dislocation/differences in treatment outcomes in patients with and without hypermobility were included.

*Results:* We identified 18 eligible studies (4391 patients). The evidence was low in quality. A case series on 82 patients found that there was a relationship between generalised joint laxity and patellar instability. This was corroborated by a study comparing 104 patients with patellar dislocation to 110 patients without. Prevalence of generalised joint laxity was six time higher in the former (64.4% vs 10.9%, p < 0.001).

Five studies found surgical intervention aimed at correcting patellar dislocation in patients with idiopathic hypermobility led to satisfactory outcomes. There was conflicting evidence regarding if hypermobile patients have worse outcomes than non-hypermobile patients following medial patellofemoral ligament reconstruction (MPFLR) in two studies. In addition, this procedure had a 19.1% failure rate in patients with Ehlers Danlos Syndrome (EDS), with hypermobility associated with a higher failure rate (p = 0.03). One study showed the type of graft used made no difference in outcome scores or re-dislocation rates (p > 0.5). Another study had 7/31 (22.6%) autografts which failed, compared to 2/16 allografts (12.5%) (p = 0.69).

*Conclusion:*Joint hypermobility is a risk factor for patellar instability. Identification of at-risk groups may aid prevention of dislocations and allow for appropriate treatment. Patients with EDS experience poor outcomes following patellar stabilisation surgery, with post-operative monitoring required.

*Keywords:* patellar instability; hypermobility; Ehlers Danlos syndrome; Downs syndrome; medial patellofemoral ligament reconstruction

**1.1 Introduction**

Joint hypermobility describes the movement of joints beyond normal limits. This is usually accompanied by joint laxity.1 Joint hypermobility can present as a symptom of connective tissue disorders, including EDS and Down’s syndrome, but may also be part of benign joint hypermobility syndrome. To quantify hypermobility, the Beighton score is used.2 The most common cut off to define hypermobility is a score of >4/9.3

Patellar instability has an incidence of 5.8 per 100,000, with most patients aged between 10-16 years.4 Patellar dislocation accounts for 2% to 3% of knee joint injuries5 with an incidence of 6 in 100,000.6 Patellofemoral instability is a multifactorial phenomenon, with abnormalities such as excessive tibial tubercle lateralization and trochlear dysplasia being predisposing factors.7

Previous studies have proposed that hypermobility and ligamentous hyperlaxity are predisposing factors for patellar instability and patellar dislocation.8-9 Hypermobility is caused by collagen abnormalities which can result in ligamentous laxity. Ligamentous laxity is also seen in Down syndrome and EDS, caused by genetic abnormalities.10-11 The medial patellofemoral ligament (MPFL) is mostly made up of collagen, and is the primary stabilser of the knee.12, 13 Consequentially, the weakened connective tissue of this ligament leads to an increased risk of dislocation.

Knowledge of the relationship between hypermobility and patellar dislocation may help identify patients at risk, aiding prevention of dislocations and allowing for appropriate management. We aimed to determine if joint hypermobility leads to an increased risk of patellar instability, and to evaluate outcomes of treatment for patellar instability in those who exhibit hypermobility.

**1.2 Methods**

This systematic review was conducted in accordance with the PRISMA 2020 checklist.14 We prospectively registered our review in PROSPERO (Registration: CRD42023451103).

*1.2.1 Study eligibility*:

We included studies if they compared prevalence of patellar dislocation, differences in treatment outcomes in patients with and without hypermobility, or musculoskeletal symptoms among patients with joint laxity. Patients with idiopathic hypermobility or hyperlaxity were eligible, as well as those with conditions leading to hypermobility or hyperlaxity, including Marfan’s syndrome, EDS, and Down’s syndrome. We included full-texts and abstracts. Cross-sectional, cohort and case control studies, as well as case series randomised controlled trials were eligible. Systematic or literature reviews were excluded, along with those not analysing patients with and without hypermobility separately, case reports, letters to the editor, and cadaveric studies. There were no restrictions placed based on patient demographics, language, or publication status. Two reviewers (LH, DAAL) independently performed eligibility assessment.

*1.2.2 Search strategy*:

Electronic databases searched included: Web of Science, ScienceDirect, PEDRo, Global Health, MEDLINE, and Embase. We reviewed the ISRCTN registry, the NIHR Portfolio, the WHO International Clinical Trials Registry Platform, the UK National Research Register Archive, and OpenSIGLE to identify currently registered studies. We searched conference proceedings from the British Trauma Society, the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine, the European Federation of National Associations of Orthopaedics and Traumatology, and the British Orthopaedic Association. Backwards searching was performed by reviewing the reference lists of included studies. We utilized Google Scholar to review papers citing the studies included for eligibility (forward-searching).

Two reviewers (LH, DAAL) carried out database search independently, twice for quality assurance. The last search was conducted on the 7th of September 2023 (***Appendix A***).

*1.2.3 Data extraction:*

Baseline characteristics (patient sex and age, number of patients, follow-up duration, and imaging/treatment modality) were extracted, as well as prevalence of patellar dislocation/differences in treatment outcomes in patients with and without hypermobility. Data extraction was conducted by three reviewers (LH, RB, AI). Data were narratively synthesised owing to heterogeneous study designs, patient characteristics, and outcomes reported, preventing quantitative pooled analysis.

*1.2.4 Outcomes:*

The primary outcome was differences in prevalence of patellar instability between patients with and without hypermobility. Secondary outcomes included treatment outcomes in patients with and without hypermobility.

*1.2.5 Methodological appraisal:*

Two reviewers evaluated the risk of bias of full text studies (RB, AI). A third reviewer reviewed any disagreements (DAAL). The level of evidence of the studies was determined with the March 2009 Oxford CEBM: Levels of Evidence.15 The Downes and Black Tool for cross-sectional studies,16 the CLARITY tools for cohort and case-control studies,17 and the Institute of Health Economics case series quality appraisal checklist were utilized to carry out the risk of bias assessment.18

**1.3 Results**

Eighteen eligible articles were identified out of 14,344 records screened (***figure 1***). Of these, five investigated the effects of hypermobility on the stability of the patella (3434 knees of 3386 patients, mean age range: 12.7 to 23.5 years). The remaining 13 investigated the effects of hypermobility on surgical outcomes on those with patellar instability (1062 knees of 1005 patients, mean age range: 6.1 to 43.3 years) (***Table 1***). Reconstruction of the medial patellofemoral ligament accounted for 940 procedures.

*1.3.1 Methodological appraisal:*

All studies carried a level of evidence of 4. Only one study blinded outcome assessors, and it was unclear whether outcomes were established a priori (***Table 2***). Overall, the studies carried concerns regarding risk of bias and a low level of evidence.

*1.3.2 Relationship between patellar hypermobility and patellar dislocation:*

Two studies directly compared the prevalence of patellar instability in hypermobile individuals and healthy controls. Nomura et al found generalised joint laxity in 20 subjects (24%) with patellar dislocation, compared to eight in the control group (10%) (p = 0.013).19 The mean Carter and Wilkinson Criteria score was 1.7 (standard deviation [SD]: 1.3) in the control group, and 2.5 (SD: 1.4) in the patient group (p = 0.00004).19

Similarly, Rünow found that individuals who had a history of patellar dislocation were more likely to also have joint laxity compared to controls.20 Twelve out of 110 (10.9%) controls had joint laxity, while 67/104 (64.4%) (p < 0.001).

*1.3.3 Musculoskeletal symptoms in those with hypermobility:*

According to Stern et al, 43.4% out of 205 patients with EDS had musculoskeletal complaints pertaining to the knee (43.4%).21 Common musculoskeletal complaints of those with hypermobility included laxity (63.4%), pain (46.8%) and subluxation (23.9%). Tobias et al found that there was an association between pain and hypermobility.22 Out of 2,901 children with pain, 4.6% had hypermobility. Moderately troublesome pain at the knee (odds ratio [OR]: 1.90, 95% Cl 1.16,3.11, p = 0.011) showed a positive association with joint hypermobility. Tobias et al also suggested that obesity could be an exacerbating factor for pain in hypermobility.22 In the knee, odds ratios of 1.57 and 11.01 for lower limb pain in non-obese and obese participants with joint hypermobility, respectively, were observed.

Redler et al observed that patients with ligamentous laxity (LAX) had a lower rate of severe injuries than those without ligamentous laxity (NLX) following patellar instability events, (45% vs 74%, p = 0.004), and less osteochondral injuries (14% vs 25%, p = 0.132).23

*1.3.4 Risk of re-dislocation and complications:*

Six studies reported zero re-dislocations after surgery, (follow up range: from 1 year and 3 months to 11 years and 2 months).24-29 Niedzielski et al found soft tissue procedures led to no further dislocations in 10 out of 11 patients with patellar dislocation and ligamentous laxity.30 Pain with vigorous activity was reported by nine patients. Hiemstra et al reported re-dislocation occurred in 28 of the 590 knees (4.8%) following surgical patellofemoral stabilisation.31 Joint hypermobility (Beighton score greater than 5 in comparison with <4) was associated with graft failure (p < 0.01). Nemunatis et al found that three of 21 (14.2%) knees had recurrent dislocation after MPFLR.32

Howells and Eldridge compared outcomes in patients with and without joint hypermobility undergoing MPFLR.24 They found there was increased rate of residual (72% vs 32%; p = 0.001) and recurrent symptoms (32% vs 8%; p = 0.027) in the former. However, no difference was seen in questions regarding the satisfaction with the procedure itself. There were significantly lower rates of resumption of sport in the hypermobile group (39% vs 82%, respectively, p < 0.001).

Parikh et al found isolated MPFLR had a 19.1% failure rate in patients with Ehlers Danlos syndrome.33 Patients with hypermobility displayed higher failure rates than those who could not (p = 0.03). Similarly, Reddy et al reported complication rate in those with hypermobility was 11% (9/76).34 Within these complications, there were two patellar fractures and seven revision surgeries required for recurrent patellar instability, and no difference in complication rates between non-syndromic and syndromic patients (p = 0.9).

Bettuzzi reported that all patients experienced decreased falls following surgery.28 Limping subsided in two, and continued occasionally in two others. Ruzzini found that 84% were performed recreational activities without limping, re-dislocations or pain at the last follow-up.29 Kocon et al found that in seven knees of children with Down’s syndrome, patellar traction stabilization was achieved.35 All patients evaluated, except one in Rose et al, reported increased tibiofemoral stability after surgery.27

*1.3.5 Isokinetic and post-operative outcome scoring:*

1.3.5.1 Medial patellofemoral ligament reconstruction

Howells and Eldridge found hypermobile patients had significantly worse post-operative scores for all scoring systems (12-item short form survey mental component summary (SF-12MCS) and 12-item short form survey physical component summary (SF-12PCS), Kujala, Oxford Knee Score (OKS), International knee documentation committee (IKDC), Fulkerson level, Western Ontario and McMaster University Osteoarthritis index (WOMAC), and Tegner level) in comparison to non-hypermobile patients in the control group (p < 0.010).24 Parikh et al found post-operative patient reported outcomes (PROs) to be lower in those with EDS compared to those in the non-EDS population.33 Although the scores were worse for the hypermobile group compared to the controls, when comparing pre- and post-operative scores within patients with hypermobility, improvements were seen post-operatively for the OKS (21.80 vs 33.36, p = 0.009), Kujala (46.60 vs 64.28, p = 0.018), Fulkerson (45.00 vs 65.08, p = 0.033) and SF-12MCS (46.21 vs 58.88, p = 0.005) scores, with non-statistically significant improvements in the remaining scores, including: IKDC (41.61 vs 54.96, p = 0.173), WOMAC (74.58 vs 77.88, p = 0.767), Tegner (3.80 vs 4.13, p = 0.592) and SF-12PCS (34.56 vs 44.08, p = 0.0107). The control group experienced significant improvements in all outcome scores except the Tegner activity level (4.60 vs 5.44, p = 0.598).24

Similarly, Nemunaitis reported post-operative scores in patients with EDS showed improvements from baseline, including Banff instability instrument 2.0 (BANFF) (57.15; 95% CI 10.24), Kujala (73.5; 95% CI 8.68), Pediatric functional activity brief scale (Pedi-FABS) (6.73; 95% CI 2.86), and Pedi-IKDC(66.2; 95% CI 8.52) scores.32 Imerci et al also found that patients with either generalised joint laxity or syndromic hypermobility (including EDS and Down’s Syndrome) exhibited an increase in Lysholm score, from 53 (SD: 10) to 85 (SD: 7) (p < 0.001). Kujala score increased from 56 (SD: 10) to 86 (SD: 6) (p < 0.001).25

Tibial tubercle osteotomy and MPFLR in syndromic patients led to increased mean flexion compared with pre-operative values (117° to 154°, p < 0.001).25

Nemunaitis and Parikh performed 14 hamstring autografts and seven hamstring allografts, and found no difference in re-dislocation rates or outcome scores between the two graft types (p > 0.5).32 Parikh et al had 7/31 (22.6%) autografts which failed, compared to 2/16 allografts (12.5%) (p = 0.69).33 Within the failures of autografts, six (out of 17) occurred with a gracilis graft, one failure occurred with quadriceps tendon graft, and none occurred with semitendinosus graft (out of 13 knees).

1.3.5.2 Modified Roux-Goldthwait-Campbell procedure

Bettuzzi reported patients had a pre-operative modified Lysholm Knee score of 57.5/100, which increased to 91/100 (p <0.01) post-operatively.28 The Lysholm score in Ruzzini’s study showed significant improvement, from 55.6 (SD: 6.3) pre-operatively to 94.7 (SD: 3.4) (p < 0.05) at1 year, and 94.2 (SD: 2.6) (p< 0.05) at five years.29 In addition, Ruzzini et al reported increased range of motion post-operatively, with significant improvement in active knee extension (13.9° [SD: 4.7°] to 4.91° [SD: 3.8°], p < 0.05).29 Kujala score increased from 39.1 (SD: 4.7) to 93.3 (SD: 4.2) (p < 0.05) at 1 year, and to 92.7 (SD: 3.4) (p < 0.05) at final follow up.

1.3.5.3 Greens Quadricepsplasty

Kocon et al reported on eight knees using the quadricepsplasty technique, and on two knees undergoing Greens quadricepsplasty augmented in children with Down’s syndrome.35 In accordance with the Dugdale classification of patellofemoral instability, six out of eight patients experienced increased stability.35

1.3.5.4 Four-in-one procedure

Joo et al reported on the four-in-one procedure performed in five patients with generalised joint laxity.26 No re-dislocations were observed, and only two cases of marginal skin necrosis were noted. All patients had normal patellar tracking post-operatively, with every patient returning to normal activities. The post-operative Kujala score was 95.3 (range 88 to 98). The femoral trochleae were classed as Dejour group B or C pre-operatively, but all were group A post-operatively (Joo et al, 2007).

*1.3.6 Patient satisfaction:*

Seven studies reported on patient satisfaction from the procedures undergone.24, 26-28, 33-35 Satisfaction with the outcome was reported in 131/142 patients. Reasons for dissatisfaction varied. Kocon et al reported that the two unsatisfied patients were those who experienced recurrent dislocations.35 Rose et al had three unsatisfied patients, two of which experienced continued instability, with the other reporting pain.27 Howells and Eldrige reported six patients with hypermobility were not satisfied.24 However there was no difference in satisfaction between the hypermobile and control groups (p = 0.066).

**1.4 Discussion**

Current evidence suggests that joint hypermobility and ligamentous laxity increase the risk of patellar instability, leading to patellofemoral dislocation. Two studies found generalised joint laxity was more prevalent in patients with dislocations compared to those without.19, 20 Ligamentous laxity could be a factor in the pathogenesis of patellar instability.19 Patients with idiopathic ligamentous laxity had a lower prevalence of severe injury compared to controls,23 suggesting a potential protective effect of hypermobility. However, it was also reported that those who experienced knee pain were more likely to be hypermobile, albeit this could be attributed to obesity being an exacerbating factor.22 In those with EDS, subluxation was the third most common musculoskeletal complaint after laxity and pain.21

Subjects with joint hypermobility experienced poorer outcomes than those without hypermobility when undergoing surgery to correct patellar instability.

In those with additional structural abnormalities, certain surgical options may render patellar stability.34 Multiple techniques may be required in order to provide better support to the weakened tissues, as seen in reconstruction of the MPFL and concomitant tibial tubercle osteotomy.25

The age of the patients in the studies may need further consideration, as only three of the studies pertaining to surgical techniques in patients with hypermobility were performed in adults.23, 24, 27 Management of patellar dislocation in skeletally immature patients may be more challenging,29, 34 with those who required revision being younger.

Although hypermobile patients had worse outcomes than patients without hypermobility, there were improvements in baseline scores. Pre-operative levels of function in hypermobile patients must be taken into consideration.24 The most common surgical technique reported was MPFLR, and although hypermobility is not a contraindication for this technique, managing expectations of patients on post-operative function is important to increase satisfaction.24 Autografts and allografts were both suitable for use in hypermobility patients. Graft type utilized should be considered, as the gracilis graft showed the highest failure rate. However more research directly comparing types of graft are needed, as only two studies compared these.32, 33 Complications such as skin necrosis have been reported, which could be attributed to poor tissue quality due to ligamentous laxity.26

Identification of hypermobility is important in ensuring appropriate management steps can be taken. As hypermobility is a factor predisposing to patellar instability, it is likely that a high proportion of hypermobile patients will need stabilization surgery. For this reason, careful post-operative monitoring is required to mitigate the re-dislocation risk, and other post-operative complications. Although improvement was seen in hypermobile patients after surgery, outcomes were still poorer than in those without hypermobility. Further research into other surgical techniques and conservative management in these patients is required, as functional scores in those with hypermobility are lower than non-hypermobile populations.

The current evidence base has limitations. First, the included studies carried concerns regarding high risk of bias and low level of evidence. Second, it can be difficult to identify if hypermobility is the sole cause of instability, as many patients who presented with hypermobility had other known risk factors for patellar instability. Lastly, there were discrepancies among studies in the definition of hypermobility. Although most used the Beighton criteria,2 cut-offs differed between studies. This may affect the results and it may be that only a certain severity of hypermobility increases the risk of patella instability. Further research should adopt consistent cut-offs to yield more reliable comparisons.

**1.5 Conclusion**

Joint hypermobility predisposes to patellar instability. Identification of at-risk groups may aid prevention of dislocations and allow for the implementation of appropriate treatment strategies. Patients with EDS experience poor outcomes following surgical intervention aimed at correcting patellar instability. Careful post-operative monitoring is required.

**1.6 References**

1. Wolf JM, Cameron KL, Owens BD. Impact of Joint Laxity and Hypermobility on the Musculoskeletal system. *J Am Acad Orthop Surg Glob Res Rev* 2011;19(8):463-471. https://doi.org/10.5435/00124635-201108000-00002.
2. Beighton P, Solomon L, Soskolne CL. Articular mobility in an African population. *Ann Rheum Dis* 1973;32(5):413-18. https://doi.org/10.1136/ard.32.5.413.
3. Malek S, Reinhold EJ, Pearce GS. The Beighton Score as a measure of generalised joint hypermobility. *Rheumatol Int* 2021; 41(10):1707-1716. https://doi.org/10.1007/s00296-021-04832-4.
4. Wolfe S, Varacallo M, Thomas JD, Carroll JJ, Kahwaji CI. Patellar Instability. Accessed 11 November 2023. <https://www.ncbi.nlm.nih.gov/books/NBK482427/>. 2023
5. Petri M, Ettinger M, Stuebig T, Brand S, Krettek C, Jagodzinski M, et al. Current Concepts for Patellar Dislocation. *Arch Trauma Res* 2015;4(3). https://doi.org/10.5812/atr.29301.
6. Krebs C, Tranovich M, Andrews K, Ebraheim N. The medial patellofemoral ligament: Review of the literature. *J Orthop* 2018;15(2):596-599. https://doi.org/10.1016/j.jor.2018.05.004.
7. Laidlaw MS, Diduch DR. Current Concepts in the Management of Patellar Instability. *Indian J Orthop* 2017;51:493-504. https://doi.org/10.4103/ortho.IJOrtho\_164\_17.
8. Arendt EA, Fithian DC, Cohen E. Current concepts of lateral patella dislocation. *Clin sports med* 2012;21(3): 499-519. https://doi.org/10.1016/s0278-5919(02)00031-5.
9. Stefancin JJ, Parker RD. First-time Traumatic Patellar Dislocation A Systematic Review. *Clin Orthop Relat Res* 2007;455:93-101. https://doi.org/10.1097/blo.0b013e31802eb40a.
10. Rombaut L, Malfait F, Cools A, De Paepe A, Calders P. Musculoskeletal complaints, physical activity and health-related quality of life among patients with the Ehlers–Danlos syndrome hypermobility type. *Disabil Rehabil* 2010;32(16):1339-1345. https://doi.org/10.3109/09638280903514739.
11. Rebouças Moreira TA, Demange MK, Gobbi RG, Mustacchi Z, Pécora JR, Tírico LEP, et al. Trochlear dysplasia and patellar instability in patients with Down syndrome. *Rev Bras Ortop* 2015;50(2): 159-163. https://doi.org/10.1016/j.rboe.2015.03.005.
12. Kiel J, Kaiser K. Patellofemoral Arthritis. Accessed 11 November 2023. <https://www.ncbi.nlm.nih.gov/books/NBK513242/>. 2023.
13. Veteto A, McIntrye M, Hintz M, Cramberg M, Kondrashov P. Histological structure of the Medial and Lateral Patellofemoral Ligaments and Implications for Reconstructive Surgery and Anterior Knee Pain. *Mo Med* 2023;120(2):134-138.
14. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372. https://doi.org/10.1136/bmj.n71.
15. Centre for Evidence-Based Medicine. Oxford Centre for Evidence-Based Medicine: Levels of Evidence. Accessed 02 December 2022. https://www.cebm.ox.ac.uk/resources/levels-of-evidence/oxford-centre-for-evidence-based-medicine-levels-of-evidence-march-2009. 2009
16. Downes MJ, Brennan ML, Williams HC, Dean RS. Development of a critical appraisal tool to assess the quality of cross-sectional studies (AXIS). *BMJ Open* 2016;6(12):e011458. https://doi.org/10.1136/bmjopen-2016-011458.
17. DistillerSR. Resources. Accessed 07 September 2023. https://www.distillersr.com/resources/methodological-resources/. 2023.
18. Institute of Health Economics. Case Series Studies Quality Appraisal Checklist. Accessed 02 December 2022. https://www.ihe.ca/research-programs/rmd/cssqac/cssqac-about. 2014.
19. Nomura C, Inoue M, Kobayashi S. Generalized Joint Laxity and Contralateral Patellar Hypermobility in Unilateral Recurrent Patellar Dislocators. *Arthroscopy* 2006;22(8): 861-865. https://doi.org/10.1016/j.arthro.2006.04.090.
20. Rünow A. The Dislocating Patella: Etiology and Prognosis in Relation to Generaked Joint Laxity and Anatomy of the Patellar Articulation. *Acta Orthop Scand* 2009;54(Supplement 201):1-15. https://doi.org/10.3109/17453678309154170.
21. Stern CM, Pepin MJ, Stoler JM, Kramer DE, Spencer SA, Stein CJ. Musculoskeletal Conditions in a Pediatric Population with Ehlers-Danlos Syndrome. *J Pediatr* 2016;181:261-266. https://doi.org/10.1016/j.jpeds.2016.10.078.
22. Tobias JH, Deere K, Palmer S, Clark EM, Clinch J. Joint Hypermobility Is a Risk Factor for Musculoskeletal Pain During Adolescence. *Arthritis Rheumm* 2013;65(4):1107-1115. https://doi.org/10.1002/art.37836.
23. Redler LH, Dennis ER, Mayer GM, Kalbain IL, Nguyen JT, Shubin Stein BE, et al. Does Ligamentous Laxity Protect Against Chondral and Osteochondral Injuries in Patients With Patellofemoral Instability*? Orthop J Sports Med* 2022;10(7):23259671221107609. https://doi.org/10.1177/23259671221107609.
24. Howells NR, Eldridge JD. Medial patellofemoral ligament reconstruction for patellar instability in patients with hypermobility. *J Bone Joint Surg Br* 2012; 94-B(12):1655-1659. https://doi.org/10.1302/0301-620X.94B12.29562.
25. Imerci A, McDonald TC, Rogers KJ, Thacker MM, Atanda A Jr. Outcomes of medial patellofemoral ligament reconstruction and tibial tubercle osteotomy in syndromic adolescents with patellar dislocation. *J Clin Orthop Trauma* 2022;14;25:101770. https://doi.org/10.1016/j.jcot.2022.101770.
26. Joo SY, Park KB, Kim BR, Park HW, Kim HW. The ‘four-in-one’ procedure for habitual dislocation of the patella in children. *J Bone Joint Surg Br* 2007;89(12):1645-1649. https://doi.org/10.1302/0301-620X.89B12.19398.
27. Rose PS, Johnson CA, Hungerford DS, McFarland EG. Total knee arthroplasty in Ehlers-Danlos syndrome. *J Arthroplasty* 2004;19(2):190-196. https://doi.org/10.1016/j.arth.2003.03.001.
28. Bettuzzi C, Lampasi M, Magnani M, Donzelli O. Surgical treatment of patellar dislocation in children with Down syndrome: a 3-to 11-year follow up study*. Knee Surg Sports Traumatol Arthrosc* 2008;17(4): 334-40. https://doi.org/10.1007/s00167-008-0652-5.
29. Ruzzini L, Donati F, Russo R, Costici PR. Modified Roux-Goldthwait procedure for management of patellar dislocation in skeletally immature patients with Down syndrome. *Indian J Orthop* 2019;53(1):122-27. https://doi.org/10.4103/ortho.IJOrtho\_505\_17.
30. Niedzielski KR, Malecki K, Flont P, Fabis J. The results of an extensive soft tissue procedure in the treatment of obligatory patellar dislocation in children with ligamentous laxity. *Bone Joint J* 2015;97-B(1):129-133. https://doi.org/10.1302/0301-620X.97B1.33941.
31. Hiemstra LA, Lafave M, Kerslake S. Generalized joint hypermobility more common in surgical failure cases after patellofemoral stabilization*. Journal of ISAKOS* 2021;6(6):439-440. https://doi.org/10.1007/s00167-019-05489-0.
32. Nemunaitis J, Parikh SN. Outcomes of Isolated Medial Patellofemoral Ligament Reconstruction for Recurrent Patellar Instability in Ehlers-Danlos Syndrome. *Orthop J Sports Med* 2022;10(5 suppl2):2325967121S00509. https://doi.org/10.1177/2325967121S00509.
33. Parikh SN, Nemunaitis J, Wall EJ, Gupta R, Veerkamp MW. Outcomes of Isolated Medial Patellofemoral Ligament Reconstruction for Patellar Instability In Ehlers-Danlos Syndrome. *Journal of ISAKOS* 2023;8(Supplement 1):121. https://doi.org/10.1016/j.jisako.2023.03.311.
34. Reddy G, Hayer PS, UlIslam S, Mehta NJ, Iqbal HJ, Stables G, et al. Outcomes of Allograft Medial Patellofemoral Ligament Reconstruction in Children and Adolescents with Hypermobility. *Int J Appl Basic Med Res* 2022;12(3):161-166. https://doi.org/10.4103/ijabmr.ijabmr\_25\_22.
35. Kocon H, Kabacyj M, Zgoda M. The results of the operative treatment of patellar instability in children with Down’s syndrome. *J Pediatr Orthop B* 2012;21(5):407-410. <https://doi.org/10.1097/bpb.0b013e328354f684>.

Appendix A: search strategy

Joint hyperlaxity OR Joint hypermobil\* OR knee hypermobil\* OR Hypermobil\* OR hypermobility spectrum disorder OR Ehlers Danlos OR Marfan OR connective tissue dis\* OR Collagen dis\* OR Down’s OR Down’s Syndrome

AND

Patell\* OR kneecap

AND

Dislocat\* OR Sublux\* OR Instability

*Deduplicate*

List of figures captions

***Fig. 1***: PRISMA diagram depicting the study selection process

Figure 1

Records removed *before screening*:

Duplicate records removed

(n = 526)

Records identified from:

Databases (n = 2925)

Registers (n = 0)

Conference proceedings (n = 10506)

Citation searching (n = 540)

Forward searching (n = 899)

**Identification**

Records screened

(n = 14344)

Records excluded (n = 6):

Case report (n = 2)

Did not evaluate the effects of hypermobility on patellar instability (n = 2)

Animal study (n = 2)

**Screening**

Records assessed for eligibility

(n = 24)

Studies included in review

(n = 18)

**Included**

Table 1: Baseline characteristics of included studies

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Study | Study design, level of evidence | Imaging modality/ treatment  | Number of patients (male, female) | Mean patient age (years) | Number of knees | Re-dislocation rate | Follow-up duration |
| Nomura et al, 200619 | Case Series, 4 | N/A | Overall: 164 (46,118)  Instability group: 82 (23,59)  Control group: 82 (23, 59)  | Instability group: 22.9 ± 9.2   Control group: 23.5 ± 5.7  | Overall: 164  Instability group: 82  Control group: 82  | NA | N/R |
| Stern et al, 201721 | Case Series, 4 | Imaging 140 radiographs (including 4 scanograms and 2 fluoroscopies) 102 MRIs (80 non contrast and 22 arthrograms) 16 CTs 9 Bone scans  4 US 4 density scans   Treatments 167 physical activity, occupational therapy, or home exercise 138 immobilizations (including braces, boots, casts and/or crutches) 83 rest/activity modification 73 orthotics 66 medications 59 surgeries  | EDS: 205 (57, 148)  | 12.7 ± 3.6  | 205  | NR | 5-year study period with the median number of visits per patient being 4   |
| Tobias et al, 201322 | Case Series, 4 | N/A | Overall 2,901 (1267, 1634) Hypermobile: 134 (17, 117)Without hypermobility: 2767 (1250, 1517) | 13.8 at the start of assessment   17.8 by the end  | Overall 2,901 Hypermobile: 134 Without hypermobility: 2767  | NA | 4 years  |
| Rünow, 198320 | Case Series, 4 | Radiographic examination of the quadriceps tendon, Insall index, the Norman index and the condylar angle  | 104 (37, 67)  | 22 for males (12-47)  22 for females (12-43  | 140  | NA | 8 years  |
| Reboucas Moreira et al, 201511 | Cross-sectional study, 3  | Radiographs to evaluate trochlear and femoro-patellar congruence angle, and patellar height | 12 (6,6)  | 16.4 (6-36)  | 24 (11 with stable patellae, 13 with unstable patellae)  | NA | NR |
| Redler et al, 202223 | Cohort study, 3 | MPFLr  | 171 (32,139) With ligamentous laxity: 96Without ligamentous laxity: 75 | 22  | 171  | 58 required another surgery.29 from the lax and 29 from the non-lax group | N/A |
| Niedzielski et al, 201530 | Case Series, 4 | Extensive soft tissue surgical procedure: lateral release, Galeazzi semitendinosus tenodesis, a Roux-Goldthwait procedure, and vastus medialis advancement   The leg was immobilised for six weeks after the operation, followed by strengthening and restoration of range of movement.  | 11 (4, 7)  | 13.8 (12 to 15)  | 11  | 1 knee (9.1%) | 8.1 years (5-15)  |
| Howells and Eldridge, 201224 | Case control study, 3 | Medial patellofemoral ligament (MPFL) reconstruction  | Overall: 75 (7,68)  Hypermobile group: 25 (2, 23)  Control group: 50 (5,45)  | Hypermobile group: 25.4 (17-49)  Control group: 26.12 (16-49)  | Hypermobile group: 25   Control group: 50  | 0 knees | Hypermobile group: 15.04 months (6-30)  Control group: 16.08 months (6-42)  |
| Bettuzzi et al, 200828 | Case Series, 4 | Modified Roux-Goldthwait-Campbell procedure   | 6 (male vs female not reported)  | 10 (6 yrs 6 mths -13yrs 4mths  | 10  | 0 | 8 years and 8 months (3yrs 6mths – 11yrs 5mths)  |
| Kocon et al, 201235 | Case Series, 4 | -Greens quadricepsplasty in 6 cases (8 knees)  - Greens quadricepsplasty augumented with modified Galeazzi procedure -semitendinosus tenodesis in 2 cases (2 knees)  | 8 (3,5)  | 7 years 9 months (6-11)  | 10  | 2 (20%) | 3 years and 3 months |
| Ruzzini et al, 201929 | Case Series, 4 | Modified Roux-Goldthwait procedure  | 19 (8,11)  | 9.5 (3.7-15)  | 23  | 0 | Minimum 5 year follow up. Mean follow up 134 months.  |
| Nemunaitis and Parikh, 202132 | Case Series, 4 | Medial Patellofemoral Ligament Reconstruction (14 autograft: 7 allograft) MPFL reconstruction with concomitant surgery (7 patients) MPFL reconstruction with chondroplasty of patella/ lateral femoral condyle (6 patients)  | 16 (0,16) – consecutive EDS patients  | 15.4 | 21 | 3 knees (14.2%) – entire cohort  | Minimum 2yrs  |
| Parikh et al, 202333 | Case Series, 4 | Isolated MPFL reconstruction  | 31 (4, 27)   | 14.9  | 47  | 19.1% required revision MPFLR for stabilization. Nine knees required subsequent surgeries involving other procedures (19.1%). | Minimum 2yrs (retrospective outcomes review mean: 7.2yrs & PROs mean: 5.2yrs)  |
| Joo et al, 200726 | Case Series, 4 | Radiographs – used to show evidence for any patella alta (all patellae found centrally in intercondylar notch on skyline view)  CT – mean external tibial rotation and femoral anteversion was 17˚ (14˚ to 21˚) and 22˚ (12˚ to 26˚) ‘Four-in-one’ procedure  | 5 (0,5)  | 6.1 years (range 4.9 to 6.9)  | 6  | 0 knees   | Mean: 54.5 months (range 31 to 66 months)  |
| Reddy et al, 202234 | Case Series, 4 | Allograft MPFL reconstruction MPFL reconstruction revision with tibial tubercle osteotomy (6 patients) MPFL reconstruction revision with tracheoplasty (9 patients)  | 57 (14,43) | 14 (range 7-16) | 76 | 9 knees: 2 patellar fractures 7 revision surgeries for recurrent instability  | Mean follow-up: 3yrs (range 1-4yrs)  |
| Imerci et al, 202225  | Case Series, 4 | MPFL and TTO  | 6 (1,5)   | 15.8   | 10  | 0 redislocations  | 2.2 years (this is for the whole study, individual ones not available) |
| Rose et al, 200427 | Case Series, 4 | TKA | 10(0,10)  | 43.3  | 12  | 0 | 65 months |
| Hiemstra et al, 202131 | Case control study, 3 | Commonest revision procedures (frequency NR) Isolated MPFLR revisionMPFLR + tibial tubercle osteotomy MPFL reconstruction revision with tracheoplasty  | 590 | NR | 590 | 28 knees (4.8%) – entire cohort  | Minimum 24 months (range 24-137)  |

Table 2 : Results of the risk of bias assessment

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IHE case series quality appraisal checklist questions18 | Imerci et al, 202225 | Joo et al, 200726 | Nomura et al, 200619 | Reddy et al, 202234 | Rombaut et al, 200910 | Rose et al, 200427 | Rünow et al, 198320 | Stern et al, 201721 | Tobias et al, 201322 | Niedzielski et al, 201530 | Bettuzzi et al, 200928 | Kocon et al, 201235 | Ruzzini et al, 201929 |
| Was the hypothesis/aim/objective of the study clearly stated? | Yes | Partial | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Partial | Yes | Yes |
| Was the study conducted prospectively? | No | Unclear | Yes | No | Yes | No | Unclear | No | Yes | No | No | Yes | No |
| Were the cases collected in more than one centre? | No | No | Unclear | No | No | No | No | No | Yes | No | No | Unclear | Unclear |
| Were patients recruited consecutively? | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear |
| Were the characteristics of the patients included in the study described? | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Were the eligibility criteria (i.e. inclusion and exclusion criteria) for entry into the study clearly stated? | Partial | No | Partial | Partial | Yes | Partial | Yes | Yes | Yes | Yes | Partial | Yes | Yes |
| Did patients enter the study at a similar point in the disease? | No | No | No | Yes | Yes | Yes | No | No | Yes | Yes | Yes | Yes | Yes |
| Was the intervention of interest clearly described? | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Were additional interventions (co-interventions) clearly described? | Yes | N/A | Yes | Yes | Yes | N/A | Yes | N/A | N/A | N/A | Yes | Yes | N/A |
| Were relevant outcome measures established a priori? | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear |
| Were outcome assessors blinded to the intervention that patients received? | Unclear | Unclear | Unclear | Unclear | Unclear | No | No | Unclear | Unclear | Unclear | Unclear | Unclear | Unclear |
| Were the relevant outcomes measured using appropriate objective/subjective methods? | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Were the statistical tests used to assess the relevant outcomes appropriate? | Yes | Unclear | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | N/A | Yes |
| Was follow-up long enough for important events and outcomes to occur?  | Yes | Yes | N/A | Yes | N/A | Yes | Unclear | N/A | Yes | Yes | Yes | Yes | Yes |
| Were losses to follow-up reported? | No | No | No | No | No | No | No | No | Yes | No | No | No | No |
| Did the study provide estimates of random variability in the data analysis of relevant outcomes? | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Were the adverse events reported? | Yes | Yes | N/A | Yes | N/A | Yes | N/A | N/A | N/A | Yes | Yes | Yes | Yes |
| Were the conclusions of the study supported by results? | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Were both competing interests and sources of support for the study reported? | Yes | Partial | No | Yes | Yes | Partial | Partial | Partial | Partial | Partial | No | Partial | Yes |
| Risk of bias assessment(High/low/some concerns) | High | High | High | High | Some concerns | High | High | High | High | High | High | High | Some concerns |

|  |  |  |
| --- | --- | --- |
| Clarity tool for case control studies17 | Hiemstra et al, 201931 | Howells and Eldridge, 201224 |
| Can we be confident in the assessment of exposure? | Definitely Yes | Definitely Yes |
| Can we be confident that cases developed the outcome of interest and controls had not? | Definitely Yes | Definitely Yes |
| Were the cases (those who were exposed and developed the outcome of interest) properly selected? | Definitely Yes | Definitely Yes |
| Were the controls (those who were exposed and did not develop the outcome of interest) properly selected? | Probably yes  | Definitely Yes |
| Were cases and controls matched according to important prognostic variables or was statistical adjustment carried out for those variables? | Definitely Yes | Definitely Yes |
| Risk of bias assessment | Low | Low |

|  |  |
| --- | --- |
| Appraisal tool for cross-sectional studies risk of bias assessment questions16 | [Rebouças Moreira](https://pubmed.ncbi.nlm.nih.gov/?sort=date&term=Rebou%C3%A7as+Moreira+TA&cauthor_id=26229910) et al, 201511 |
| Were the aims/objectives of the study clear? | Yes |
| [Was the study design appropriate for the stated aim(s)?](#_bookmark5) | Yes |
| [Was the sample size justified?](#_bookmark6) | No |
| [Was the target/reference population clearly defined? (Is it clear who the](#_bookmark8) [research was about?)](#_bookmark8) | Yes |
| [Was the sample frame taken from an appropriate population base so that it](#_bookmark9) [closely represented the target/reference population under investigation?](#_bookmark9) | Partial |
| [Was the selection process likely to select subjects/participants that were](#_bookmark11) [representative of the target/reference population under investigation?](#_bookmark11) | Yes |
| [Were measures undertaken to address and categorise non-responders?](#_bookmark12) | No |
| [Were the risk factor and outcome variables measured appropriate to the aims](#_bookmark13) [of the study?](#_bookmark13) | Yes |
| [Were the risk factor and outcome variables measured correctly using](#_bookmark13) [instruments/measurements that had been trialled, piloted or published](#_bookmark13) [previously?](#_bookmark13) | Yes |
| [Is it clear what was used to determined statistical significance and/or](#_bookmark14) [precision estimates? (e.g. p-values, confidence intervals)](#_bookmark14) | No |
| [Were the methods (including statistical methods) sufficiently described to](#_bookmark16) [enable them to be repeated?](#_bookmark16) | Yes |
| [Were the basic data adequately described?](#_bookmark18) | Yes |
| [Does the response rate raise concerns about non-response bias?](#_bookmark19) | No |
| [If appropriate, was information about non-responders described?](#_bookmark19) | N/A |
| [Were the results internally consistent?](#_bookmark20) | Yes |
| [Were the results presented for all the analyses described in the methods?](#_bookmark21) | Yes |
| [Were the authors' discussions and conclusions justified by the results?](#_bookmark23) | Yes |
| [Were the limitations of the study discussed?](#_bookmark29) | Yes |
| [Were there any funding sources or conflicts of interest that may affect the](#_bookmark31) [authors’ interpretation of the results?](#_bookmark31) | No |
| [Was ethical approval or consent of participants attained?](#_bookmark32) | Yes |
| Risk of bias assessment | Some concerns |

|  |  |
| --- | --- |
| Clarity tool for cohort studies17 | Redler et al, 202223 |
| Was selection of exposed and non-exposed cohorts drawn from the same population? | Definitely yes |
| Can we be confident in the assessment of exposure? | Definitely yes |
| Can we be confident that the outcome of interest was not present at start of study? | Definitely yes |
| Did the study match exposed and unexposed for all variables that are associated with the outcome of interest or did the statistical analysis adjust for these prognostic variables? | Definitely no |
| Can we be confident in the assessment of the presence or absence of prognostic factors? | Definitely yes |
| Can we be confident in the assessment of outcome? | Definitely yes |
| Was the follow up of cohorts adequate? | Definitely yes |
| Were co-interventions similar between groups? | NA |
| Risk of bias assessment | Some concerns |