REVIEW ARTICLE

Key Predictors of Medial Meniscal Ramp Lesions in Anterior Cruciate Ligament-Injured Patients: Systematic Review and Meta-Analysis

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Abstract

Meniscal ramp lesions are defined as lesions at the meniscocapsular junction of the posterior horn of the medial meniscus and are commonly associated with anterior cruciate ligament (ACL) injuries. These lesions contribute to increased anterior and rotational laxities of the knee and lead to continuous instability and graft failure of ACL reconstruction (ACLR) if left untreated. This systematic review and meta-analysis aim to identify and quantify the key preoperative risk factors for medial meniscal ramp lesions (MMRLs) in patients with ACLR. The systematic searching for articles was done in PubMed, Cochrane CENTRAL, OVID/Medline, and Scopus for publications from 2008 to June 2024 as per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020. This systematic review included 15 studies involving 9,110 patients, with data extraction and analysis conducted using random-effect models. The pooled prevalence of MMRL was 21.9%, with a range of 9.3–42.7%. Significant predictors of MMRL were male sex (OR: 1.59; 95% CI: 1.34–1.85; $P < 0.001$), younger than 30 years of age (odds ratio [OR]: 1.96; 95% confidence interval [CI]: 1.29–2.97; $P = 0.002$), complete ACL tear (OR: 3.10; 95% CI: 1.45–6.21; $P = 0.004$), concomitant lateral meniscal tear (OR: 1.56; 95% CI: 1.14–2.15; $P = 0.008$), and presence of posteromedial tibial bone marrow edema on magnetic resonance imaging (MRI) (OR: 2.16; 95% CI: 1.26–3.54; $P = 0.005$). Revision ACLR and contact injury mechanisms were insignificant concerning MMRL occurrence. This suggests an increased occurrence of ramp lesions in young males with complete ACL ruptures, lateral meniscal tears, or edema of the posteromedial tibial plateau. Early detection from detailed MRI examination and intraoperative evaluation of the posteromedial compartment must be encouraged; this will reduce missed diagnoses, thereby improving knee stability and reducing the chances of graft failure as a consequence of ACLR.

Key words: Anterior cruciate ligament reconstruction, medial meniscus ramp lesion, meta-analysis, magnetic resonance imaging, risk factors

INTRODUCTION

Meniscal ramp lesions of the meniscus, which are specifically located in the meniscal synovial region and linked to anterior cruciate ligament (ACL) deficiency, tear of medial meniscus that affects the peripheral attachment of its posterior horn, lead to separation from the postero-medial capsule.[1] Approximately 17% of individuals subjected to arthroscopic reconstruction of the ACL reconstruction (ACLR) have medial meniscal ramp lesions (MMRLS). In other populations, this prevalence may reach 41%.[2,3] Meniscal ramp lesions have been linked to greater

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anterior and rotational knee laxity in ACL-deficient knees, according to prior research,[4,5] and knee biomechanics can only be restored by fixing these lesions. In addition, compared to controls, individuals with meniscal ramp lesions show faster cartilage deterioration in the medial compartment.[6] Thus, it is crucial to identify these injuries and avoid ACLR graft failure.

Even if previous studies' varying sensitivity raised doubts about its accuracy,[7,8] the best imaging technique for identifying meniscus ramp lesions is magnetic resonance imaging (MRI).[9,10] Although arthroscopic confirmation has been the gold standard in this regard, it has been discovered that the usual anterolateral arthroscopic viewing portal has insufficient sensitivity in detecting ramp lesions.[11,12] The authors of this study have therefore proposed two less widely used viewing portals, the Gillquist view and the posteromedial portal, as a way to accurately diagnose ramp damage.[11-13]

Optimizing patient outcomes is crucial, especially when depending on traditional diagnostic techniques, given the biomechanical ramifications of leaving ramp lesions unrepaired during ACLR – and the related risk of graft failure. Knowing which patients are more likely to have ramp lesions may help treat surgeons to become suspicious in some populations and ultimately reduce the number of missed ramp lesions, given the inconsistent effectiveness of current diagnostic techniques and the potential for improved outcomes from repairing ramp lesions.

This systematic review aimed to identify and analyze the key preoperative risk factors for MMRL in patients with ACL injuries using current evidence from observational studies.

METHODOLOGY

The systematic review protocol was developed a priori by all authors and adhered to the latest Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA, 2020) guidelines [Figure 1].[14] This review aimed to identify

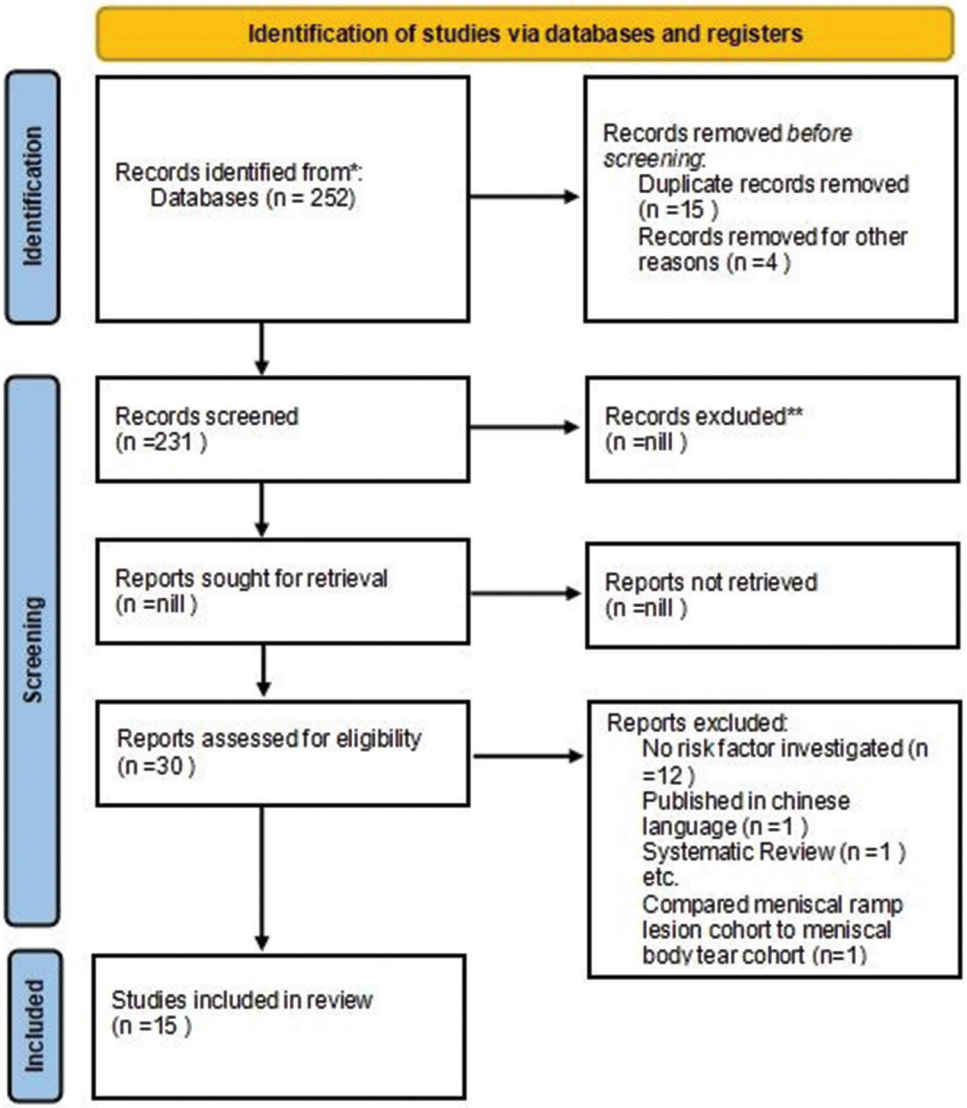

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines of included studies

the risk factors for MMRL in patients with ACL injuries. The formulation of the review followed the Population, Intervention, Comparison, and Outcome (PICO) framework:

- Population: Patients of all age groups and both sexes with ACL injuries who underwent ACLR
- Intervention: Diagnosis of medial meniscus ramp lesions (MMRL) during ACLR
- Comparative study: A Diagnosis of Ramp Lesions by Arthroscopy – The Gold Standard Compared with MRI or other clinical tools for diagnosis during pre-operative period
- Outcome: Risk factor for MMRL outcome: Risk factors for MMRL: Demographics, imaging features, and injury characteristics
- Focused question (PICO): The key pre-operative risk factors for MMRL among patients undergoing ACLR are as follows:

Search strategy

Searches were done using PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), OVID/Medline, and Scopus databases on those studies published between the years 2008 and June 2024. Some of the Boolean search terms used include the below-mentioned keywords: "Meniscus OR meniscal OR menisc*" AND "ramp." Appendix-A gives a detailed search strategy by database.

Besides, a gray literature search on Google Scholar was done to complement the manual reference list search done for each included study.

The database searching and selecting studies thereof were performed by a total of two reviewers. Agreement or the input of a third reviewer was used to resolve any difference in the study selection.

Data extraction and quality assessment

Two reviewers independently applied a standardized format for data extraction on the study design, population characteristics, MMRL prevalence, and factors associated thereof.

The MINORS checklist 15 was used to independently appraise the quality of the included studies. This scores any study according to whether it follows the comparative or non-comparative study criteria, thus assuring rigorous appraisal of study quality.

Inclusion criteria

All studies published in English that investigated the possible risk factors for ramp lesions in ACL-injured patients. Any condition that readers would consider likelihoods that may exist preoperatively with either occurrence of ramp lesions or demographic characteristics or radiologic findings concerning those likely associated with ramp lesions was defined as a risk factor in this review. All studies are agreed to have been diagnosed by intraoperative verification.

Exclusion criteria

The criteria were instituted to exclude studies that did not fit the requirements and quality of this review. Studies with cadaver specimens and those on animal models were excluded, along with those that were based on scientific research articles. Survey articles, case reports, and editorials would also be considered inappropriate to include. All intraoperative or post-operative findings related to ramp lesions that did not fall into the boundaries of study objectives were disregarded.

All studies were considered purely 1, 2, and 3 levels of evidence by direct comparison of cases and controls, in addition to level 4 for studies providing enough data for the computation of odds ratios (ORs). Minimal follow-up duration was not enforced since the primary focus was to evaluate for possible risk factors for ramp lesions. Following title and abstract screening of all retrieved items, studies irrelevant to the investigation of meniscal ramp or meniscocapsular lesions were excluded. All the remaining complete articles were then evaluated meticulously for eligibility according to the established inclusion and exclusion criteria. The reference lists were further scrutinized of the included studies for any potentially relevant publications that may have been missed during the initial search**.**

Quality assessment

The methodological quality of the included studies was assessed using the MINORS checklist. This checklist consists of 12 criteria, of which only four are relevant to comparative studies. Additional group-specific criteria were used to evaluate potential biases in the cohort selection. For non-comparative subjects, the maximum MINORS score was 16, while for comparative studies, it was 24.

Data extraction and statistical analysis

Pooled effect sizes were determined using DerSimonian-Laird random-effect models[16], which accounted for the variability among studies. Heterogeneity was anticipated due to differences in surgeon expertise, study design, and patient populations.

Each study's risk factors were documented and ORs were computed from unique 2-by-2 tables. Risk variables were categorized into four groups based on previously established criteria: Strong evidences, moderate evidences, little evidences, and marginal to no evidence.[17]

- Strong evidence: Statistically significant factors ($P < 0.05$) with either a protective effect (OR < 0.8) or doubling of risk (OR > 2.0) for ramp lesions.
- Moderate evidence: Statistically significant factors ($P < 0.05$) with ORs: 1.5–2.0 or 0.8–0.9 if protective.
- Little evidence: Statistically significant factors with ORs of 1.0–1.5 or 0.9–1.0 if protective.
- Marginal to no evidence: Non-significant ORs ($P > 0.05$) that did not logically correlate with ramp lesions.

Risk variables used for 1:1 cohort matching were excluded from quantitative meta-analysis to maintain data integrity.

RESULTS

Study characteristics [Table 1 and Figure 2]

A total of fifteen studies[2,4,18-24,27,32-35] were included in both qualitative and quantitative analyses. Among these, 7 (58.3%) were retrospective case–control studies, 4 (33.3%) were retrospective case series, and 1 (8.3%) was a retrospective cohort study.[18]

Patient demographics

Across the 15 studies,[2-4,18-24,27,32-35] a total of 9,110 patients were analyzed. The combined mean age was 28.7 ± 3.5 years, with males comprising 52% of the study population. The combined prevalence across studies of MMRL was 21.9%, with individual study rates ranging from 9.3% to 42.7%.

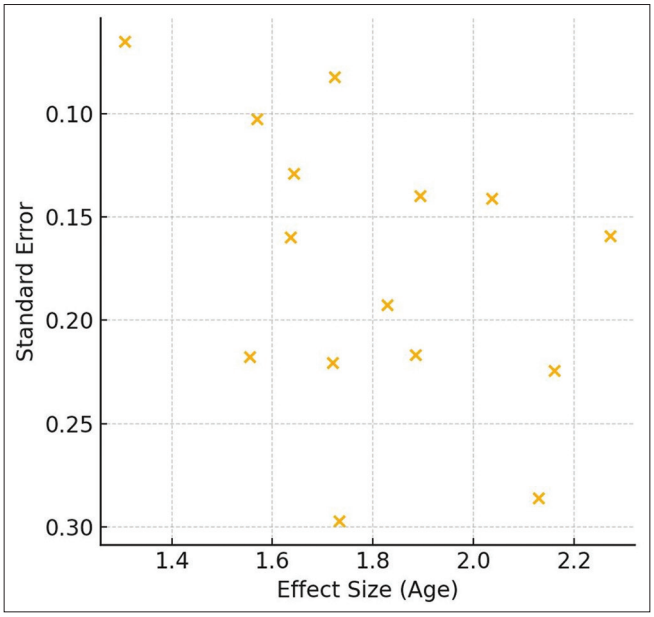

Figure 2: Forest plot of key risk factors for MMRL in ACL-injured patients. ACL: Anterior cruciate ligament, ACLR: Anterior cruciate ligament reconstruction, MRI: Magnetic resonance imaging, OR: Odds ratio, MMRL: Medial meniscal ramp lesions

Assessment of bias and methodological quality

The quality of included studies[2-4,18-24,27,32-35] was evaluated using the MINORS checklist, with a mean score of 15.5 ± 3.4 across the studies. While comparative studies scored an average of 18.9, non-comparative studies had lower scores, averaging 11.4. Most studies demonstrated a moderate risk of bias due to retrospective design, potential for selection bias, and lack of blinding in some cases. To mitigate bias, studies were critically appraised for methodological rigor, and only studies that confirmed MMRL diagnosis through surgical or arthroscopic confirmation were included. Further research should consider designing therapies aimed at diminishing bias commensurate with the sources of identified bias.

In the present instance, we constructed funnel plots for the two most prominent risk factors of age and sex for the purposes of providing an overview of their relative susceptibility to publication bias [Figures 3 and 4]. It is worthy of mention that most funnel plots across all centers showed an obvious degree of differential asymmetry suggestive of small-study effects.

In addition, Egger regression was carried out on these two risk factors with the intent of testing for publication bias. The following is evidence against publication bias:

- Age: Coefficient= 1.58, $P = 0.123$ (greater than significance cut-off signaling little publication bias)
- Sex: Coefficient= 2.12, $P = 0.160$ (greater than significance cut-off signaling little publication bias).

Thus, while there is slight asymmetry in the funnel plots with respect to gene findings, such asymmetry is insufficient to argue that the risk factor analyses have been severely biased by publication. However, it remains possible that some negative studies were unpublished, which could result in an overestimation of effect sizes. Future reviews should aim to incorporate unpublished data and clinical trial results to provide a more comprehensive perspective.

Risk factors

The 15 studies[2-4,18-24,27,32-35] collectively examined 47 distinct risk factors for MMRL. Risk factors reported across multiple studies, including complete versus partial ACL tears, contact-related injuries, MRI-detected posteromedial bone marrow edema, patient sex, age, revision ACLR, chronic injury status, and coexisting lateral meniscal tears, were subjected to a random-effects meta-analysis. Instead, a qualitative synthesis was carried out where there was significant heterogeneity or when a risk factor was evaluated in just one study.

Sex and risk of ramp lesions

Sex and the presence of MMRL were examined in Eight studies.[3,4,18-23] Male sex was substantially linked to a higher probability of ramp lesions than female sex, according to the

Table 1: Characteristics of included studies

Lead author (year)	Study design	Population	No. of patients	Prevalence of MMRL (%)	Risk factors
Liu *et al*.[18]	Case-control	Primary ACLR	868	16.6	Sex, age, chronic injury
DePhillipo *et al*.[2]	Case series	Primary and revision ACLR	301	16.6	Sex, age, BMI, chronic injury, sports participation, contact injury, concomitant injuries
Di Vico *et al*.[20]	Case series	Primary ACLR	115	9.6	Sex, chronic injury
Seil *et al*.[3]	Case-control	Primary and revision ACLR	224	23.7	Sex, CLMT, PTBE, contact injury, tear severity
Sonnery-Cottet *et al*.[23]	Case-control	Primary and revision ACLR	3214	23.9	Sex, age, revision ACLR, chronic injury, knee laxity, CLMT
Yeo *et al*.[4]	Case-control	Primary ACL tear	78	9.0	Sex, PHMM vertical tear, corner notch sign, perimeniscal fluid, posterior irregularity, complete fluid filling between posterior capsule and PHMM, posterior capsule edema
Balazs *et al*.[19]	Case series	Primary and revision ACLR	372	43.7	Sex, revision ACLR, CLMT, PTBE, contact injury, race, smoking, tear severity, laterality, previous ipsilateral meniscal surgery, level of play
Bernholt *et al*.[27]	Case series	Primary ACLR	825	NR	Posterolateral tibial plateau and lateral femoral condyle impaction fractures
DePhillipo *et al*.[24]	Cohort	Primary ACLR	100	18.6	Sex, age, BMI, contact injury, chronic injury
Kim *et al*.[21]	Case-control	Primary ACLR	275	34.5	Sex, age, BMI, time from injury, contact injury, Segond fracture, side-to-side laxity, medial and lateral tibial/meniscal slope, CLMT, PTBE, varus alignment >3 degrees, high-grade pivot shift
Mouton *et al*.[22]	Case-control	Primary and revision ACLR	275	21.1	Sex
Song *et al*.[32]	Case-control	Primary ACLR	106	15.8	BMI, medial meniscal slope, medial posterior tibial slope
Ziyi Tang *et al*.[33]	Case-control	Primary ACL tear	202	17.4	MTP AP length, MTP depth, MTP AP length/ MFC diameter ratio, LPTS, asymmetry of LMPTS
Riccardo Cristiani *et al*.[34]	Case series	Primary ACL tear	253	39.5	Age, gender, BMI, pre-injury Tegner activity level, activity at injury, concomitant injuries on MRI (lateral meniscus, medial collateral ligament, isolated deep MCL, lateral collateral ligament, pivot-shift-type bone bruising, posteromedial tibial bone bruising, medial femoral condyle bone bruising, lateral femoral condyle impaction, Segond fracture)
Pierre-Jean Lambrey *et al*.[35]	Cohort	Primary and revision ACLR	5359	15.3	Patient demographics, revision surgery, pivot shift, side-to-side anteroposterior laxity, medial collateral ligament injury, lateral meniscal tear, volume of ligament remnant

ACLR: Anterior cruciate ligament reconstruction, BMI: Body mass index, CLMT: Concomitant lateral meniscal tear, MMRL: Medial meniscal ramp lesion, NR: Not reported, PHMM: Posterior horn medial meniscus, PTBE: Posterior tibial bone marrow edema, MFC: Medial femoral condyle, MTP AP: Length: Medial tibial plateau anteroposterior length, LPTS: Lateral posterior tibial slope; asymmetry of LMPTS; asymmetry of LPTS; MPTS.

pooled analysis (OR, 1.59; 95% CI: 1.34–1.85; $P < 0.001$). Male sex was found to be a significant risk factor for MMRL with a moderate level of confidence because the heterogeneity among the studies was minimal ($I^2 = 0\%$; $P = 0.86$).

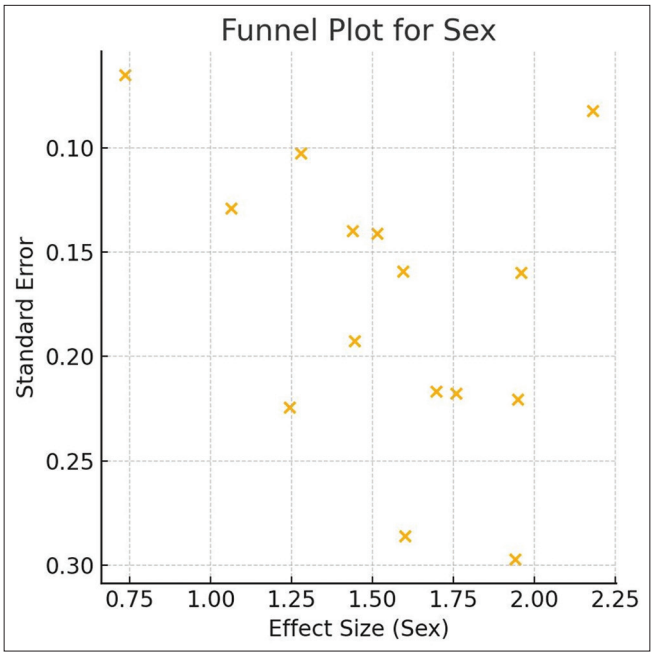

Figure 3: Funnel plot by age

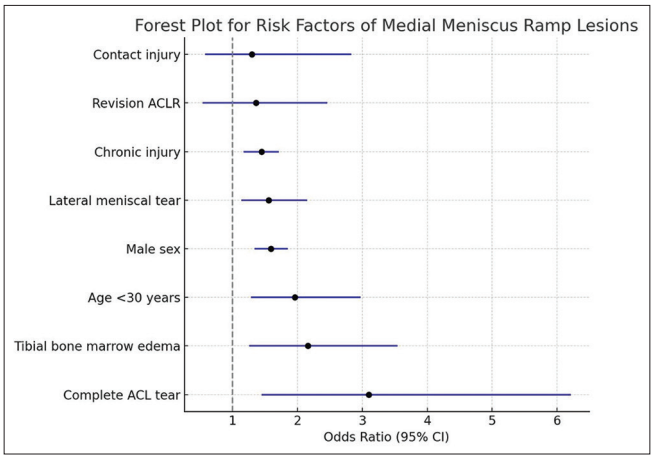

Figure 4: Funnel plot by sex

Age and risk of ramp lesions

Three studies[18,23,24] investigated the relationship between age and MMRL. Patients under 30 years of age had significantly higher odds of having ramp lesions than those aged >30 years (OR: 1.96; 95% CI: 1.29–2.97; P = 0.002). Although heterogeneity was substantial (I^2 = 67.1%; P = 0.08), the data suggest that younger age is a moderately strong risk factor for MMRL.

ACLR-related risk for meniscal ramp injury

Two studies[19,23] examined the association between ramp lesions and revision ACLR. According to pooled analysis, revision ACLR did not show a significant correlation with development of ramp lesions (OR: 1.36; 95% CI: 0.54–2.46; P = 0.56). However, the heterogeneity was considerable (I^2 = 84.7%; P = 0.009), reflecting the variation in the study results. Thus, current evidence suggests that revision ACLR is not a significant predictor of ramp lesions.

Ramp lesions and chronic ACL injury

The relationship between ramp lesions and chronic ACL injuries, defined as injuries lasting more than 24 months, was investigated in three studies.[18,20,23] When compared to those with shorter injury length, the pooled analysis showed that chronic ACL injuries were substantially associated with a higher chance of ramp lesions (OR, 1.45; 95% CI: 1.17–1.71; P = 0.001). Lack of heterogeneity (I^2 = 0; P = 0.61) strengthens this association and the positioning chronicity of injury as a definitive risk factor.

Concomitant lateral menisci tear and ramp lesions

Four studies[3,19,21,23] explored the impact of concurrent lateral meniscal tears on the presence of ramp lesions. Pooled analysis revealed a significant link between the two, with concomitant lateral meniscal tears substantially increasing the probability of ramp lesions (OR: 1.56; 95% CI: 1.14–2.15; P = 0.008). The heterogeneity was moderate (I^2 = 62.5%; P = 0.045), lending credence to the notion that structural disruption of the lateral meniscus plays a pivotal role in the formation of ramp lesions.

Poster medial tibial bone marrow edema as a risk factor

Pre-operative MRI findings of poster medial tibial bone marrow edema were identified as strong indicator of presence of ramp lesion as demonstrated by three studies.[3,19,21] Patients presenting with this MRI finding had a significantly higher risk of ramp lesions (OR: 2.16; 95% CI: 1.26–3.54; P = 0.005). Although heterogeneity was moderate (I^2 = 56.9%; P = 0.098), the evidence suggests that posteromedial tibial edema is a notable risk factor, suggesting that the internal trauma manifested by this edema mirrors the underlying pathology of ramp lesions.

Role of contact mechanisms in the occurrence of meniscal ramp lesions

Four studies[3,19,21,24] investigated whether contact injury leading to ACL rupture is a predictor of ramp lesions. The pooled analysis found no significant association between contact injuries and the presence of ramp lesions (OR: 1.30; 95% CI: 0.58–2.83; P = 0.52). Heterogeneity is an important aspect (I^2 = 81.5%; P = 0.003), thereby creating doubt in the hypothesis that contact injury is a consistent predictor or meaningful indicator; indeed, there is little supporting evidence for the proposition that contact mechanisms alone increase ramp lesion risks.

Severity of ACL injury and ramp lesions

Finally, two studies[3,19] determined the relationship between ramp lesions and the severity of ACL injuries (complete versus partial). In the pooled results, a complete torn ACL

had a strong association with a higher chance of occurrence of ramp lesion (OR: 3.1; 95% CI: 1.45–6.21; $P = 0.004$). There was, however, $I^2 = 0\%$; $P = 0.81$, further endorsing that strength. There is really strong evidence for this extent that is ACL injury has degree – failure mostly torn completely – will have strong influence on ramp lesions development.

DISCUSSION

Risk factors related to MMRL under arthroscopic reconstruction of ACLR include ramp lesions in which almost all aspects of age stratified into younger age (<30 years), complete tears of the ACL, and posteromedial tibial edema on MRI. These contrast parameters suggest that young, more active people, with a complete or severe injury to the ACL can have a much higher risk of MMRL development.

Male sex and associated lateral meniscal tears were identified as the two most significant risk factors. Such observation tallies with the evidence that men who are majorly engaged in high-impact sports and strenuous physical activities are at high-risk individuals in developing their severe knee injuries, ramp lesions included. Meanwhile, some other studies have reported that chronic ACL injuries revised after <24 months are weakly associated with the incidence of ramp lesions. Hence, it can be inferred that chronicity of the lesion by itself may not be a determining factor in the cause of ramp lesion formation; the entire set of factors, i.e., biomechanical stressors, could be more relevant.

Interestingly, such study does little or no evidence that linking revision ACLRs or contact injuries with ramp lesions has been discovered. It had meant that revision ACLR, usually accompanied by more complex knee pathology, might not have its inherent defined risk factors for ramp lesions. The available data would further indicate that although common triggers of rupture of the ACL tend to be by contact injuries, they, however, do not directly impact the ramp lesions.

Surgeons with this knowledge would identify and treat ramp lesions during the various forms of reconstruction of the ACL. Early identification of risk factors would enhance outcome measures while minimizing the likely complications of graft failure in younger males and those with concomitant meniscal injuries. Further emphasis on research should be directed to help elucidate the possible biomechanical mechanisms in ramp lesion formation and to identify those subgroup benefits from tailored diagnostics and therapeutic approaches. The present study identifies male sex and age under 30 as significant risk factors for the development of Medial menisci ramp lesions (MMRL) in patients subjected to primary or revision ACLR. This is in accordance with the prior research by Sonnery-Cottet *et al.*,[23] where it was found that males have a 50% increased probability to develop ramp lesions compared to females. Likewise, Liu *et al.* (2022) noted significantly higher incidence of ramp lesions in males during primary ACLR than in females (18.6% vs. 12.0%; $P = 0.017$). Such findings are consistent with the general literature regarding menisci injuries where males are usually more prone to such injuries, specifically between the age levels of 21 and 30 years.[25] This demographic should trigger suspicion for ramp lesions at the time of ACLR and warrant an assessment of the posteromedial compartment.

To the best of our knowledge, this aligns with prior research conducted by Sonnery-Cottet *et al.*,[23] who discovered that males tend to have a 1.5-fold higher probability of developing ramp lesions than females. Liu *et al.* also mentioned in their study (2022) that there is an alarmingly taller reading of ramp lesions among males than among females subjected to primary ACLR (18.6% vs. 12.0%; $P = 0.017$). They correspond with broad data on meniscus injuries which generally occur, more probed among men aged 21-30 years. 25 Alarm should be raised for ramp lesions during ACLR, and a detailed evaluation of the posteromedial compartment should ultimately be undertaken. Furthermore, prior studies like Balazs *et al.* have confirmed that ramp lesions were substantially linked with the presence of posteromedial tibial bone marrow edema on pre-operative MRI, increasing the risk by 112% (OR: 3.0; $P < 0.001$).[19] This raises the possibility of a contact mechanism during the ACL injury. Nevertheless, there was little indication in this investigation that contact injuries and ramp lesions are related. Strong correlations between male sex, younger age, and the possible contribution of anteromedial rotatory subluxation to ramp lesions are examples of supporting evidence. In addition, Yeo *et al.*[4] discovered that fluid filling between the posterior horn medial meniscus and capsule and posterior border irregularity were important markers of ramp lesions, which may be connected to bone bruising.

Given the strong evidence from our meta-analysis, pre-operative MRI screening for ramp lesions is recommended, as MRI has high specificity in detecting these lesions.[26]

Furthermore, the presence of lateral menisci tears on the same side significantly increased the likelihood of ramp lesions by 54% (OR: 1.5). This association highlights the need for careful evaluation of patients with lateral meniscal tears for potential concurrent ramp lesions to improve the surgical outcomes.

A lateral meniscal rupture was associated with a 190% higher risk of ramp lesions in patients following primary or revision ACL repair, according to Sonnery-Cottet et al.[23] Similarly, lateral meniscal rupture was linked to a 1.7-fold increased risk of ramp lesions, according to Balazs et al.[19] The relative instability brought on by lateral meniscal injuries or contusions as a result of lateral compartment or ACL damage may be related to ramp lesions, according to these studies. To better understand the fundamental pathoanatomic mechanisms, more research is necessary as the exact nature of this association is yet unknown.

In both initial and revision ACLR instances, patients with total ACL tears were found to have a threefold higher risk of acquiring ramp lesions than those with partial tears. Although this result is in line with earlier research, the effect size seen in this study was smaller. Seil et al.,[3] for example, found that people with total ACL ruptures were 8.7 times more likely to present with ramp lesions than people with partial rips, indicating a much increased risk.

These results reinforce the importance of assessing ramp lesions during ACLR, particularly in patients with complete tear. The difference in risk may be attributed to increased knee hypermobility caused by complete ACL ruptures, which place more strain on the meniscocapsular junction. By contrast, patients with partial ACL tears may retain some stability, thereby reducing the likelihood of ramp lesion development. This suggests that non-operative management of partial tears may help prevent additional stress on the meniscocapsular structures, potentially avoiding ramp lesions.

Biomechanical consequences of not addressing ramp lesions during ACLR highlight the importance of accurately identifying risk factors. Studies have shown that untreated ramp lesions can lead to persistent anterior and rotational knee instability, including increased anterior tibial translation, internal and external rotation, and pivot shift in ACL-deficient knees.[4,28] Notably, when ramp lesions coexist with ACL injuries, the pivot shift is often not corrected by ACLR alone. However, repairing the ramp lesion during ACLR restores stability and eliminates pivot shifts.[29]

All these observations suggest that ramp lesions should be kept in mind by a surgeon in specific patients with risk factors such as posteromedial tibial bone marrow edema. Detachment of the meniscocapsular junction may cause hypermobility of the posteromedial compartment, thus preventing the natural healing process of this damage and endangering the result of surgery. The identification and repair of ramp lesions would certainly be a step toward achieving optimal knee stability and better rehabilitation results for patients undergoing ACLR.[30]

Clinical implications

Identification of young male sex and complete ACL tear as significant risk factors for MMRL has a direct impact on clinical practice. When performing an ACLR, surgeons should maintain a high degree of suspicion for ramp lesions in male patients under 30 years of age, especially with MRI evidence of posteromedial tibial edema or associated lateral meniscal tears. Pre-operative MRI facilitates the hunting of these risk factors, but the diagnosis and treatment of ramp lesions may need intraoperative assessment through the posteromedial portal. The early diagnosis and intervention of MMRL at the time of ACLR may help to prevent a rickety knee from lasting and also the reduction of graft failure, leading to beneficial long-term outcomes.

Limitations

The study had several limitations. Publication bias, as always has to be borne in mind while undertaking systematic reviews, can affect the results. We did not want to be limited by the mere statistical significance of reported risk factors and, hence, included all published ones. Another limitation is that most of the risk factors are not amenable to meta-analysis, so potentially a whole spectrum of possible risk variables for ramp lesions was probably missed. The studies included in this investigation mostly fell under Level 3 or 4 evidence, indicating that the general quality of the studies featured is quite poor. Quality evidence is necessary to establish cause-effect relations and investigate further risk factors. Because we included both primary and revision ACLR patients, variability might have been introduced as revision patients are likely to have been predisposed to a different risk profile: having undergone previous surgery. However, the analysis failed to demonstrate a significant difference between revisions and primary ACLR patients concerning the incidence of ramp lesions. Further investigation has to be done to give a better definition of those risk factors for ramp lesions as well as improve their evidence quality. Future studies should fill in the critical gaps in the literature covering prospective, longitudinal, standardized diagnostic criteria research in patients with MMRL. Opportunities for clinical insight into ramp lesions may include studying their biomechanical role in ACL-deficient knees. Novel imaging modalities, such as 3D MRI or dynamic MRI, may further enhance pre-operative identification of ramp lesions and, finally, large, multicenter randomized controlled trials comparing the different surgical options for treating ramp lesions.

CONCLUSION

Younger age, male sex, full ACL tears, poster medial tibial bone marrow edema on MRI, and concurrent lateral meniscal tears are some of the major risk variables for medial meniscus ramp lesions in patients having ACLR that was identified by this comprehensive study. Results indicate the need for a full pre-operative examination, especially MRI, to detect ramp lesions, which may otherwise lead to knee instability. While there is scant or conflicting data to support any of the other variables revision ACLR and chronic ACL injury, identification of possible links here will lead to better ramp lesion management and improved accuracy of diagnosis. More and better studies must be done to establish these links and confirm causation with the ultimate objective of improving clinical outcomes for patients with ACL injuries.

REFERENCES

1. DePhillipo NN, Moatshe G, Chahla J, Aman ZS, Storaci HW, Morris ER, *et al.* Quantitative and qualitative assessment of the posterior medial meniscus anatomy: Defining meniscal ramp lesions. Am J Sports Med 2019;47:372-8.
2. DePhillipo NN, Cinque ME, Chahla J, Geeslin AG, Engebretsen L, LaPrade RF. Incidence and detection of meniscal ramp lesions on magnetic resonance imaging in patients with anterior cruciate ligament reconstruction. Am J Sports Med 2017;45:2233-7.
3. Seil R, Mouton C, Coquay J, Hoffmann A, Nührenbörger C, Pape D, *et al.* Ramp lesions associated with ACL injuries are more likely to be present in contact injuries and complete ACL tears. Knee Surg Sports Traumatol Arthrosc 2018;26:1080-5.
4. Ahn JH, Bae TS, Kang KS, Kang SY, Lee SH. Longitudinal tear of the medial meniscus posterior horn in the anterior cruciate ligament-deficient knee significantly influences anterior stability. Am J Sports Med 2011;39:2187-93.
5. Mouton C, Magosch A, Pape D, Hofmann A, Nührenbörger C, Seil R. Ramp lesions of the medial meniscus are associated with a higher grade of dynamic rotatory laxity in ACL-injured patients in comparison to patients with an isolated injury. Knee Surg Sports Traumatol Arthrosc 2020;28:1023-8.
6. Guimaraes JB, Schwaiger BJ, Gersing AS, Neumann J, Facchetti L, Li X, *et al.* Meniscal ramp lesions: Frequency, natural history, and the effect on knee cartilage over 2 years in subjects with anterior cruciate ligament tears. Skeletal Radiol 2021;50:551-8.
7. Arner JW, Herbst E, Burnham JM, Soni A, Naendrup JH, Popchak A, *et al.* MRI can accurately detect meniscal ramp lesions of the knee. Knee Surg Sports Traumatol Arthrosc 2017;25:3955-60.
8. Willinger L, Balendra G, Pai V, Lee J, Mitchell A, Jones M, *et al.* Medial meniscal ramp lesions in ACL-injured elite athletes are strongly associated with medial collateral ligament injuries and medial tibial bone bruising on MRI. Knee Surg Sports Traumatol Arthrosc 2021;30:1502-10.
9. Yeo Y, Ahn JM, Kim H, Kang Y, Lee E, Lee JW, *et al.* MR evaluation of the meniscal ramp lesion in patients with anterior cruciate ligament tear. Skeletal Radiol 2018;47:1683-9.
10. Zappia M, Sconfienza LM, Guarino S, Tumminello M, Iannella G, Mariani PP. Meniscal ramp lesions: Diagnostic performance of MRI with arthroscopy as reference standard. Radiol Med 2021;126:1106-16.
11. Kim SH, Lee SH, Kim KI, Yang JW. Diagnostic accuracy of sequential arthroscopic approach for ramp lesions of the posterior horn of the medial meniscus in anterior cruciate ligament-deficient knee. Arthroscopy 2018;34:1582-9.
12. Malatray M, Raux S, Peltier A, Pfirrmann C, Seil R, Chotel F. Ramp lesions in ACL deficient knees in children and adolescent population: A high prevalence confirmed in intercondylar and posteromedial exploration. Knee Surg Sports Traumatol Arthrosc 2018;26:1074-9.
13. Bumberger A, Koller U, Hofbauer M, Tiefenboeck TM, Hajdu S, Windhager R, *et al.* Ramp lesions are frequently missed in ACL-deficient knees and should be repaired in case of instability. Knee Surg Sports Traumatol Arthrosc 2020;28:840-54.
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:n71.
15. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (minors): Development and validation of a new instrument. ANZ J Surg 2003;73:712-6.
16. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials 1986;7:177-88.
17. Snoeker BA, Bakker EW, Kegel CA, Lucas C. Risk factors for meniscal tears: A systematic review including meta-analysis. J Orthop Sports Phys Ther 2013;43:352-67.
18. Liu X, Feng H, Zhang H, Hong L, Wang XS, Zhang J. Arthroscopic prevalence of ramp lesion in 868 patients with anterior cruciate ligament injury. Am J Sports Med 2011;39:832-7.
19. Balazs GC, Greditzer HG 4th, Wang D, Marom N, Potter HG, Marx RG, *et al.* Ramp lesions of the medial meniscus in patients undergoing primary and revision ACL reconstruction: Prevalence and risk factors. Orthop J Sports Med 2019;7:2325967119843509.
20. Di Vico G, Di Donato SL, Balato G, Correra G, D'Addona A, Maffulli N, *et al.* Correlation between time from injury to surgery and the prevalence of ramp and hidden lesions during anterior cruciate ligament reconstruction. A new diagnostic algorithm. Muscles Ligaments Tendons J 2018;7:491-7.
21. Kim SH, Seo HJ, Seo DW, Kim KI, Lee SH. Analysis of risk factors for ramp lesions associated with anterior cruciate ligament injury. Am J Sports Med 2020;48:1673-81.
22. Mouton C, Magosch A, Pape D, Hoffmann A, Nuhrenborger C, Seil R. Ramp lesions of the medial meniscus are associated with a higher grade of dynamic rotatory laxity in ACL-injured patients in comparison to patients with an isolated injury. Knee Surg Sports Traumatol Arthrosc 2020;28:1023-8.
23. Sonnery-Cottet B, Praz C, Rosenstiel N, Blakeney WG, Ouanezar H, Kandhari V, *et al.* Epidemiological evaluation of meniscal ramp lesions in 3214 anterior cruciate ligament-injured knees from the SANTI study group database: A risk factor analysis and study of secondary meniscectomy rates following 769 ramp repairs. Am J Sports Med 2018;46:3189-97.
24. DePhillipo NN, Dornan GJ, Dekker TJ, Aman ZS, Engebretsen L, LaPrade RF. Clinical characteristics

and outcomes after primary ACL reconstruction and meniscus ramp repair. Orthop J Sports Med 2020;8:2325967120912427.
25. Poehling GG, Ruch DS, Chabon SJ. The landscape of meniscal injuries. Clin Sports Med 1990;9:539-49.
26. Koo B, Lee SH, Yun SJ, Song JG. Diagnostic performance of magnetic resonance imaging for detecting meniscal ramp lesions in patients with anterior cruciate ligament tears: A systematic review and meta-analysis. Am J Sports Med 2019;48:2051-9.
27. Bernholt DL, DePhillipo NN, Crawford MD, Aman ZS, Grantham WJ, LaPrade RF. Incidence of displaced posterolateral tibial plateau and lateral femoral condyle impaction fractures in the setting of primary anterior cruciate ligament tear. Am J Sports Med 2020;48:545-53.
28. Stephen JM, Halewood C, Kittl C, Bollen SR, Williams A, Amis AA. Posteromedial meniscocapsular lesions increase tibiofemoral joint laxity with anterior cruciate ligament deficiency, and their repair reduces laxity. Am J Sports Med 2016;44:400-8.
29. DePhillipo NN, Moatshe G, Brady A, Chahla J, Aman ZS, Dornan GJ, *et al.* Effect of meniscocapsular and meniscotibial lesions in ACL-deficient and ACL-reconstructed knees: A biomechanical study. Am J Sports Med 2018;46:2422-31.
30. Ahn JH, Wang JH, Lim HC, Bae JH, Park JS, Yoo JC, *et al.* Double transosseous pull out suture technique for transection of posterior horn of medial meniscus. Arch Orthop Trauma Surg 2009;129:387-92.
31. Song GY, Liu X, Zhang H, Wang QQ, Zhang J, Li Y, *et al.* Increased medial meniscal slope is associated with greater risk of ramp lesion in noncontact anterior cruciate ligament injury. Am J Sports Med 2016;44:2039-46.
32. Tang Z, Luo Y, Liu D, Zhou S, Xu Z, Zhu T, *et al.* Investigation of the anatomic risk factors in acute anterior cruciate ligament ruptures to develop ramp lesions of the medial meniscus by quantitative MRI. Insights Imaging 2024;15:133.
33. Cristiani R, Van De Bunt F, Kvist J, Stålman A. High prevalence of meniscal ramp lesions in anterior cruciate ligament injuries. Knee Surg Sports Traumatol Arthrosc 2023;31:316-24.

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