Ankle dorsiflexion range of motion in patellofemoral pain: systematic review and meta-analysis

Amplitude de movimento de dorsiflexão do tornozelo na dor femoropatelar: revisão sistemática e metanálise

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Abstract

Introduction: Decreased ankle dorsiflexion (ADF) range of motion (ROM) during dynamic activities has been reported in subjects with patellofemoral pain (PFP) and is theorised to play a role in its development. **Objective:** To compare the maximum ADF angle between individuals with PFP and asymptomatic controls. **Methods:** A systematic review and meta-analysis of studies of humans with PFP undergoing maximum ADF angle assessment, published in peer-reviewed journals in English. We searched CINAHL, Cochrane CENTRAL, EMBASE, LILACS, MEDLINE, PEDro, SciELO, SCOPUS, SPORTDiscus, and Web of Science databases. The outcome of interest was PFP, and the exposure of interest was maximum ADF ROM. Data extraction and risk-of-bias scoring were conducted in duplicate and independently. The Joanna Briggs Institute critical appraisal tools were used to assess the risk of bias. Effect sizes were pooled using random-effects models and reported as standardised mean differences (SMD). Subgroup analyses were conducted for ADF assessment characteristics. **Results:** Twelve studies providing 15 datasets were included. No significant difference in maximum ADF was found between individuals with PFP and asymptomatic controls (SMD = -0.3875; 95% CI: -1.02 to 0.25; p = 0.2123), with high heterogeneity (I^2 = 95.56%). Subgroup analysis showed differences related to the type of assessment (active or passive) but not to position or weight-bearing status. **Conclusion:** Maximum ADF does not consistently differ between individuals with PFP and asymptomatic controls. Assessment of this variable in isolation does not appear sufficient to explain the presence of patellofemoral pain.

Keywords: Patellofemoral pain. Ankle. Dorsiflexion. Meta-analysis. Range of motion.

Resumo

Introdução: *A redução da amplitude de movimento de dorsiflexão do tornozelo (DFT) durante atividades dinâmicas tem sido observada em indivíduos com dor femoropatelar (DFP), sendo considerada um possível fator envolvido em seu desenvolvimento.* ***Objetivo:*** *Comparar o ângulo máximo de DFT entre indivíduos com DFP e controles assintomáticos.* ***Métodos:*** *Trata-se de uma revisão sistemática e meta-análise de estudos com indivíduos com DFP submetidos à avaliação da DFT máxima, publicados em periódicos revisados por pares e em inglês. As bases CINAHL, Cochrane CENTRAL, EMBASE, LILACS, MEDLINE, PEDro, SciELO, SCOPUS, SPORTDiscus e Web of Science foram consultadas. O desfecho de interesse foi DFP; e a exposição, a amplitude máxima de DFT. Extração de dados e avaliação do risco de viés foram realizadas de forma independente por dois revisores, utilizando a ferramenta do Joanna Briggs Institute. Os tamanhos de efeito foram agrupados por modelos de efeitos aleatórios e expressos como diferenças médias padronizadas (DMP). Realizaram-se análises de subgrupos conforme características da avaliação da DFT.* ***Resultados:*** *Foram incluídos 12 estudos com 15 conjuntos de dados. Não houve diferença significativa na DFT máxima entre os grupos com DFP e controles assintomáticos (DMP = -0,3875; IC 95%: -1,02 a 0,25; p = 0,2123), com alta heterogeneidade (I^2 = 95,56%). Diferenças foram observadas quanto ao tipo de avaliação (ativa ou passiva), mas não quanto à posição ou descarga de peso.* ***Conclusão:*** *A DFT máxima não difere consistentemente entre indivíduos com e sem DFP. A avaliação isolada da DFT não parece suficiente para explicar a presença de DFP.*

Palavras-chave: *Dor femoropatelar. Tornozelo. Dorsiflexão. Metanálise. Amplitude de movimento.*

Introduction

Patellofemoral pain (PFP) is characterised by pain in the peripatellar or retropatellar region,[1-4] with an estimated annual prevalence of 22.7% in the general population, 29.2% in females and 15.5% in males.[5,6] PFP can be aggravated by activities that load the patellofemoral joint (PFJ) in a flexed position, such as squatting, ascending or descending stairs, prolonged sitting with flexed knees, running or jumping.[1-4,6,7]

Ankle dorsiflexion (ADF) is a movement that occurs primarily at the talocrural joint, and its restriction during dynamic activities has been reported in individuals with PFP. Consequently, it is believed to play a role in the presence of this condition.[7-13]

Restricted ADF range of motion (ROM) during weight-bearing (WB) tasks is associated with increased subtalar pronation and tibial internal rotation to add motion. This increased tibial internal rotation demands a concurrent increase in femoral internal rotation, thereby promoting greater dynamic knee valgus during movements such as landing from a jump or running, squatting, and step-down movements.[7,8,14-16] Greater dynamic knee valgus is thought to increase hip adductor torque, contributing to large vectors of lateralization force of the patella, and reducing the patellofemoral contact, favoring increased patellofemoral pressure and, hence, the pain.[15,17,18] Thereby, limited ADF ROM can be linked to the presence of PFP in the context of excessive dynamic knee valgus.[7]

The source of reduced ADF ROM can be capsular restrictions of the talocrural joint, local arthrokinematic restrictions in posterior talar glide relative to the ankle mortise, and/or tightness in the calf muscles associated with a loss of flexibility in the Achilles tendon.[12,16-20]

There are several methods available to measure ADF ROM in both non-weight-bearing (NWB) and WB positions, with the knee flexed or extended, and either actively or passively moving the ankle joint.[7-10,14,21-34] WB measures are believed to more accurately indicate the available ROM in functional activities,[35] and may be more reliable (ICC = 0.93-0.96) than measures obtained in a NWB assessment (ICC = 0.32-0.72).[36] Regarding tools, the NWB ADF ROM method commonly uses a standard goniometer.[9,25,27,28,32,33] The WB lunge position ADF ROM can be obtained using a goniometer, inclinometer, infrared sensors, or a tape measure using the distance-to-wall technique.[7-9,14,21-30,34,37]

Given the association between ADF ROM deficiency and kinematic compensations, ADF ROM assessment has been carried out routinely, either in research or clinical practice, as part of the examination of orthopaedic lower extremity problems.[1,14,18,38,39] However, the existing literature remains controversial regarding whether individuals with PFP exhibit reduced ADF ROM in comparison to asymptomatic controls.[21,25,27-29,31] Therefore, this study aimed to compare the maximum ADF angle in individuals with PFP and asymptomatic controls.[7-9,29]

Methods

This systematic review was registered prior to the completion of the initial search (PROSPERO registration: CRD42024554645) and was developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[40]

Eligibility criteria and information sources

We included observational studies (cohort, case-control and cross-sectional designs) of human participants with PFP undergoing maximum ADF angle assessment, published in peer-reviewed journals and in English. Any intervention studies, including randomised control trials, for baseline data were considered for this review. Studies were excluded if they did not assess or report maximum ADF, lacked a control group, included knee pathologies other than PFP, did not receive a response from authors upon contact, or were reviews or qualitative studies. We searched CINAHL, Cochrane CENTRAL, EMBASE, LILACS, MEDLINE, PEDro, SciELO, SCOPUS, SPORTDiscus and Web of Science databases.

Search strategy and selection process

Searches were conducted for articles published up to 13 May 2025. Search strategies were conducted using MeSH terms, Emtree terms, and keywords related to the outcome of interest (PFP) and the exposure of interest (maximum ADF ROM), which underwent a Peer Review of Electronic Search Strategies (PRESS) by an experienced university librarian to confirm that the databases and search terms on each platform were appropriate.[41] Full details of search strategies from all databases can be seen in the Supplemental material 1.

On 11 June 2024, two of the authors (ATMC and NNK) performed the search independently. We updated the database search on 13 May 2025. A single investigator (NNK) exported all records identified by the search strategy to the Mendeley reference manager (Thomson Reuters, Philadelphia, USA), for the organisation in folders by database and removal of duplicate records. After removing duplicates, the team of authors (ATMC, MBC, NNK, and KAMZ), in pairs, independently screened titles and abstracts of all records retrieved.

Following the initial screening, the authors cross-checked their search results to ensure they were identical. The pre-selected records from each database were grouped, resulting in a general number of records to be assessed for eligibility by full text. The team of authors screened full-text records independently and in duplicate, but reviewer pairs were changed. They also carried out a search to identify other potential studies through reference-checking of publications eligible for full-text review. Any disagreements during the initial or full-text screenings were resolved through consensus meetings, with the involvement of a third reviewer. All studies that met the inclusion criteria made up the review sample.[42]

Data collection process

The team of reviewers (ATMC, MBC, NNK and KAMZ) extracted data independently using a custom spreadsheet. This extraction was performed by one reviewer and checked by a second reviewer. Any discrepancies were resolved by consensus discussion. When necessary, we contacted the authors by email to request missing data.[42]

Data items

For the purposes of this study, PFP was defined as retropatellar or peripatellar pain reproduced during squatting or other functional activities that load the PFJ in a flexed position, such as stair climbing or descending.[2,3] The maximum ankle dorsiflexion ROM was defined as maximum ROM of the foot toward the tibia (NWB) or of the tibia relative to the ground (WB).[37]

Study risk of bias and certainty of evidence assessment

The level of evidence did not depend on the study design hierarchy. It was categorized based on the methodological quality assessed by the Joanna Briggs Institute (JBI) critical appraisal tools, considering each type of design included.[43] The answers to the tool items are "yes", "no", "unclear" or "not applicable". Methodological quality was categorised as: low ("yes" score ≤ 49%), moderate ("yes" score 50 to 69%), and high ("yes" score ≥ 70%). The level of evidence ranged from level I (evidence from high-quality studies)

to III (evidence from low-quality studies). The study was assigned as low quality/level of evidence III if it had significant limitations that substantially reduced confidence in the estimate, such as the following: PFP was not clearly assessed in a standard way, based on level A of recommendation in Clinical Practice Guidelines;[2,3] the confounding factors were not identified, or the study did not state the strategies to deal with them; for this evaluation, age, sex, race, height, weight, habitual stretching the triceps surae or mobilisation the ankle were considered confounding factors for ADF ROM;[44,45] the ADF was not assessed in a standard, valid and reliable way for cases and controls.

In three teams of two (ATMC, MBC and NNK), each reviewer independently evaluated the risk of bias and level of evidence for each included study. Discrepancies were resolved by consensus with a third reviewer (KAMZ).

Statistical analysis

Effect measures: The analysis was carried out using the standardised mean difference (SMD) as the outcome measure. Pooled effects from random-effects meta-analyses were reported as SMD, calculated using Cohen's d statistic, along with 95% confidence intervals (CIs). Given that all analyses included fewer than 20 study comparisons, the Knapp-Hartung method was employed to calculate CIs, as it provides more robust and reliable estimates of between-study variance in meta-analyses with a limited number of comparisons. Heterogeneity (τ^2) was estimated using the restricted maximum-likelihood method. In addition to the estimate of τ^2, the Q-test for heterogeneity and the I^2 statistic were reported. Funnel plot asymmetry was assessed using the rank correlation and regression tests, with the standard error of the observed outcomes as the predictor. Negative SMD values represent a lower ADF in the PFP group. R software was used for meta-analysis.[42]

Analysis of subgroups or subsets: Studies were stratified by ADF assessment characteristics (WB vs. NWB, knee extended vs. flexed, and passive vs. active movement). When not reported, the SD was estimated from the standard errors[33] or 95% CI[32] as suggested in the Cochrane Handbook.[42] If the body mass index (BMI) was missing, the mean of this variable was estimated by dividing the mean weight (in kilograms) by the square of the mean height (in metres), and the SD was considered missing data.[9,10,29,31,32] For studies including two or more groups with PFP or Controls, in which the ADF angle was evaluated in the same way for all participants, we calculated the mean of the means and the combined SD of each type of group (PFP or Control) for the variables ADF angle, mass, height and/or BMI, in order to obtain only one PFP and one control group.[10,28,33]

Results

We found 672 records through databases searching. After removing duplicates, we screened 372 titles and abstracts and 82 full studies. Eleven papers met the inclusion criteria.[7-10,21,25,27-29,31,32] Reference checking yielded one more article that fulfilled inclusion criteria.[33] As three studies assessed ADF using both the knee extended and flexed,[7,9,21] 15 datasets were extracted from 12 articles (Figure 1).

Study characteristics

Our pooled analysis is based on summary data from nine case-controls,[7,9,10,21,25,27,28,32,33] two cross-sectionals,[8,31] and one cohort.[29] The total number of participants was 1,356 (mean age 25.16 years), 546 of whom had PFP (mean age 25.19 years, 68% female) and 810 controls (mean age 25.13 years, 67.1% female), and the sample size ranged from 13 to 271. Half of the studies did not report[7,10,21,25,27,32] and two included diverse types of physical or professional activity,[9,29] making it difficult to quantify the level of physical demand precisely. The characteristics of the included studies are summarised in Table 1.

Eight studies assessed ADF with knee extended, of which five were NWB, all used the goniometer (mean ROM ranged from 6.3 to 22.2 degrees),[9,25,28,32,33] and three were WB, of which two used the inclinometer[7,21] and one used the goniometer[29] (mean ROM ranged from 21.6 to 40.9 degrees). Seven studies assessed ADF with knee flexed, of which two were NWB, all used the goniometer (mean ROM ranged from 14.8 to 34.3 degrees)[9,27] and five were WB, all used the inclinometer[7,8,10,21,31] (mean ROM ranged from 17.3 to 47.5 degrees). Extracted data relating to measurement methods are presented in Table 2.

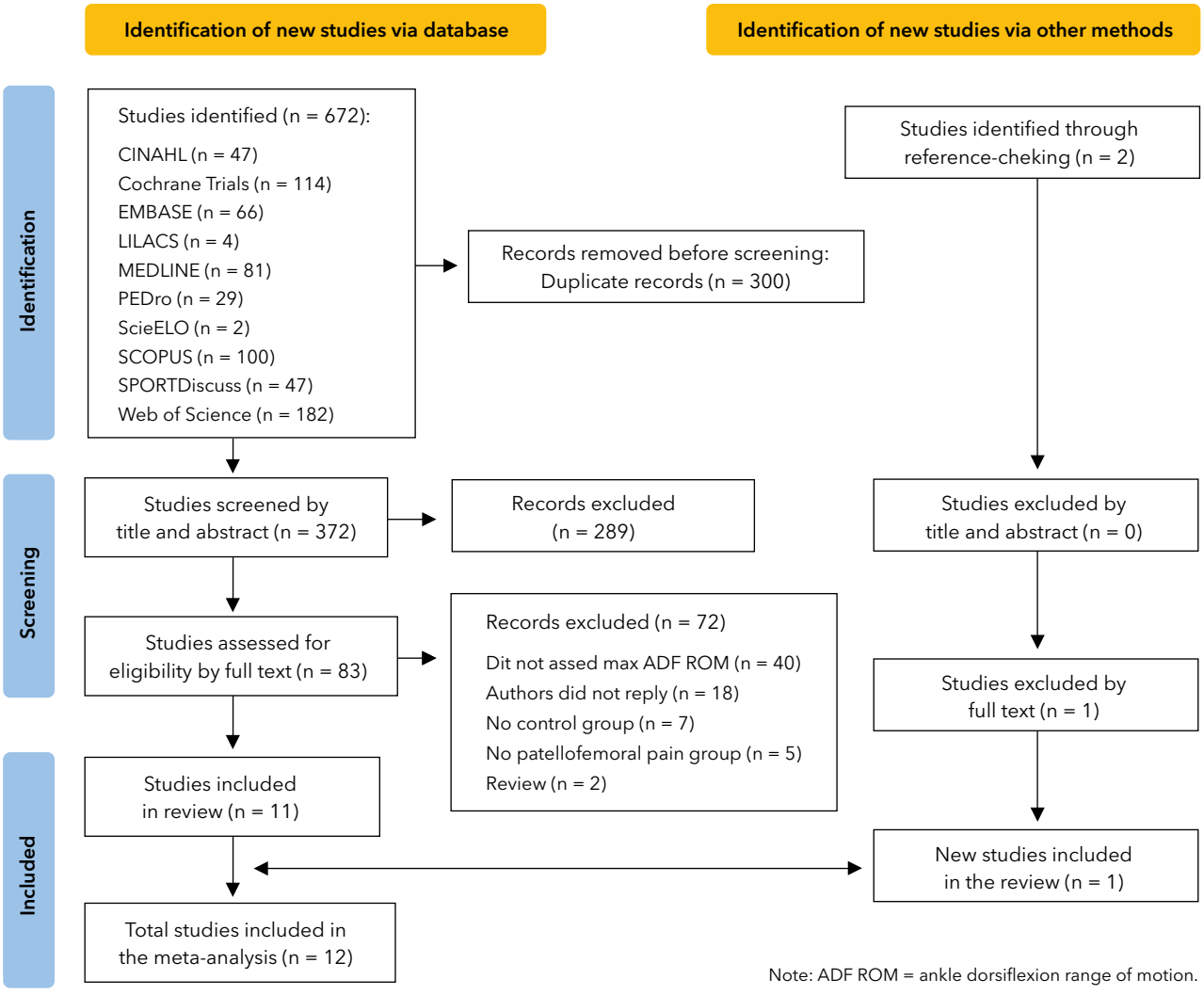

Figure 1 - PRISMA 2020 flow diagram template for systematic reviews.

Table 1 - Characteristics of included studies (n = 12)

Study	PFP participants[a]	Control participants[a]	PFP inclusion criteria	Activity
Barton et al., 2010[21]	n = 20; 75% female Age = 22.8 ± 4.1 years BMI = 23.7 ± 3.5 kg/m²	n = 20; 75% female Age = 21.9 ± 3.5 years BMI = 22.0 ± 3.3 kg/m²	> 6 weeks > 30 (VAS: 0-100)	MD
Branco et al., 2022[31]	n = 26; 19.2% female Age = 35.5 ± 5.6 years BMI = 25.0 ± MD kg/m²	n = 24; 29.7% female Age = 38.8 ± 7.6 years BMI = 24.5 ± MD kg/m²	> 12 weeks > 3 (NPS: 0-10)	Cycling
Emamvirdi et al., 2023[8]	n = 20; 100% female Age = 23.1 ± 2.1 years BMI = 20.2 ± 0.7 kg/m²	n = 20; 100% female Age = 22.8 ± 2.3 years BMI = 20.2 ± 0.6 kg/m²	> 12 weeks > 3 (NPRS: 0-10)	Basketbal
Hassan et al., 2022[7]	n = 70; 61% female Age = 25.5 ± 3.5 years BMI = 23.7 ± 3.2 kg/m²	n = 70; 50% female Age = 24.9 ± 6.1 years BMI = 24.0 ± 2.4 kg/m²	> 12 weeks > 3 (VAS: 0-10)	MD

Note: BMI = body mass index; MD = missing data; NPRS = Numerical Pain Rating Scale; NPS = Numerical Pain Scale; PFP = patellofemoral pain; VAS = visual analogue scale. Age and BMI values are presented as mean ± standard deviation.

Table 1 - Characteristics of included studies (n = 12) (continued)

Study	PFP participants[a]	Control participants[a]	PFP inclusion criteria	Activity
Manojlović et al., 2022[25]	n = 18; 72.2% female Age = 24.6 ± 12.5 years BMI = 22.7 ± 3.8 kg/m²	n = 37; 70.3% female Age = 21.6 ± 8.8 years BMI = 21.9 ± 2.9 kg/m²	> 12 weeks > 3 (VAS: 0-10)	MD
Messier et at., 1991[33]	n = 16; 25% female Age = MD ± MD years BMI = MD ± MD kg/m²	n = 20; 30% female Age = MD ± MD years BMI = MD ± MD kg/m²	MD MD	Running
Mølgaard et al., 2011[32]	n = 13; 69% female Age = 16.9 ± 0.8 years BMI = 20.7 ± 1.8 kg/m²	n = 22; 68% female Age = 16.7 ± 0.1 years BMI = 21.4 ± 2.5 kg/m²	> 4 weeks MD	MD
Piva et al., 2005[9]	n = 30; 57% female Age = 25.8 ± 6.0 years BMI = 26.7 ± MD kg/m²	n = 30; 56.7% female Age = 25.7 ± 5.9 years BMI = 23.6 ± MD kg/m²	> 4 weeks > MD (NPRS: 0-10)	Mixed
Rodrigues et al., 2023[27]	n = 15; 100% female Age = 26.3 ± 4.2 years BMI = 24.5 ± 3.6 kg/m²	n = 15; 100% female Age = 29 ± 5.2 years BMI = 23.1 ± 3.3 kg/m²	> 8 weeks > 3 (VAS: 0-10)	MD
Silva et al., 2018[10]	n = 23; 100% female Age = 34.3 ± 2.4 years BMI = 22.3 ± MD kg/m²	n = 23; 100% female Age = 34.3 ± 2.4 years BMI = 22.3 ± MD kg/m²	MD MD	MD
Steinberg et al., 2017[28]	n = 271; 100% female Age = MD ± MD years BMI = 17.6 ± 1.1 kg/m²	n = 271; 100% female Age = MD ± MD years BMI = 17.7 ± 1.9 kg/m²	MD MD	Dance
Witvrouw et al., 2000[29]	n = 24; 55% female Age = 18.6 ± MD years BMI = 21.2 ± MD kg/m²	n = 258; 45.7% female Age = 18.6 ± MD years BMI = 21.5 ± MD kg/m²	> 6 weeks MD	Mixed

Note: BMI = body mass index; MD = missing data; NPRS = Numerical Pain Rating Scale; NPS = Numerical Pain Scale; PFP = patellofemoral pain; VAS = visual analogue scale. Age and BMI values are presented as mean ± standard deviation.

Table 2 - Average ankle dorsiflexion angle according to assessment method

Study	Method	Knee extended		Knee flexed	
		PFP	Control	PFP	Control
Manojlović et al., 2022[25]	Non-weight-bearing	$18.2^{P\alpha}$	$15.2^{P\alpha}$	–	–
Messier et at., 1991[33]		$6.3^{A\alpha}$	$6.4^{A\alpha}$	–	–
Mølgaard et al., 2011[32]		$22.2^{P\alpha*}$	$17.7^{P\alpha}$	–	–
Piva et al., 2005[9]		$7.4^{A\alpha*}$	$17.6^{A\alpha}$	$14.8^{A\alpha*}$	$21.7^{A\alpha}$
Steinberg et al., 2017[28]		$12.3^{P\alpha*}$	$11.0^{P\alpha}$	–	–
Rodrigues et al., 2023[27]		–	–	$34.3^{P\alpha}$	$31.8^{P\alpha}$
Barton et al., 2010[21]	Weight-bearing	$40.9^{A\beta}$	$34.8^{A\beta}$	$47.5^{A\beta}$	$43.7^{A\beta}$
Branco et al., 2022[31]		–	–	$44.6^{A\beta}$	$43.2^{A\beta}$
Emamvirdi et al., 2023[8]		–	–	$41.0^{A\beta*}$	$46.9^{A\beta}$
Hassan et al., 2022[7]		$21.6^{A\beta}$	$22.9^{A\beta}$	$30.2^{A\beta*}$	$33.2^{A\beta}$
Silva et al., 2018[10]		–	–	$17.3^{A\beta*}$	$34.1^{A\beta}$
Witvrouw et al., 2000[29]		$32.1^{A\alpha*}$	$35.2^{A\alpha}$	–	–

Note: ^{A}Active; ^{P}Passive; $^{\alpha}$Goniometer; $^{\beta}$Inclinometer; PFP = patellofemoral pain. *Significant difference in comparison to the control group ($p < 0.05$).

Risk of bias and certainty of evidence

Eleven studies were assessed as being at high risk of bias, and one as being at low risk of bias. There was an unclear risk of bias regarding the exposure period in 11 studies.[7-10,21,25,27,28,31-33] Three studies did not report clearly whether PFP presence or absence was assessed in a standardised, valid and reliable manner, as proposed in the current guidelines.[31-33]

Eleven studies did not identify all of the confounding factors listed above, nor indicate strategies for dealing with them.[7-10,21,25,27,28,31-33] These studies were at high risk of performance bias. A summary of the risk-of-bias assessment is provided in the Supplemental material 2.

Dorsiflexion in PFP versus Control

A total of 15 datasets from 12 studies were included in the analysis. The SMD ranged from -3.65 to 0.78, 53% of which were negative. The random-effects model estimated an average SMD of -0.3875 (95% CI: -1.02 to 0.25), which was a non-significant result (p = 0.2123). The Q-test indicated significant heterogeneity among true outcomes: Q(14) = 166.06, p < 0.0001, τ^2 = 1.1567, I^2 = 95.56%. The 95% prediction interval ranged from -2.78 to 2.01, suggesting that while the average outcome was negative, positive effects were possible in some studies.

Sensitivity analyses

We conducted sensitivity analyses by removing the study by Silva et al.[10] as studentized residual analysis identified it as a potential outlier in the context of this model, with a residual exceeding ± 2.94. This study also had an unusually high Cook's distance, indicating significant influence on the results. When removed from the model, the effect size changed from -0.39 to -0.18 and the result remained non-significant (p = 0.4048). A summary of the results is provided in Figure 2. Neither the rank correlation nor the regression tests indicated funnel plot asymmetry (p = 1.0 and p = 0.8703, respectively).

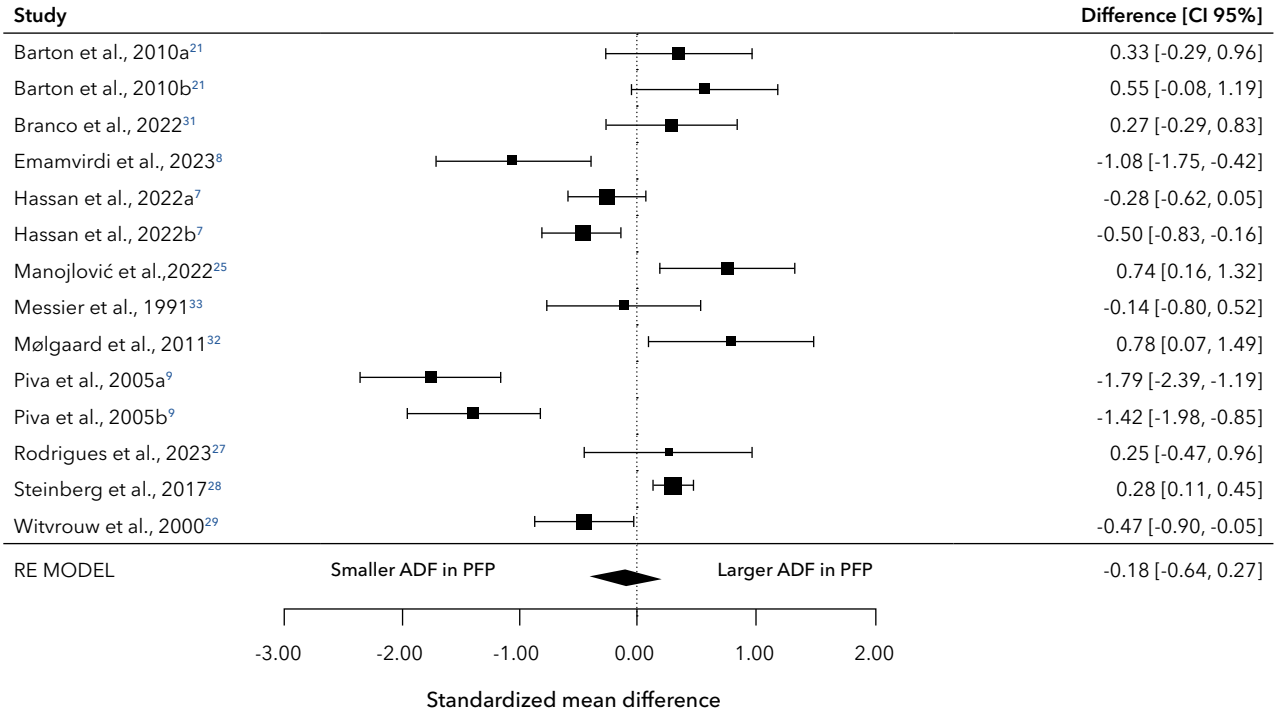

Figure 2 - Comparison of ankle dorsiflexion of patellofemoral pain versus control group.

Note: ab = different datasets extracted from the same article. CI = confidence interval; PFP = patellofemoral pain; RE = random effect.

Subgroup analysis

Due to the high heterogeneity among the studies ($p \leq 0.0001$, $I^2 = 95.56\%$), subgroup analysis was performed to assess the potential causes of heterogeneity. This analysis revealed that the type of ADF movement (passive or active) had an impact on the results ($p = 0.0155$). However, other assessment characteristics (WB or NWB, knee extended or flexed) did not influence the results. The combined estimate of ten studies in which ADF movement was classified as "active" showed a negative but non-significant result (-0.45; 95% CI, -1.0000 to 0.0900; $p = 0.0934$), with high heterogeneity among the studies ($p < 0.0001$; $I^2 = 88.43\%$). In contrast, the estimate of four studies conducted in a "passive" manner was significant and positive (0.42; 95% CI: 0.01 to 0.83; $p = 0.0463$), with low heterogeneity ($p = 0.2781$; $I^2 = 29.73\%$). Overall, substantial heterogeneity was observed between subgroups ($p \leq 0.0001$; $I^2 = 93.03\%$) (Table 3). The meta-regression analysis was conducted to assess the association between the minimum duration of pain, mass, height, BMI, and ADF. The results did not show a significant association between these variables ($p > 0,05$).

Table 3 - Outcomes of the subgroup analyses of parameters

Subgroup	No. of data (n)	Effect size (95% CI)	p-value	I^2 (%)	p heterogeneity	p for between*
ADF movement	-		0.0155	85.00	-	
Active	10 (888)	-0.45 (-1.00 to 0.09)	0.0934	88.43	< 0.0001	< 0.0001
Passive	4 (662)	0.42 (0.01 to 0.83)	0.0463	29.73	0.2781	
Knee	-		0.5583	91.18	-	
Extended	8 (1,190)	-0.07 (-0.76 to 0.61)	0.8056	92.78	< 0.0001	< 0.0001
Flexed	6 (360)	-0.33 (-1.17 to 0.51)	0.3606	87.51	< 0.0001	
Weight-bearing	-		0.9761	90.79	-	
NWB	7 (818)	-0.19 (-1.14 to 0.76)	0.6447	93.84	< 0.0001	< 0.0001
WB	7 (732)	-0.19 (-0.70 to 0.33)	0.4075	78.84	0.0011	
Knee extended	-		0.8377	92.43	-	
NWB	5 (728)	-0.02 (-1.33 to 1.28)	0.9611	94.38	< 0.0001	< 0.0001
WB	3 (462)	-0.20 (-1.15 to 0.74)	0.4521	58.00	0.1049	
Knee flexed	-		0.5686	89.09	-	
NWB	2 (90)	-0.60 (-11.2 to 9.1)	0.6017	92.20	0.0004	< 0.0001
WB	4 (270)	-0.19 (-1.35 to 0.97)	0.6358	85.76	0.0005	

Note: ADF = ankle dorsiflexion; CI = confidence interval; NWB = non-weight-bearing; WB = weight-bearing. *p for between subgroup heterogeneity.

Discussion

To our knowledge, this study is the first systematic review and meta-analysis to evaluate differences in maximum ADF between individuals with PFP and asymptomatic controls. The pooled estimate indicated a non-significant difference in ADF between individuals with PFP and controls (SMD = -0.39; 95% CI: -1.02 to 0.25; $p = 0.2123$), with substantial heterogeneity observed across studies. The 95% prediction interval suggested that individual studies could yield either reduced or increased ADF values.

These findings reveal considerable variability among studies and suggest that ADF differences between individuals with PFP and asymptomatic controls are not consistent in direction or magnitude. Supporting this, in a population-based study involving 800 healthy ankles, Chan et al.[38] demonstrated that ADF ROM varies widely, suggesting that the ankle-foot dorsiflexion index, calculated as the difference between ADF with the knee flexed and extended, may be of greater clinical relevance, showing considerably less variability.

The sensitivity analysis confirmed the robustness of the findings. The removal of the study by Silva et al.,[10] identified as an influential outlier, reduced the effect size from -0.39 to -0.18, but the non-significant result remained unchanged. This suggests that no single study unduly influenced the overall result. Furthermore, neither the rank correlation nor the regression tests indicated significant funnel plot asymmetry (p = 0.56 and p = 0.15, respectively), suggesting a low likelihood of publication bias.

There were several differences in the techniques used to measure ADF. Nevertheless, the findings from subgroup analyses suggest that neither knee position (extended or flexed) nor WB conditions provided conclusive evidence of differences in ADF among individuals with PFP and asymptomatic controls. To date, there is no other review available for direct comparison with our results. However, we propose that possible explanations for these non-significant differences may include the biological variability inherent to human ADF,[38] as well as methodological limitations.[11]

The non-significant difference between the groups in the WB condition with the knee flexed in this study was unexpected. The assessment of maximal ADF in the WB condition with the knee flexed, such as in the lunge test, increases PFJ loading and may elicit or exacerbate PFP.[1,3,7] Although fear of pain during the performance of test movements was not considered in the studies included in the present review, a reduction in knee flexion during the lunge, and a consequent decrease in ADF ROM, would be expected in individuals with PFP compared with control groups, as a strategy to avoid discomfort. This hypothesis stems from the established interrelationship between the ankle and knee in the sagittal plane during movements in closed kinematic chain,[12] the evidence that individuals with PFP may exhibit reduced knee flexion during walking, running, and stair negotiation compared with healthy controls, potentially reflecting a compensatory movement strategy,[15] and from our clinical observations which suggest that the behaviour of individuals with PFP may align with the fear-avoidance model,[46] a perspective also shared by other authors.[34] Moreover, the results of Oliveira et al.´ study[6] suggest a strong association between kinesiophobia and reduced peak knee flexion during stair descent in women with PFP pain.

The observed divergence between active and passive ADF assessments suggests that these measurement approaches may capture fundamentally different constructs,[11] which could explain their differing associations with PFP. Active range of motion requires voluntary engagement and is thus susceptible to modulation by pain perception, motor control, and psychological readiness. The act of moving the ankle to its maximum range involves nearing the motor barrier, where discomfort or fear of exacerbating pain may inhibit the complete execution of voluntary movement.[4,6,11,13,34] The hypothesis regarding the influence of pain on active ADF outcomes may be supported by a recent systematic review and meta-analysis, which reported that kinesiophobia is moderately associated with reduced self-reported function in individuals with PFP.[4] Furthermore, Piva et al.[34] indicated that fear-avoidance beliefs were the strongest predictor of function and pain outcomes after rehabilitation in patients with PFP.

In contrast, passive dorsiflexion more directly reflects joint and soft tissue extensibility.[13] Among the four studies that assessed ADF passively, three conducted the assessment with the knee extended, a position influenced by the length of the gastrocnemius muscle.[16,38] Limited flexibility of the gastrocnemius reduces ADF with the knee extended. Piva et al.[9] investigated the association between PFP and gastrocnemius muscle tightness, as assessed through NWB active ADF dorsiflexion, and reported that individuals with PFP exhibited significantly reduced gastrocnemius flexibility. Sannasi et al.[47] investigated the same association using WB active assessment and reported a strong association between gastrocnemius tightness and PFP. Witvrouw et al.[29] also investigated the same association by measuring WB active ADF and reported that young athletes followed over a 2-year period who developed PFPS had decreased gastrocnemius flexibility. Given the results of these studies, a reduction in ADF with the knee extended would be expected in individuals with PFP compared to control groups. Moreover, Chan et al.[38] showed that gastrocnemius tightness in a large healthy adult sample was positively correlated with age and negatively correlated with physical activity. Therefore, it is possible that the greater passive ADF observed in individuals with PFPS may be influenced by natural inter-individual variability, a greater amount of mechanical force applied to the joint by the examiner in this group, or differences between groups in factors influencing joint mobility.[11,29,38,44,45]

Age, sex, and ethnicity are considered the primary biological factors influencing joint mobility.[44,45] While the age and sex were homogeneous between groups in most studies,[7-10,21,25,27-29,32] ethnicity was not reported. However, ethnic differences exist: Caucasians tend to exhibit lower ROM,[48,49] whereas African,[49,50] Asian,[49,51] and Arab[49,52] populations of similar age and sex show higher ROMs.

Moreover, evidence suggests that joint mobility may be influenced by transient contextual factors at the time of assessment. For instance, both stretching exercise habits, recent physical activity, and warm-up routines have been found to enhance joint ROM, while joint hypermobility may be reduced on the dominant side of the body, environmental temperature can influence the flexibility of muscles, ligaments, and tendons, thereby affecting joint mobility. Additionally, hormonal variations throughout the menstrual cycle are believed to influence knee joint laxity,[44,45] and scar tissue with adhesions may lead to hypomobility.[13] However, all studies lacked adequate control or reporting of factors directly related to ankle mobility, such as habitual calf stretching or ankle mobilisation, potentially affecting group homogeneity and outcomes.

Furthermore, the marked difference in inter-study heterogeneity, high in the active group and low in the passive group, may underscore the influence of WB conditions. Notably, 100% of the studies assessing passive ADF employed NWB conditions, whereas 70% of those evaluating active ADF did so under WB conditions, and the subgroup analysis of ADF under WB conditions showed higher heterogeneity (I^2 = 93.84%) than that under NWB conditions (I^2 = 78.84%). This can be explained by the fact that NWB ADF isolates motion at the talocrural joint.[9,53] In contrast, the WB ADF assesses tibial movement towards the ground, which results from the combined motion of the talocrural, subtalar, and midfoot joints.[35,38] This introduces multiple degrees of freedom to the ankle–foot complex, enabling diverse movement patterns and thereby increasing both the heterogeneity and absolute values of ADF.[7,9,38,53] Although NWB ADF tends to produce more consistent data, it is considered less clinically relevant, as it does not replicate the demands of most functional activities involving the lower limbs, given that it is performed in an open kinetic chain.[7,9,38,53] In contrast, WB ADF is regarded as more clinically meaningful, as it reflects the functional loading patterns experienced by the ankle–foot complex during daily life and sports movements.[35,38]

There are no known valid clinical tests for PFP currently.[3] According to Witvrouw et al.,[29] PFP may be indistinguishable from other knee pain, even for experienced clinicians. It presents a broad spectrum of clinical characteristics, and diagnosis is based on a cluster of signs and symptoms recommended in Clinical Practice Guidelines, following the ruling out of other pathoanatomical conditions.[3] However, some studies included in this review demonstrated inadequacies in the diagnostic process for PFP,[31-33] which may have influenced the results.

Our findings suggest that ADF ROM in individuals with PFP may not be significantly influenced by minimum pain duration, body mass, height, or BMI. This is consistent with the findings of Hoch and McKeon,[54] who reported no significant relationships between WB ADF and height or body mass in healthy adults, and with Chan et al.,[38] who also found no significant association between ADF and height or body weight in a population-based study.

Limitations

This meta-analysis has some limitations that should be considered when interpreting the results, including a lack of consistent high-quality evidence to support the findings. The biggest threats to internal validity were related to the possibility of selection bias, and the reporting of, and adjustment for, potential ADF ROM influences such as ethnicity, psychological factors, lifestyle habits, ambient temperature, and menstrual cycle phase. The absence of these data precluded the performance of a meta-regression to assess the influences of these variables on the meta-analysis results.

A subgroup analysis by sex could not be conducted, as the eight included studies enrolling both males and females did not present their results separately.[7,9,21,25,29,31-33] Likewise, subgroup analysis by level or type of physical activity was not feasible, as six studies did not report this variable[7,10,21,25,27,32] and two involved heterogeneous forms of physical or occupational activity.[9,29]

Limitations also included methodological heterogeneity in the assessment of ADF across studies. Furthermore, the exclusion of grey literature may have led to publication bias, although statistical tests did not detect funnel plot asymmetry.

Lastly, external validity is limited, as most studies focused on specific populations, such as athletes or adolescents, restricting the generalisability of the findings to the broader PFP population.

Clinical implications

Joint ROM is a fundamental component of movement-related functions. In musculoskeletal physical therapy practice, the assessment of ADF ROM has become increasingly common, with its limitation being associated with the presence of PFP. The principal clinical message is that the isolated assessment of ADF is insufficient to explain the occurrence of PFP, reinforcing the need for a comprehensive biomechanical evaluation incorporating proximal and distal kinetic chain factors.

Future directions

Therefore, to clarify the relationship between ADF and PFP, future research should: (1) Ensure that the PFP diagnosis was based on the recommendations outlined in the Clinical Practice Guidelines; (2) During range of motion testing, the examiner should carefully observe whether pain or tissue restriction predominates in limiting movement; (3) Identify and control internal and external factors that may influence ADF.

Conclusion

This meta-analysis did not demonstrate a statistically significant difference in maximum ADF between individuals with PFP and asymptomatic controls. Although active ADF assessments indicated a non-significant trend towards a reduction in the PFP group, and passive assessments suggested greater ADF, substantial heterogeneity and methodological variability among studies limit the ability to draw definitive conclusions.

Authors' contributions

KAMZ and LRM contributed to the study concept and design. KAMZ provided study supervision. ATMC, MBC, NNK, and KAMZ were responsible for data acquisition, screening of eligible papers, data extraction, and quality appraisal of the included papers. LRM performed the statistical analysis and data interpretation. All authors contributed to the drafting and critical revision of the final manuscript and approved its final version. The corresponding author attests that all listed authors meet the authorship criteria and that no others meeting the criteria have been omitted.

Data availability statement

Research data is not available.

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Supplemental material 1 - Reproducible searches for: Ankle dorsiflexion in patellofemoral pain: systematic review and meta-analysis

CINAHL (via EBSCOhost) (on 11 june 2024 and on 13 may 2025)

1. TI ("patellofemoral pain syndrome" OR ("patello femoral" (pain OR syndrome OR disorder)) OR (femoropatellar (pain OR syndrome OR disorder)) OR ("femoro patelar" (pain OR syndrome OR disorder)) OR (retropatellar (pain OR syndrome OR disorder)) OR ("retro patelar" (pain OR syndrome OR disorder)) OR (peripatellar (pain OR syndrome OR disorder)) OR ("peri patelar" (pain OR syndrome OR disorder)) OR pfps OR "anterior knee pain" OR "runners knee") OR AB ("patellofemoral pain syndrome" OR ("patello femoral" (pain OR syndrome OR disorder)) OR (femoropatellar (pain OR syndrome OR disorder)) OR ("femoro patelar" (pain OR syndrome OR disorder)) OR (retropatellar (pain OR syndrome OR disorder)) OR ("retro patelar" (pain OR syndrome OR disorder)) OR (peripatellar (pain OR syndrome OR disorder)) OR ("peri patelar" (pain OR syndrome OR disorder)) OR pfps OR "anterior knee pain" OR "runners knee").
2. TI ((ankle (range OR dorsiflexion OR motion OR angle)) OR (talocrural (range OR dorsiflexion OR motion OR angle)) OR (gastrocnemius (length* OR stretch* OR tight* OR flexibility OR short*)) OR (soleus (length* OR stretch* OR tight* OR flexibility OR short*)) OR (calf (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("plantar flexors" (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("triceps surae" (length* OR stretch* OR tight* OR flexibility OR short*))) OR AB ((ankle (range OR dorsiflexion OR motion OR angle)) OR (talocrural (range OR dorsiflexion OR motion OR angle)) OR (gastrocnemius (length* OR stretch* OR tight* OR flexibility OR short*)) OR (soleus (length* OR stretch* OR tight* OR flexibility OR short*)) OR (calf (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("plantar flexors" (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("triceps surae" (length* OR stretch* OR tight* OR flexibility OR short*))).
3. S1 AND S2.

COCHRANE Central Register of Controlled Trials (on 11 june 2024 and on 13 may 2025)

1. ("Patellofemoral Pain Syndrome" OR ("patello femoral" OR femoropatellar OR "femoro patelar" or retropatellar or "retro patelar" or peripatellar or "peri patelar" NEAR/2 (pain or syndrome or disorder)):ti,ab,kw OR PFPS:ti,ab,kw OR "anterior knee pain":ti,ab,kw OR (chondro* NEAR/2 patella*):ti,ab,kw OR "runner's knee":ti,ab,kw AND Trials.
2. ((Ankle OR Talocrural NEAR/2 (Range OR Dorsiflexion OR Motion OR Angle)) OR (Gastrocnemius OR Soleus OR Calf OR "Plantar Flexors" OR "Triceps Surae" NEAR/2 (Length* OR Stretch* OR Tight* OR Flexibility OR Short*))):ti,ab,kw AND Trials.
3. #1 AND #2 AND Trials.

EMBASE (embase.com) (on 11 june 2024 and on 13 may 2025)

1. 'patellofemoral pain syndrome':ab,ti OR (('patello femoral' NEAR/2 (pain OR syndrome OR disorder)):ab,ti) OR ((femoropatellar NEAR/2 (pain OR syndrome OR disorder)):ab,ti) OR (('femoro patelar' NEAR/2 (pain OR syndrome OR disorder)):ab,ti) OR ((retropatellar NEAR/2 (pain OR syndrome OR disorder)):ab,ti) OR (('retro patelar' NEAR/2 (pain OR syndrome OR disorder)):ab,ti) OR ((peripatellar NEAR/2 (pain OR syndrome OR disorder)):ab,ti) OR (('peri patelar' NEAR/2 (pain OR syndrome OR disorder)):ab,ti) OR pfps:ab,ti OR 'anterior knee pain':ab,ti OR 'runners knee':ab,ti.
2. ((ankle NEAR/3 (range OR dorsiflexion OR motion OR angle)):ab,ti) OR ((talocrural NEAR/3 (range OR dorsiflexion OR motion OR angle)):ab,ti) OR ((gastrocnemius NEAR/3 (length* OR stretch* OR tight* OR flexibility OR short*)):ab,ti) OR ((soleus NEAR/3 (length* OR stretch* OR tight* OR flexibility OR short*)):ab,ti) OR ((calf NEAR/3 (length* OR stretch* OR tight* OR flexibility OR short*)):ab,ti) OR (('plantar flexors' NEAR/3 (length* OR stretch* OR tight* OR flexibility OR short*)):ab,ti) OR (('triceps surae' NEAR/3 (length* OR stretch* OR tight* OR flexibility OR short*)):ab,ti).
3. #1 AND #2.

LILACS (BVS) (on 11 june 2024 and on 13 may 2025)

tw:("patellofemoral pain syndrome" OR ("patello femoral" (pain OR syndrome OR disorder)) OR (femoropatellar (pain OR syndrome OR disorder)) OR ("femoro patelar" (pain OR syndrome OR disorder)) OR (retropatellar (pain OR syndrome OR disorder)) OR ("retro patelar" (pain OR syndrome OR disorder)) OR (peripatellar (pain OR syndrome OR disorder)) OR ("peri patelar" (pain OR syndrome OR disorder)) OR pfps OR "anterior knee pain" OR "runners knee") AND ((ankle (range OR dorsiflexion OR motion OR angle)) OR (talocrural (range OR dorsiflexion OR motion OR angle)) OR (gastrocnemius (length* OR stretch* OR tight* OR flexibility OR short*)) OR (soleus (length* OR stretch* OR tight* OR flexibility OR short*)) OR (calf (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("plantar flexors" (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("triceps surae" (length* OR stretch* OR tight* OR flexibility OR short*))) AND (db:("LILACS")).

MEDLINE/PubMed (via National Library of Medicine) (on 11 june 2024 and on 13 may 2025)

("patellofemoral pain"[Title/Abstract:~2] OR "patellofemoral syndrome"[Title/Abstract:~2] OR "patello-femoral pain"[Title/Abstract:~2] OR "patello-femoral syndrome"[Title/Abstract:~2] OR "patellofemoral disorder"[Title/Abstract:~2] OR "patello-femoral disorder"[Title/Abstract:~2] OR "femoropatellar pain"[Title/Abstract:~2] OR "femoropatellar syndrome"[Title/Abstract:~2] OR "femoropatellar disorder"[Title/Abstract:~2] OR "femoro-patellar pain"[Title/Abstract:~2] OR "femoro-patellar syndrome"[Title/Abstract:~2] OR "femoro-patellar disorder"[Title/Abstract:~2] OR "retropatellar pain"[Title/Abstract:~2] OR "retropatellar syndrome"[Title/Abstract:~2] OR "retropatellar disorder"[Title/Abstract:~2] OR "retro-patellar pain"[Title/Abstract:~2] OR "retro-patellar syndrome"[Title/Abstract:~2] OR "retro-patellar disorder"[Title/Abstract:~2] OR "peripatellar pain"[Title/Abstract:~2] OR "peripatellar syndrome"[Title/Abstract:~2] OR "peripatellar disorder"[Title/Abstract:~2] OR "peri-patellar pain"[Title/Abstract:~2] OR "peri-patellar syndrome"[Title/Abstract:~2] OR "peri-patellar disorder"[Title/Abstract:~2] OR "PFPS"[Title/Abstract] OR "anterior knee pain"[Title/Abstract:~2] OR "runner's knee"[Title/Abstract:~0]) AND ("Ankle Range"[Title/Abstract:~2] OR "Ankle Dorsiflexion"[Title/Abstract:~2] OR "Ankle Motion"[Title/Abstract:~2] OR "Ankle Angle"[Title/Abstract:~2] OR "Talocrural Range"[Title/Abstract:~2] OR "Talocrural Dorsiflexion"[Title/Abstract:~2] OR "Talocrural Motion"[Title/Abstract:~2] OR "Talocrural Angle"[Title/Abstract:~2] OR "Gastrocnemius Length"[Title/Abstract:~2] OR "Gastrocnemius Lengthened"[Title/Abstract:~2] OR "Gastrocnemius Stretched"[Title/Abstract:~2] OR "Tight Gastrocnemius"[Title/Abstract:~2] OR "Gastrocnemius Tightness"[Title/Abstract:~2] OR "Tightened Gastrocnemius" [Title/Abstract:~2] OR "Gastrocnemius Flexibility"[Title/Abstract:~2] OR "Shortened Gastrocnemius"[Title/Abstract:~2] OR "Gastrocnemius Shortening"[Title/Abstract:~2] OR "Soleus Length"[Title/Abstract:~2] OR "Soleus Lengthened"[Title/Abstract:~2] OR "Soleus Stretched"[Title/Abstract:~2] OR "Tight Soleus"[Title/Abstract:~2] OR "Soleus Tightness"[Title/Abstract:~2] OR "Tightened Soleus"[Title/Abstract:~2] OR "Soleus Flexibility"[Title/Abstract:~2] OR "Shortened Soleus"[Title/Abstract:~2] OR "Soleus Shortening"[Title/Abstract:~2] OR "Calf Length"[Title/Abstract:~2] OR "Calf Lengthened"[Title/Abstract:~2] OR "Calf Stretched"[Title/Abstract:~2]OR "Tight Calf"[Title/Abstract:~2] OR "Calf Tightness"[Title/Abstract:~2] OR "Tightened Calf"[Title/Abstract:~2] OR "Calf Flexibility"[Title/Abstract:~2] OR "Shortened Calf"[Title/Abstract:~2] OR "Calf Shortening"[Title/Abstract:~2] OR "Plantar Flexors Length"[Title/Abstract:~2] OR "Plantar Flexors Lengthened"[Title/Abstract:~2] OR "Plantar Flexors Stretched"[Title/Abstract:~2] OR "Tight Plantar Flexors"[Title/Abstract:~2] OR "Plantar Flexors Tightness"[Title/Abstract:~2] OR "Tightened Plantar Flexors"[Title/Abstract:~2] OR "Plantar Flexors Flexibility"[Title/Abstract:~2] OR "Shortened Plantar Flexors"[Title/Abstract:~2] OR "Plantar Flexors Shortening"[Title/Abstract:~2] OR "Triceps Surae Length"[Title/Abstract:~2] OR "Triceps Surae Lengthened"[Title/Abstract:~2] OR "Triceps Surae Stretched"[Title/Abstract:~2]OR "Tight Triceps Surae"[Title/Abstract:~2] OR "Triceps Surae Tightness"[Title/Abstract:~2] OR "Tightened Triceps Surae"[Title/Abstract:~2] OR "Triceps Surae Flexibility"[Title/Abstract:~2] OR "Shortened Triceps Surae"[Title/Abstract:~2] OR "Triceps Surae Shortening"[Title/Abstract:~2]).

PEDro (via pedro.org.au) (on 11 june 2024 and on 13 may 2025)

"Patellofemoral pain" AND ankle.

SciELO (via scielo.org) (on 11 june 2024 and on 13 may 2025)

1. "patellofemoral pain syndrome" OR ("patello femoral" (pain OR syndrome OR disorder)) OR (femoropatellar (pain OR syndrome OR disorder)) OR ("femoro patelar" (pain OR syndrome OR disorder)) OR (retropatellar (pain OR syndrome OR disorder)) OR ("retro patelar" (pain OR syndrome OR disorder)) OR (peripatellar (pain OR syndrome OR disorder)) OR ("peri patelar" (pain OR syndrome OR disorder)) OR pfps OR "anterior knee pain" OR "runners knee".
2. (ankle (range OR dorsiflexion OR motion OR angle)) OR (talocrural (range OR dorsiflexion OR motion OR angle)) OR (gastrocnemius (length* OR stretch* OR tight* OR flexibility OR short*)) OR (soleus (length* OR stretch* OR tight* OR flexibility OR short*)) OR (calf (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("plantar flexors" (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("triceps surae" (length* OR stretch* OR tight* OR flexibility OR short*)).
3. #1 AND #2.

SCOPUS (via scopus.com) (on 11 june 2024 and on 13 may 2025)

1. "patellofemoral pain syndrome" OR ("patello femoral" W/2 (pain OR syndrome OR disorder)) OR (femoropatellar W/2 (pain OR syndrome OR disorder)) OR ("femoro patelar" W/2 (pain OR syndrome OR disorder)) OR (retropatellar W/2 (pain OR syndrome OR disorder)) OR ("retro patelar" W/2 (pain OR syndrome OR disorder)) OR (peripatellar W/2 (pain OR syndrome OR disorder)) OR ("peri patelar" W/2 (pain OR syndrome OR disorder)) OR pfps OR "anterior knee pain" OR "runners knee".
2. (ankle W/3 (range OR dorsiflexion OR motion OR angle)) OR (talocrural W/3 (range OR dorsiflexion OR motion OR angle)) OR (gastrocnemius W/3 (length* OR stretch* OR tight* OR flexibility OR short*)) OR (soleus W/3 (length* OR stretch* OR tight* OR flexibility OR short*)) OR (calf W/3 (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("plantar flexors" W/3 (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("triceps surae" W/3 (length* OR stretch* OR tight* OR flexibility OR short*)).
3. #1 AND #2.

SPORTDiscus (EBSCOhost) (on 11 june 2024 and on 13 may 2025)

1. TI ("patellofemoral pain syndrome" OR ("patello femoral" (pain OR syndrome OR disorder)) OR (femoropatellar (pain OR syndrome OR disorder)) OR ("femoro patelar" (pain OR syndrome OR disorder)) OR (retropatellar (pain OR syndrome OR disorder)) OR ("retro patelar" (pain OR syndrome OR disorder)) OR (peripatellar (pain OR syndrome OR disorder)) OR ("peri patelar" (pain OR syndrome OR disorder)) OR pfps OR "anterior knee pain" OR "runners knee") OR AB ("patellofemoral pain syndrome" OR ("patello femoral" (pain OR syndrome OR disorder)) OR (femoropatellar (pain OR syndrome OR disorder)) OR ("femoro patelar" (pain OR syndrome OR disorder)) OR (retropatellar (pain OR syndrome OR disorder)) OR ("retro patelar" (pain OR syndrome OR disorder)) OR (peripatellar (pain OR syndrome OR disorder)) OR ("peri patelar" (pain OR syndrome OR disorder)) OR pfps OR "anterior knee pain" OR "runners knee").
2. TI ((ankle (range OR dorsiflexion OR motion OR angle)) OR (talocrural (range OR dorsiflexion OR motion OR angle)) OR (gastrocnemius (length* OR stretch* OR tight* OR flexibility OR short*)) OR (soleus (length* OR stretch* OR tight* OR flexibility OR short*)) OR (calf (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("plantar flexors" (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("triceps surae" (length* OR stretch* OR tight* OR flexibility OR short*))) OR AB ((ankle (range OR dorsiflexion OR motion OR angle)) OR (talocrural (range OR dorsiflexion OR motion OR angle)) OR (gastrocnemius (length* OR stretch* OR tight* OR flexibility OR short*)) OR (soleus (length* OR stretch* OR tight* OR flexibility OR short*)) OR (calf (length* OR stretch* OR tight* OR flexibility OR short*)) OR

("plantar flexors" (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("triceps surae" (length* OR stretch* OR tight* OR flexibility OR short*))).

3. S1 AND S2.

Web of Science Core Collection (via webofscience.com) (on 11 june 2024 and on 13 may 2025)

1. "patellofemoral pain syndrome" OR ("patello femoral" (pain OR syndrome OR disorder)) OR (femoropatellar (pain OR syndrome OR disorder)) OR ("femoro patelar" (pain OR syndrome OR disorder)) OR (retropatellar (pain OR syndrome OR disorder)) OR ("retro patelar" (pain OR syndrome OR disorder)) OR (peripatellar (pain OR syndrome OR disorder)) OR ("peri patelar" (pain OR syndrome OR disorder)) OR pfps OR "anterior knee pain" OR "runners knee".

2. (ankle (range OR dorsiflexion OR motion OR angle)) OR (talocrural (range OR dorsiflexion OR motion OR angle)) OR (gastrocnemius (length* OR stretch* OR tight* OR flexibility OR short*)) OR (soleus (length* OR stretch* OR tight* OR flexibility OR short*)) OR (calf (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("plantar flexors" (length* OR stretch* OR tight* OR flexibility OR short*)) OR ("triceps surae" (length* OR stretch* OR tight* OR flexibility OR short*)).

3. #1 AND #2.

Supplemental material 2 - Risk of bias and certainty of evidence

Table S1 - Critical appraisal of case-control studies

Study	1	2	3	4	5	6	7	8	9	10	% Yes	LE
Barton et al., 2010[1]	Y	Y	Y	Y	Y	N	N	Y	UN	Y	90	III
Hassan et al., 2022[2]	Y	Y	Y	Y	Y	N	N	Y	UN	Y	70	III
Manojlović et al., 2022[3]	Y	Y	Y	Y	Y	N	N	Y	UN	Y	90	III
Messier et al., 1991[4]	Y	Y	Y	Y	Y	N	N	N	UN	Y	60	III
Molgaard et al., 2011[5]	Y	Y	Y	Y	Y	N	N	UN	UN	Y	80	III
Piva et al., 2005[6]	Y	Y	Y	Y	Y	N	N	Y	UN	Y	80	III
Rodrigues et al., 2023[7]	Y	Y	Y	Y	Y	N	N	Y	UN	Y	90	III
Silva et al., 2018[8]	Y	Y	Y	Y	Y	N	N	Y	UN	Y	80	III
Steinberg et al., 2017[9]	Y	Y	Y	Y	Y	N	N	Y	UN	Y	90	III

Note: LE = level of evidence; N = no; UN = unclear; Y = yes. Joanna Briggs Institute tools for case control studies items: (1) Were the groups comparable other than the presence of disease in cases or the absence of disease in controls? (2) Were cases and controls matched appropriately? (3) Were the same criteria used for identification of cases and controls? (4) Was exposure measured in a standard, valid and reliable way? (5) Was exposure measured in the same way for cases and controls? (6) Were confounding factors identified? (7) Were strategies to deal with confounding factors stated? (8) Were outcomes assessed in a standard, valid and reliable way for cases and controls? (9) Was the exposure period of interest long enough to be meaningful? (10) Was appropriate statistical analysis used?

Table S2 - Critical appraisal of case-control studies

Study	1	2	3	4	5	6	7	8	% Yes	LE
Branco et al., 2022[10]	Y	Y	Y	UN	N	N	Y	Y	87.5	III
Emamvirdi et al., 2023[11]	Y	Y	Y	Y	N	N	Y	Y	75.0	III

Note: LE = level of evidence; N = no; UN = unclear; Y = yes. Joanna Briggs Institute tools for cross-sectional studies items: (1) Were the criteria for inclusion in the sample clearly defined? (2) Were the study subjects and the setting described in detail? (3) Was the exposure measured in a valid and reliable way? (4) Were objective, standard criteria used for measurement of the condition? (5) Were confounding factors identified? (6) Were strategies to deal with confounding factors stated? (7) Were the outcomes measured in a valid and reliable way? (8) Was appropriate statistical analysis used?

Table S3 - Critical appraisal of cohort studies

Study	1	2	3	4	5	6	7	8	9	10	11	% Yes	LE
Witvrouw et al., 2000[12]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	90.9	I

Note: LE = level of evidence; N = no; UN = unclear; Y = yes. Joanna Briggs Institute tools for cohort studies items: (1) Were the two groups similar and recruited from the same population? (2) Were the exposures measured similarly to assign people to both exposed and unexposed groups? (3) Was the exposure measured in a valid and reliable way? (4) Were confounding factors identified? (5) Were strategies to deal with confounding factors stated? (6) Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)? (7) Were the outcomes measured in a valid and reliable way? (8) Was the follow up time reported and sufficient to be long enough for outcomes to occur? (9) Was follow up complete, and if not, were the reasons to loss to follow up described and explored? (10) Were strategies to address incomplete follow up utilized? (11) Was appropriate statistical analysis used?

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