Review

The effect of quadriceps anatomical factors on patellar stability: A systematic review

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ABSTRACT

Purpose: The aim of this systematic review was to analyse the effect of quadriceps anatomical factors on patellar stability.

Methods: The protocol for this review was registered on PROSPERO with registration number CRD42022334265. A systematic PRISMA compliant database search was conducted. Electronic databases (MEDLINE, Global Health, MIDIRS, Embase, PsycARTICLES and APA PsycInfo), currently registered studies, conference proceedings and the reference lists of included studies were searched. A narrative synthesis provided a summary of current evidence pertaining to the effect of quadriceps anatomical factors on patellar stability.

Results: A total of 9168 records were screened in the initial search. Of these, 20 articles satisfied the inclusion criteria, assessing 754 knees of 689 patients, and 69 cadaveric knees. Vastus medialis obliquus strength (VMO) affected patellar stability up to 15° of knee flexion, whereas medial retinaculum integrity did so up to 30° of knee flexion. Studies disagreed as to whether this applied to the rest of knee flexion. There is conflicting evidence regarding the effect of VMO elevation, cross-sectional area and angulation on patellar stability. The lateral retinaculum contributed to patellar stability throughout the entirety of knee flexion. Quadriceps angle altered patellar orientation during knee flexion, but not extension.

Conclusion: Whilst vastus medialis obliquus strength was found to be a determinant of patellar stability, there is conflicting evidence regarding the effect of VMO morphological parameters on patellar stability. The lateral retinaculum provided stability throughout the entirety of knee flexion, and the medial retinaculum did so up to 30° of flexion.

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Contents

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1. Introduction

Patellar instability can lead to dislocation of the patella, which accounts for 2–3% of injuries of the knee joint [1]. The incidence of patellar dislocation is 6 in every 100,000 patients per year. This may approach 29 in 100,000 patients per year for those between 10 and 17 years of age [2]. Acute patellar dislocation can lead to knee effusion, femoral condyle contusion, and rupture of the medial patellofemoral ligament (MPFL) [1,3]. The latter can result in an associated tear of the VMO and the medial retinaculum [2].

An initial patellar dislocation can lead to recurrent dislocations in 15% to 44% of patients [4]. In addition, six months after the injury, 58% of patients note limitations when carrying out strenuous activity. Other symptoms include severe knee pain, swelling, and the inability to run [5].

Patellar instability can arise from a traumatic event with anatomical predisposing factors increasing the risk of recurrent dislocation. Examples of the latter include MPFL incompetence, trochlear dysplasia, and excessive tibial tubercle lateralization [6]. An understanding of the underlying anatomical factors leading to patellar instability is key to help guide treatment strategy [6]. Knowledge of the aetiology of patellar instability is required given the potential detrimental consequences arising from patellar dislocation. Previous studies have proposed that quadriceps anatomy can impact patellar stability [7,8]. The aim of this systematic review was to analyse current evidence pertaining to quadriceps anatomical factors affecting patellar stability.

2. Methods

We aimed to evaluate the effect of quadriceps anatomical factors on patellar stability using a PRISMA compliant search [9]. The protocol for this review was registered on PROSPERO with registration number CRD42022334265.

2.1. Study eligibility

All studies evaluating quadriceps anatomical factors affecting patellar stability were included, both cadaveric and in-vivo. Papers not reporting original data such as literature or systematic reviews were excluded, along with articles for which the full text was not available, case reports, animal studies and letters to the editor. Studies describing theoretical models and studies reporting subjects with concomitant morphological abnormalities of the lower limb were also excluded. There were no constraints based on language or publication status.

2.2. Search strategy and data extraction

We searched the following electronic databases via OVID from their inception to 03/07/2022, using a PRISMA compliant search strategy: MEDLINE, Global Health, MIDIRS, Embase, PsycARTICLES and APA PsycInfo. Currently registered studies were reviewed using the databases ISRCTN registry, the National Institute for Health Research Portfolio, the UK National Research Register Archive, the WHO International Clinical Trials Registry Platform, and OpenSIGLE (system for information on grey literature in Europe). Conference proceedings from the European federation of national associations of orthopaedics and traumatology (EFORT), British Orthopaedic Association and British Trauma Society were searched. The reference lists of included studies were also searched.

The database search and data extraction were conducted independently by the first and second authors. Searches were conducted twice for quality assurance. The first search was conducted on 11/06/2022. The search was repeated on 03/07/2022. The following search strategy was implemented:

(Quadriceps) AND (Patella* OR kneecap) AND (Stability OR Dislocat* OR Sublux* OR Instability)
Deduplicate

2.3. Methodological appraisal

Level of evidence and risk of bias of each study included were evaluated independently by the first and second authors. The level of evidence of the studies presented was determined with the March 2009 Oxford Centre for Evidence-Based Medicine: Levels of Evidence [10]. The anatomical quality assessment (AQUA) tool was used to assess the risk of bias of anatomical studies [11]. The Cochrane Collaboration's risk of bias tool was used to assess risk of bias in randomized controlled trials (RCTs) [12].

3. Results

A total of 9168 records were screened in the initial search with 36 potentially eligible articles identified (Figure B.1). Sixteen articles were excluded on the bases of the pre-specified exclusion criteria. A total of 20 studies were included, evaluating 754 knees of 689 patients, and 69 cadaveric knees. A narrative synthesis was performed given the heterogeneity of the data, preventing quantitative pooled analysis.

The effect of quadriceps strength, morphology and integrity of quadriceps attachments onto the patella on patellar stability were evaluated.

3.1. Study quality assessment

The findings of the study quality assessment are presented in Table B.1. Of the 18 studies included, only a single study was interventional [13]. This could be attributed to observational studies being better suited to evaluating the effect of quadriceps anatomical factors on patellar stability. The single interventional study was an RCT which presented a high risk of bias due to the lack of blinding of assessors and participants, and the possible bias in the measurement of CT images [13].

Fifteen of the 20 studies included carried a low risk of bias, with the rest exhibiting some concerns or a high risk [7,13–16]. Methodological concerns included not reporting subjects' demographic characteristics (e.g. age and sex) [7,15,16], lack of blinding in an RCT [13], and missing data [14]. Overall, the majority of studies included in this review did not exhibit major methodological limitations (Table B.1).

3.2. Quadriceps morphology and patellar stability

Shu et al compared MRI data of 75 knees (54 patients) with recurrent lateral patellar dislocation (LPD) and 75 knees (70 patients) without recurrent LPD [17]. Patients with recurrent LPD showed significantly higher sagittal VMO elevation, coronal elevation, and muscle-fibre angulation. The angulation of VMO fibres may affect its tension. Decreased VMO tension could lead to a lateral shift of the patella [17]. Shu's findings are contradicted by Balcarek et al [18], who evaluated 82 subjects: 30 with acute patellar dislocation, 30 with recurrent dislocation, and 22 controls. MRI identified VMO cross-sectional area, muscle fibre angulation and craniocaudal extent of the VMO did not differ between groups. Overall, VMO morphology did not differ between patients with patellar dislocation and the control group. Lin et al [19] evaluated 138 knees of 112 patients with CT axial images of the VMO at 0°, 15° and 30° of knee flexion. There was a statistically significant correlation between the VMO cross-sectional area and patellar tilt at 0° and 30° of knee flexion. This was not the case for 15°. There was no statistically significant correlation between VMO cross-sectional area and patellar shift at 0° to 30° of knee flexion.

3.3. Quadriceps strength and patellar stability

Stephen et al carried out a cadaveric study of nine normal knees, and loaded the vastus medialis, VMO and vastus lateralis with varying degrees of tension at 0°, 10°, 20°, 30°, 60° and 90° of knee flexion [8]. They found that reducing the tension on the vastus medialis led to a significant increase in lateral patellar tilt (of 2.8°) and translation (4 mm), which overall led to a reduction of patellar stability. This was true for all tested flexion angles. They also found that a 10 N laterally-directed force led to an increasingly unstable patella as the vastus medialis and lateralis were unloaded. The effect of the altered muscle load was less when the knee was flexed. Removing the load from both the VMO and vastus lateralis led to a significant increase in lateral patellar translation and tilt. The tensions applied were lower than those that would be observed in live subjects. Constant tension was applied throughout the entirety of knee flexion. Stephen et al opened the patellofemoral joint capsule during the study, which could potentially have impacted patellar stability [8]. Sheehan et al administered a motor branch block to the VMO in 18 asymptomatic female subjects. This led to significant changes in lateral and medial patellofemoral shift and external rotation. This was true from 0 to 40° of knee flexion [20].

Elias et al removed all tissues in 10 cadaveric knees so that only the retinaculae, patellar tendon and quadriceps remained [21]. These were loaded with different forces at 40°, 60° and 80° of knee flexion. Increasing the force exerted by the VMO decreased the lateral pressure on the patella. When no force was applied by the VMO, the lateral pressure on the patella

was larger at each flexion angle. A higher lateral pressure could indicate a higher chance of patellar dislocation. Forces applied were of a magnitude patients would be able to exert.

Senavongse and Amis tested patellar stability in eight cadaveric knees from 0° to 90° of knee flexion with the quadriceps tensed to 175 N [22]. The skin and proximal quadriceps were removed, with the retinaculae preserved. When the VMO was released, less force was required to cause a 10 mm displacement of the patella. The loss of VMO tension had the lowest effect when the knees were extended.

Sakai et al [7] contradict Stephen et al [8], Elias et al [21] and Senavongse and Amis [22]. They applied force on the quadriceps muscle compartment of seven cadaveric knees, and measured the force required to displace the patella between 0° and 90° of knee flexion. The forces applied on the VMO ranged from 0 to 40 N. At 0° and 15° of knee flexion, when the VMO force was decreased, there was a statistically significant increase in patellar tilt compared to when the VMO muscle had normal loading. However, they did not find any significant decreases in lateral patellar displacement beyond 15°, despite modifying the force exerted by the VMO. There were no differences in patellar tilt and rotation between the normal group and the vastus medialis oblique weakened group, except for patellar rotation at 0° of knee flexion, when the load in the VMO was 75% of normal.

Taşkıran et al evaluated 40 knees of 27 live subjects and separated them in three groups [23]. Group one served as controls (16 knees), group two presented with patellar pain but no history or findings of patellar instability (12 knees), and group three consisted of patients with a history of two or more patellar dislocations (12 knees). They took CT scans and performed electromyograms (EMG) of the VMO strength at 0°, 15°, 30° and 45° degrees of knee flexion, and measured congruence and tilt angles. A balanced EMG activity was present in all groups at 45°. Moreover, the only statistically significant difference was that the EMG value for group 3 was lower than group 1 at 15°, indicating a weak VMO possibly led to patellar instability at 15°.

3.4. The quadriceps tendon and patellar stability

No studies evaluating the relationship between QT ruptures and patellar instability were found. This could be because quadriceps tendon (QT) rupture has an incidence of only 1.37/100,000 patients per year [24]. Therefore its effects on patellar stability are relatively unknown.

3.5. Medial retinaculum and patellar stability

Zhao et al conducted a RCT comparing medial retinaculum plication (MRP) (28 patients) and vastus medialis plasty (VMP) (26 patients) for adolescents with recurrent patellar dislocation [13]. Final patellar position was significantly better after VMP, but not after MRP. Patellar position deteriorated over time, and the VMP group demonstrated significantly better clinical results compared with the MRP group. Difference in re-dislocation rate between groups was not statistically significant (17.9% for MRP, 7.7% for VMP). However, instability rate was 50% for MRP and 19.2% in VMP, a statistically significant difference. Zhao claimed MRP was less reliable for maintaining patellar stability than VMP for recurrent patellar dislocation in adolescents.

Mitrogiannis et al applied forces to dislocate the patella by 5 mm laterally in 0°, 45° and 90° of knee flexion in six cadaveric knees [15]. All structures surrounding the patella were dissected, except the medial retinaculum. A greater amount of force was required to dislocate the patella when the medial retinaculum was intact than when it was dissected, particularly in low flexion angles. Farahmand et al applied forces to displace the patella laterally by 5 mm in different degrees of knee flexion in six cadaveric knees [25]. Like Mitrogiannis, Farahmand found the medial retinaculum played a significant role in maintaining patellar stability between 0° and 30° of knee flexion. However Farahmand observed its contribution was insignificant past 30°- 45° of knee flexion.

Gobbi et al matched 39 patients with patellar instability to 39 controls [26]. Mean distance from the proximal pole of the patella to the most distal vastus medialis insertion was 17.59 mm in the control group, and 15.02 mm in the patellar instability group ($p < 0.001$). In 75.6% of knees in the patellar instability group, the vastus medialis inserted into the medial retinaculum and not into the patella. This occurred in 52.6% of control knees. Overall, the patella instability group demonstrated a more proximal insertion of the vastus medialis and less patellar coverage relative to controls.

3.6. Lateral retinaculum and patellar stability

Merican et al removed the skin and subcutaneous tissue of nine cadaveric knees, but preserved the deep fascia, the retinaculae and the iliotibial band [27]. They applied 175 N to the quadriceps and 30 N to the iliotibial band. The lateral retinaculum was released in its proximal, middle and distal portions while attempting to displace the patella 10 mm medially and laterally at 0°, 20°, 30°, 60°, and 90° of flexion. As the lateral retinaculum was progressively released, there was decreased medial and lateral stability, with a larger decrease in medial stability than lateral stability. The middle part of the retinaculum had the most significant contribution to stability (particularly at 20° and between 30° and 90° of flexion). They attributed this to the fact that this region is dense and thicker, and its fibres run transversally. Releasing the entire lateral retinaculum (including the capsule) led to a statistically significant decrease in lateral patellar stability throughout the entire range of flexion.

Ostermeier et al removed the skin and subcutaneous tissue of eight cadaveric knees [28]. The muscles, joint capsule, ligaments and tendons were preserved. An extension moment of 31 Nm was applied through 0° and 120° of knee flexion following lateral retinacular release. This led to statistically significant lateral displacement and tilt of the patella at 0°, 100° and 120°. Lateral retinacular release led to a change in patellar tilt at 40° and 80°, but no statistically significant change in relative lateral patellar position was observed at these angles.

3.7. Quadriceps rotation and patellar stability

The Q-angle (or Quadriceps angle) is the angle formed between the quadriceps muscles and the patella tendon [29]. Tsakoniti et al [30] divided 36 healthy individuals into two groups: 17 individuals with a low Q-angle (lower than 15°), and 19 individuals with a high Q-angle (larger than 15°). Q-angle measured in full knee extension did not alter patellar orientation. There was no statistically significant difference in sulcus angle, patellar tendon length to maximum patellar width ratio, patella-lateral condyle index, lateral patellar tilt, and bisect offset with the quadriceps relaxed between the high and low Q-angle groups (p > 0.05). However, the low Q-angle group had a statistically significant higher bisect offset with the quadriceps contracted than the high Q-angle group (65.9% vs 58.4%, p < 0.05). Biedert and Warnke evaluated 56 knee joints of 34 patients, and also found that Q-angle in knee extension did not alter patellar orientation [14]. This was 13.38° in women, and 12.16° in men. Whether this difference was statistically significant was not reported.

Mizuno et al applied loads on the quadriceps, hamstrings and hip to induce knee flexion and modify the Q-angle at their discretion in six cadaveric knees [16]. All muscles were removed except the quadriceps, semimembranosus and biceps femoris. The joint capsule, retinaculum and patellofemoral ligaments were not disrupted. They found that an increase in the Q-angle led to a lateral shift of the patella from 20° to 60° of knee flexion, and to the patella tilting medially from 20° to 80° of knee flexion. Overall, increasing the Q-angle could lead to lateral patellar dislocation or increased lateral patellofemoral contact pressures. Conversely, a decrease in Q-angle led to the patella tilting laterally at 20° and from 50° to 80° of knee flexion. Decreasing the Q-angle did not lead to a medial shift of the patella [16]. Freedman et al compared 43 patients with patellofemoral pain with 30 controls [31]. The Q-angle was measured with the quadriceps relaxed and contracted, from 0 to 45° of knee flexion. Increasing the Q-angle led to medial patellar displacement and tilt in the patellofemoral pain group. This was not the case for the control group.

Maine et al introduced the quadriceps torsion angle [32]. Femoral neck version was measured from the midpoint between the anterior and posterior femoral neck cortices to the center of the femoral head. The quadriceps torsion line ran from the anterior aspect of the sartorius to the junction of the anterior and posterior compartments of the thigh. The femoral neck version line and the quadriceps torsion line were calculated relative to the posterior condylar axis to determine quadriceps torsion angle. Maine et al evaluated 29 patients (15 with patellar dislocation, 14 controls) (age ranged from eight to 19 years) [32]. The quadriceps torsion angle was found to be a fair classifier of patients into the dislocation group.

4. Discussion

Current evidence suggests VMO strength is a determinant of patellar stability. However, whether this is true for the entirety of knee flexion remains unclear. Three cadaveric studies found VMO muscle strength provided stability throughout the entirety of knee flexion [8,21,22], whereas another cadaveric study and an in-vivo study claimed that this was only true between 0° and 15°of knee flexion [7,23]. These discrepancies in results can be attributed to differences in methodology, such as different structures being preserved in the cadaveric studies. Administering a motor nerve block to the VMO led to significant changes in patellar kinematics, further corroborating this muscle plays a role in maintaining patellar stability [20]. Strengthening the VMO could reduce the risk of patellar dislocation. However, whether this muscle can be strengthened through training is questionable [6]. Three in-vivo studies disagreed regarding the difference in VMO elevation and fibre orientation between patients with and without recurrent patellar dislocations [18,19,27]. Conflicting evidence warrants further research to determine whether VMO morphology affects patellar stability.

No studies evaluating the relationship between QT ruptures and patellar instability were found. Gathering data regarding the effect of QT tendon rupture on patellar stability could be hindered by their rarity [24]. Cadaveric studies could help determine the relationship between the degree of QT rupture and the severity of patellar dislocation/instability. This injury pattern is rare and the significance of a lack of evidence is therefore unlikely to be clinically relevant, as active flexion and extension is severely limited or not possible dependent on the severity of injury to the quadriceps tendon in these circumstances.

Two studies found the integrity of the medial retinaculum played a key role in maintaining patellar stability up to 30° of flexion [15,25]. However, Mitrogiannis found this applied throughout the entirety of flexion, whereas Farahmand found this was not true beyond 30°. This difference could be attributed to the fact that Farahmand et al did not dissect structures attaching to the patella. A single low-sample size RCT is not sufficient to reliably claim that VMP should be chosen over MRP for the treatment of recurrent patellar dislocation in adolescents [13], with more evidence needed to determine which approach is more effective. Further research is required to ascertain whether the location of vastus medialis insertion contributes to patellar instability. Two cadaveric studies found the lateral retinaculum contributed to patellar stability throughout the entirety of knee flexion [27,28]. Their concordance strengthens the validity of this claim.

Current evidence suggests Q-angle does not affect patellar orientation during full knee extension. This is not true for knee flexion [14,16,30]. Limitations of these studies include assessment of the knee joint only with the patient lying supine [14,30] and the use of cadavers [16]. Further research is required to determine whether quadriceps torsion angle predicts patellar dislocation, and whether Q-angle as a predictor of patellar instability can be used only in patients with patellofemoral pain [29].

Current evidence has limitations which affect the reliability of conclusions drawn. Firstly, there is a reliance on cadaveric studies to explore the effect of quadriceps anatomical factors on patellar stability. This could be attributed to their convenience. Using cadavers allows for the manipulation of the knee joint in ways that would not be possible in vivo. Forces can be applied arbitrarily. Moreover, a cadaveric knee can be held in a fixed position for extended periods of time, allowing for accurate measurements to be made. However, the biomechanics of a cadaveric knee are different to those observed in-vivo due to change in tissue structure post-mortem. This is exacerbated by the dissection of structures attaching to the patella. In addition, despite the observation of statistically significant results, whether these are of clinical significance remains unclear due to the inability to assess the effect of quadriceps anatomical factors on daily activities. Furthermore, of the nine cadaveric studies included, five were performed in anatomically normal knees [7,8,16,25,27], with the remaining four studies not reporting on the anatomical state of their specimens. The use of normal knees does not allow for the evaluation of the effect of anatomical abnormalities on quadriceps direction of action. These limitations hinder the applicability of cadaveric studies. In-vivo assessment of patients yields more reliable results due to the preservation of normal anatomy.

Performing in-vivo studies requires active involvement of patients, with the performance of tasks that can be uncomfortable. These include performing multiple movements, holding the knee in a fixed position, and undergoing multiple measurements. This makes the prospect of conducting in-vivo studies of large sample sizes unlikely. Secondly, the majority of studies concerning quadriceps strength identified evaluated the VMO only. The vastus lateralis was evaluated in a single study, which does not allow for a reliable analysis of its effect on patellar stability [8]. The effect of other muscles on patellar stability was not explored. Thirdly, there is a lack of a standardized approach to evaluating the effect of quadriceps anatomical factors on patellar stability. Cadaveric studies applied differing forces and dissected different structures, and in-vivo studies adopted different study designs. This hinders the prospect of conducing meta-analyses on the matter, and diminishes the reliability of comparisons between studies' results. Fourthly, none of the included studies compared bilateral quadriceps anatomy in patients with unilateral patellar dislocations. Assuming equal anatomy bilaterally, a comparison of anatomical parameters between the affected and healthy limbs could yield a reliable assessment of the effect of quadriceps anatomy on patellar stability.

Only a single study reported on the effect of anatomical parameters on the anatomy of the quadriceps. Patients with a Q-angle lower than 15˚ had a higher bisect offset with the quadriceps contracted than those with a Q-angle higher than 15˚ [30]. No study reported on the effect of anatomical abnormalities on quadriceps strength and direction of action. Most patients with patellar instability have anatomical abnormalities predisposing dislocation. These include rotational malalignment, trochlear dysplasia, and excessive tibial tubercle lateralization [6]. It is possible that these abnormalities may affect quadriceps anatomy. Therefore, abnormal quadriceps function observed in patients with patellar dislocation may not be because of a quadriceps abnormality, rather a normal muscle acting differently across an abnormal joint. Further research should explore the effects of anatomical abnormalities on quadriceps function.

Patellar instability occurs more commonly in women [33,34]. The findings of this review support this claim, with 299 of 455 patients with patellar instability being female. However, the studies included cannot be used to estimate the prevalence of patellar instability according to sex. Eligibility criteria were applied, rendering a select study population. This makes the patient demographics identified in this review different to those observed in clinical practice. Whether quadriceps anatomical factors contribute to a high female prevalence cannot be determined with current evidence. Only one study analysed anatomical parameters for men and women separately, and did not report whether Q-angle differed between them [14]. Further research should analyse quadriceps anatomical factors in men and women separately to help explain the higher prevalence in the latter. In addition, no studies reported their participants' ethnicity. Further studies should report this parameter to determine if there are differences in quadriceps anatomical factors between ethnicities, which could impact patellar stability.

5. Conclusion

Current evidence suggests VMO strength is an important determinant of patellar stability. However, whether this is true for the entirety of knee flexion remains unclear. There is conflicting evidence regarding the effect of VMO morphological parameters on patellar stability. The lateral retinaculum provided stability throughout the entirety of knee flexion, and the medial retinaculum did so up to 30° of flexion. Further in-vivo studies are required to reliably ascertain the validity of these claims. Future research should aim to determine whether the vastus medialis can be strengthened through training, stratify anatomical observations according to sex and ethnicity, and evaluate the effect of anatomical abnormalities on quadriceps strength and direction of action.

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Ethical approval

Not applicable.

Informed consent

Not applicable.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Caroline B Hing is co editor-in-chief the Knee.
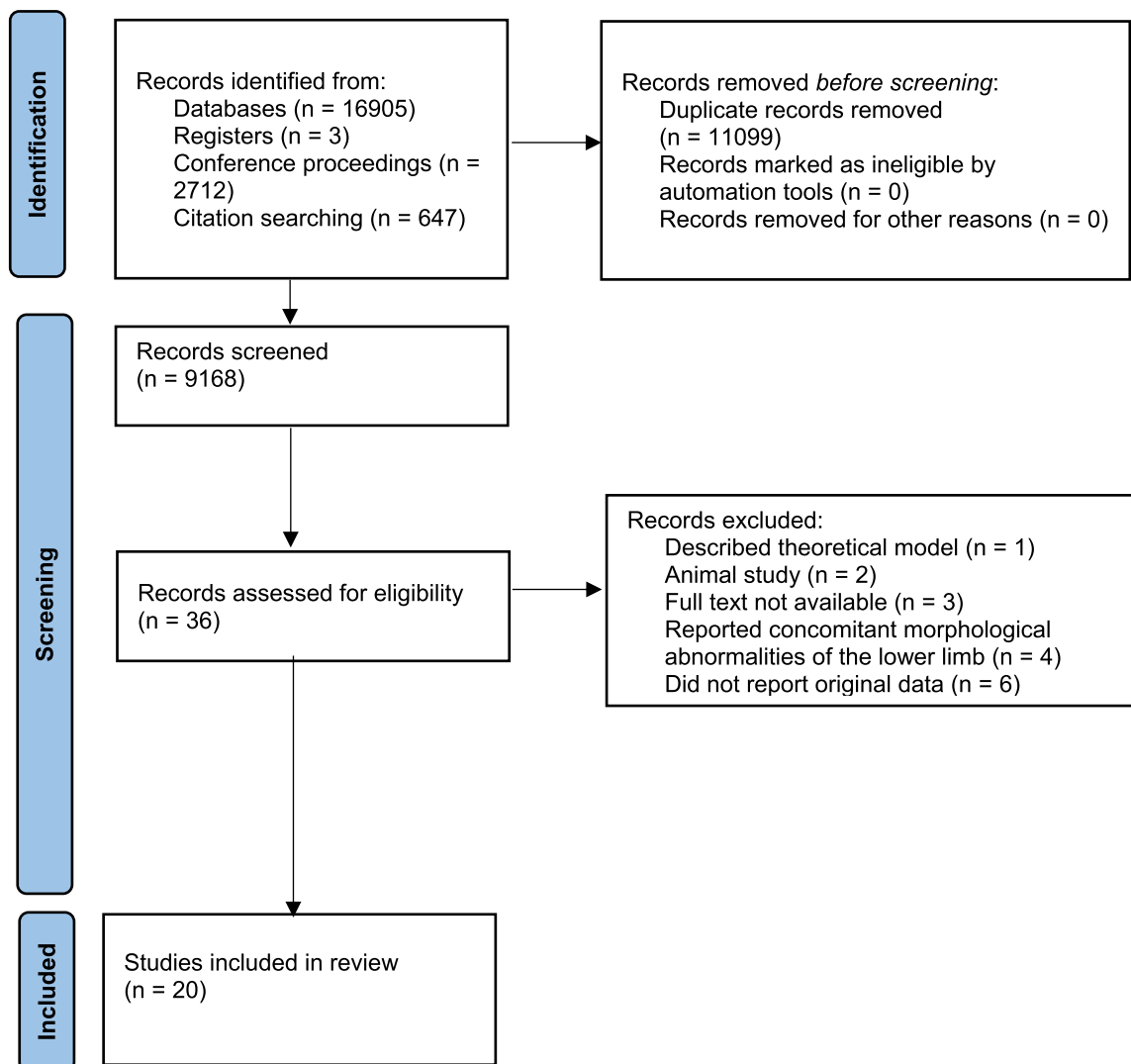
Appendix A

See Figure B.1.

Figure B.1. PRISMA diagram depicting the study collection process.

See Table B.1.

Table B.1
Level of evidence and risk of bias of studies included in this review.

Study	Study design, level of evidence	Risk of bias
Zhao et al, 2012	RCT, 2b	High
Shu et al, 2021	Case control, 3	Low
Gobbi et al, 2019	Cross-sectional, 3	Low
Lin et al, 2018	Cross-sectional, 3	Low
Maine et al, 2019	Cross-sectional, 3	Low
Balcarek et al, 2014	Case series, 4	Low
Taşkıran et al, 1998	Case series, 4	Low
Tsakoniti et al, 2011	Case series, 4	Low
Freedman et al, 2014	Case series, 4	Low
Sheehan et al, 2012	Case series, 4	Low
Biedert and Warnke, 2000	Case series, 4	High
Elias et al, 2009	Cadaveric, 4	Low
Farahmand et al, 2004	Cadaveric, 4	Low
Merican et al, 2009	Cadaveric, 4	Low
Ostermeier et al, 2007	Cadaveric, 4	Low
Senavongse and Amis, 2005	Cadaveric, 4	Low
Stephen et al, 2018	Cadaveric, 4	Low
Mizuno et al, 2011	Cadaveric, 4	Some concerns
Sakai et al, 2000	Cadaveric, 4	Some concerns
Mitrogiannis et al, 2018	Cadaveric, 4	High

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