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

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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Methods: Published and unpublished literature databases were searched to September 7, 2023.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 (4,391 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 stabilization surgery, with post-operative monitoring required.

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 and 16 years.[4] Patellar dislocation accounts for 2% –3% of knee joint injuries[5] 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]

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.

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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 stabiliser 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.

2. Methods

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

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 and 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.

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 September 7, 2023 (Appendix A).

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.

2.4. Outcomes

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

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]

3. Results

Eighteen eligible articles were identified out of 14,344 records screened (Fig. 1). Of these, five investigated the effects of hypermobility on the stability of the patella (3,434 knees of 3,386 patients, mean age range: 12.7–23.5 years). The remaining 13 investigated the effects of hypermobility on surgical outcomes on those with patellar instability (1,062 knees of 1,005 patients, mean age range: 6.1–43.3 years) (Table 1). Reconstruction of the medial patellofemoral ligament accounted for 940 procedures.

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.

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%) in the patellar dislocation group had joint laxity ($p < 0.001$).

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.[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)

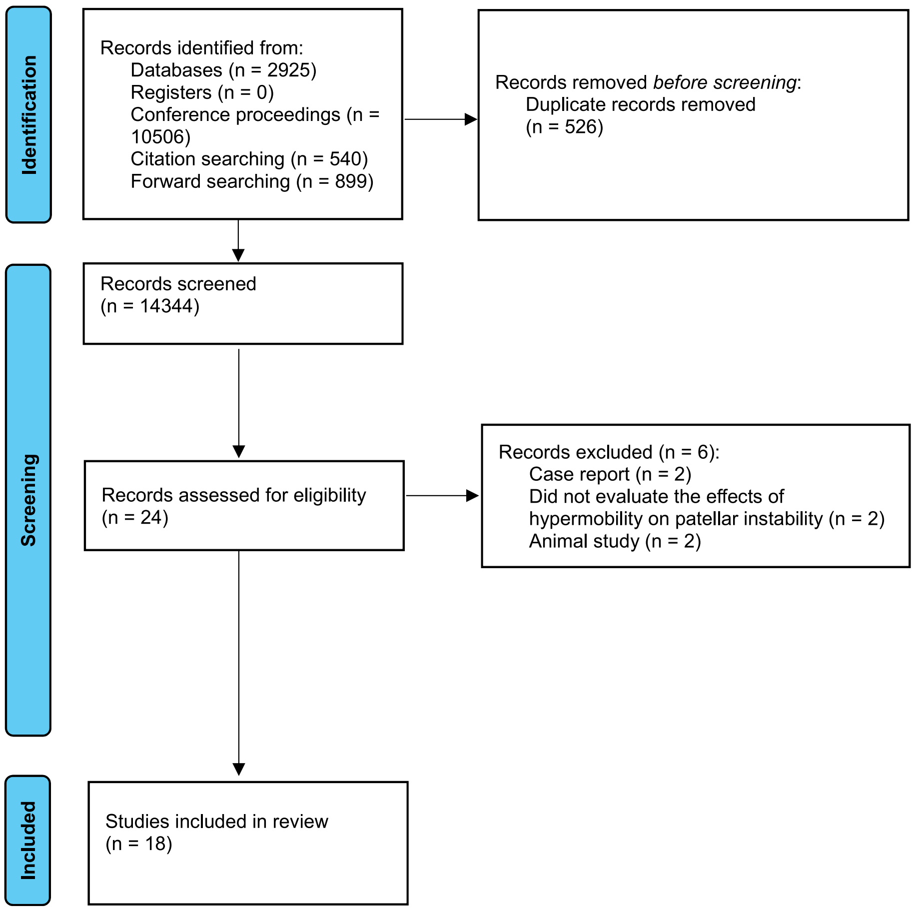

Fig. 1. PRISMA diagram depicting the study selection process.

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]

3.4. Risk of re-dislocation and complications

Six studies reported zero re-dislocations after surgery, (follow up range: 1 year to 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 stabilization.[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 (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% performed recreational activities without limping, re-dislocations or pain at the last follow-up.[29] Kocon et al. found that patellar traction stabilization was achieved in seven knees of children with Down's syndrome.[35] All patients evaluated, except one in Rose et al. reported increased tibiofemoral stability after surgery.[27]

3.5. Isokinetic and post-operative outcome scoring

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, including: IKDC (41.61 vs 54.96, p = 0.173),

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., 2006[19]	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., 2017[21]	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., 2013[22]	Case Series, 4	N/A	Overall 2901 (1267, 1634) Hypermobile: 134 (17, 117) Without hypermobility: 2767 (1250, 1517)	13.8 at the start of assessment 17.8 by the end	Overall 2901 Hypermobile: 134 Without hypermobility: 2767	NA	4 years
Rünow, 1983[20]	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., 2015[11]	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., 2022[23]	Cohort study, 3	MPFLr	171 (32,139) With ligamentous laxity: 96 Without 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., 2015[30]	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 (12–15)	11	1 knee (9.1 %)	8.1 years (5–15)
Howells and Eldridge, 2012[24]	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., 2008[28]	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., 2012[35]	Case Series, 4	-Greens quadricepsplasty in 6 cases (8 knees)	8 (3,5)	7 years 9 months (6–11)	10	2 (20 %)	3 years and 3 months

(*continued on next page*)

Table 1 (*continued*)

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
		- Greens quadricepsplasty augmented with modified Galeazzi procedure -semitendinosus tenodesis in 2 cases (2 knees)					
Ruzzini et al., 2019[29]	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, 2021[32]	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., 2023[33]	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., 2007[26]	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 4.9–6.9)	6	0 knees	Mean: 54.5 months (range 31–66 months)
Reddy et al., 2022[34]	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., 2022[25]	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., 2004[27]	Case Series, 4	TKA	10 (0,10)	43.3	12	0	65 months
Hiemstra et al., 2021[31]	Case control study, 3	Commonest revision procedures (frequency NR) Isolated MPFLR revision MPFLR + tibial tubercle osteotomy MPFL reconstruction revision with tracheoplasty	590	NR	590	28 knees (4.8 %) – entire cohort	Minimum 24 months (range 24–137)

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°–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).

Table 2
Results of the risk of bias assessment.

IHE case series quality appraisal checklist questions[18]	Imerci et al., 2022[25]	Joo et al., 2007[26]	Nomura et al., 2006[19]	Reddy et al., 2022[34]	Rombaut et al., 2009[10]	Rose et al., 2004[27]	Rünow et al., 1983[20]	Stern et al., 2017[21]	Tobias et al., 2013[22]	Niedzielski et al., 2015[30]	Bettuzzi et al., 2009[28]	Kocon et al., 2012[35]	Ruzzini et al., 2019[29]
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 studies[17]	Hiemstra et al., 2019[31]	Howells and Eldridge, 2012[24]
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

(*continued on next page*)

Table 2 (*continued*)

Clarity tool for case control studies[17]	Hiemstra et al., 2019[31]	Howells and Eldridge, 2012[24]
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 questions[16]	Rebouças Moreira et al., 2015[11]
Were the aims/objectives of the study clear?	Yes
Was the study design appropriate for the stated aim(s)?	Yes
Was the sample size justified?	No
Was the target/reference population clearly defined? (Is it clear who the research was about?)	Yes
Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?	Partial
Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?	Yes
Were measures undertaken to address and categorise non-responders?	No
Were the risk factor and outcome variables measured appropriate to the aims of the study?	Yes
Were the risk factor and outcome variables measured correctly using instruments/measurements that had been trialled, piloted or published previously?	Yes
Is it clear what was used to determined statistical significance and/or precision estimates? (e.g. p-values, confidence intervals)	No
Were the methods (including statistical methods) sufficiently described to enable them to be repeated?	Yes
Were the basic data adequately described?	Yes
Does the response rate raise concerns about non-response bias?	No
If appropriate, was information about non-responders described?	N/A
Were the results internally consistent?	Yes
Were the results presented for all the analyses described in the methods?	Yes
Were the authors' discussions and conclusions justified by the results?	Yes
Were the limitations of the study discussed?	Yes
Were there any funding sources or conflicts of interest that may affect the authors' interpretation of the results?	No
Was ethical approval or consent of participants attained?	Yes
Risk of bias assessment	Some concerns

Clarity tool for cohort studies[17]	Redler et al., 2022[23]
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

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) ($p < 0.05$) at one 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 one year, and to 92.7 (SD: 3.4) ($p < 0.05$) at final follow up.

3.5.3. Greens quadricepsplasty

Kocon et al. reported on eight knees using the quadricepsplasty technique, and on two knees undergoing augmented Greens quadricepsplasty 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]

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 88–98). The femoral trochleae were classed as Dejour group B or C pre-operatively, but all were group A post-operatively (Joo et al., 2007).

3.6. Patient satisfaction

Seven studies reported on patient satisfaction from the procedures undergone.[24,26–28,33–35] Satisfaction with outcomes 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 ($p = 0.066$).[24]

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 MPFLR 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 further research directly comparing types of graft is required, 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.

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.

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CRediT authorship contribution statement

Libbi Anne Heighes: Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, preparation, Literature search, Data extraction. **Diego Agustín Abelleyra Lastoria:** Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, preparation, Literature search, Data extraction, Risk of Bias Assessment. **Rebecca Beni:** Data extraction, Risk of Bias Assessment. **Ahsan Iftikhar:** Data extraction, Risk of Bias Assessment. **Caroline Blanca Hing:** Conceptualization, Methodology, Project administration, Supervision, Writing – review & editing.

Declaration of competing interest

None.

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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

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