



Lateral wedge insoles and foot orthoses for medial knee osteoarthritis: a systematic review of pain and the knee adduction moment

Cuñas laterales y ortesis plantares para la osteoartritis medial de rodilla: revisión sistemática del dolor y del momento de aducción

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ABSTRACT

Lateral wedge insoles and foot orthoses aim to unload the medial tibiofemoral compartment and reduce pain in medial knee osteoarthritis, but their clinical and biomechanical benefit remains uncertain. Randomized, crossover, quasi-experimental and cohort studies reporting pain, function or the knee adduction moment were included. Risk of bias was assessed with the RoB 2 tool and a checklist derived from JBI. A total of 630 records were identified, 345 were screened and 55 studies were included. Lateral wedge insoles consistently reduced the knee adduction moment immediately, most often by 4 to 25 percent at the first peak and with a dose response to wedge angle, but the effect varied widely between participants. Effects on pain were small and inconsistent: most placebo controlled trials found no advantage over neutral insoles, whereas one prescreened trial reported a reduction of 0.7 points on a 0 to 10 scale. Conclusions: Lateral wedge insoles and foot orthoses unload the medial compartment biomechanically but provide only small and inconsistent symptomatic benefit, and the response appears restricted to identifiable subgroups of patients.

Keywords: knee osteoarthritis; lateral wedge insole; foot orthoses; knee adduction moment; pain.

RESUMEN

Introducción: Las cuñas laterales y las ortesis plantares buscan descargar el compartimento tibiofemoral medial y reducir el dolor en la osteoartritis medial de rodilla, pero su beneficio clínico y biomecánico sigue siendo incierto. Se incluyeron ensayos aleatorizados, cruzados, cuasiexperimentales y de cohortes que informaran dolor, función o el momento de aducción de la rodilla. El riesgo de sesgo se evaluó con la herramienta RoB 2 y una lista derivada del JBI. Se identificaron 630 registros, se cribaron 345 y se incluyeron 55 estudios. Las cuñas laterales redujeron de forma consistente el momento de aducción de la rodilla de inmediato, con mayor frecuencia entre 4 y 25 por ciento en el primer pico y con una relación dosis respuesta con el ángulo de la cuña, aunque el efecto varió mucho entre participantes. Los efectos sobre el dolor fueron pequeños e inconsistentes: la mayoría de los ensayos controlados con placebo no hallaron ventaja frente a las plantillas neutras, mientras que un ensayo con preselección comunicó una reducción de 0,7 puntos en una escala de 0 a 10. Conclusiones: Las cuñas laterales y las ortesis plantares descargan el compartimento medial desde el punto de vista biomecánico, pero ofrecen un beneficio sintomático pequeño e inconsistente, y la respuesta parece restringirse a subgrupos identificables de pacientes.

Palabras clave: osteoartritis de rodilla; cuña lateral; ortesis plantares; momento de aducción de la rodilla; dolor.

INTRODUCTION

Osteoarthritis of the knee is among the most disabling musculoskeletal conditions worldwide, and its burden rises steadily as the population ages and as obesity becomes more prevalent. Estimates from the Global Burden of Disease have placed hip and knee osteoarthritis among the leading contributors to years lived with disability, and the knee accounts for the greater share of that burden.⁽¹⁾ The medial tibiofemoral compartment bears most of the load transmitted through the joint during walking, which explains why isolated medial disease is the most common radiographic pattern in clinical practice. The external knee adduction moment, the product of the frontal plane ground reaction force and its lever arm relative to the knee joint centre, has long served as the principal biomechanical surrogate of medial compartment loading, because a higher moment reflects a more medial position of the resultant force.⁽²⁾ The relationship between this moment and the patient experience of pain is, however, modest and inconsistent, a point that has been quantified in recent syntheses of the biomechanical literature.⁽³⁾

Lateral wedge insoles and foot orthoses are inexpensive, non invasive devices that were designed to unload the medial compartment through the foot. A lateral wedge tilts the foot into eversion, moves the centre of pressure toward the lateral side of the shoe and shortens the frontal plane lever arm of the ground reaction force, all of which lower the external knee adduction moment measured in the gait laboratory.⁽⁴⁾ Foot orthoses prescribed for medial knee osteoarthritis usually combine a lateral wedge with a medial arch support, a subtalar strap or, more recently, custom geometry produced by three dimensional printing, and each of these design choices is expected to modify both the magnitude and the inter individual reproducibility of the unloading effect.^(5,6) The theoretical appeal of the approach is strong: because the wedge acts upstream of the knee through the foot, it does not require muscle strength or adherence to an exercise programme, and it can be worn throughout the day inside ordinary footwear. The trade off is that the same wedge that unloads the medial compartment also everts the ankle and rearfoot, which may displace load toward the lateral ankle structures or toward the patellofemoral joint, and this is one of the mechanisms proposed to explain why some patients do not tolerate or do not benefit from the device.⁽⁷⁾

The published evidence is discordant, and this is precisely why the intervention remains controversial. Meta analyses of randomised trials concluded that lateral wedge insoles do not produce a clinically meaningful reduction in knee pain, even though they consistently reduce the adduction moment in laboratory studies.^(4,5) Earlier systematic reviews reached similarly cautious conclusions about the efficacy of laterally wedged insoles,⁽⁸⁾ and a systematic review restricted to placebo controlled comparisons reached the same conclusion.⁽⁹⁾ The Cochrane review of braces and orthoses judged the evidence to be of low certainty.⁽¹⁰⁾ Large randomised trials found no symptomatic advantage of a lateral wedge over a neutral insole at twelve months,⁽¹¹⁾ and early crossover studies from the preceding decade had already suggested that the pain benefit was at best modest.^(12,13) A more recent trial that first excluded biomechanical non responders before randomisation reported a small but statistically significant pain benefit,⁽¹⁴⁾ which re opened the debate about whether the devices fail on average because they are offered to the wrong patients. Since 2015 the literature has therefore shifted from the question of whether lateral wedge insoles work on average toward two narrower questions, namely which patients respond and which insole design achieves the most reliable unloading, and this recent evidence has not been brought together in a synthesis confined to the past decade. The same period saw the spread of responder analysis, three dimensional printed orthoses and wearable sensors for gait monitoring, developments that make a dedicated synthesis of the 2015 to 2024 evidence timely even though several earlier reviews exist.

The objective of this systematic review was to synthesise the evidence published between 2015 and 2024 on the effects of lateral wedge insoles and foot orthoses in adults with medial knee osteoarthritis. The review had three specific objectives: to describe the design, population and methodological quality of the included studies; to determine whether these devices reduce self reported knee pain and physical function; and to determine whether they reduce the knee adduction moment and related surrogates of medial knee load.

METHODS

This systematic review was conducted and reported according to the PRISMA 2020 statement.⁽¹⁵⁾

Studies were eligible when they enrolled adults with medial tibiofemoral knee osteoarthritis; evaluated a lateral wedge insole or a foot orthosis intended to unload the medial compartment; compared the device with a neutral or flat insole, a sham device, no device, usual care or another orthosis; and reported at least one of knee pain, self reported physical function or the knee adduction moment or a related measure of medial load.

Randomised trials, crossover trials, quasi experimental studies and prospective cohorts were included. Reviews, protocols, editorials, case reports, computational studies without human participants and studies that enrolled only healthy participants were excluded. Publications had to fall between 2015 and 2024 and to provide an English or Spanish title and abstract. Studies were not excluded on the basis of the wedge angle, the type of foot orthosis or the choice of comparator, so that the full range of designs used in clinical practice was captured.

Scopus, PubMed, OpenAlex and Crossref were searched. The core search combined population and intervention terms with a publication year filter, for example in Scopus: TITLE-ABS-KEY("lateral wedge" AND "knee osteoarthritis") AND PUBYEAR > 2014 AND PUBYEAR < 2025. Equivalent queries used "foot orthoses", "laterally wedged", "knee adduction moment" and "valgus insole" as variants, and the same strategy was adapted to the syntax of each database. In full, the five core queries were TITLE-ABS-KEY("lateral wedge" AND "knee osteoarthritis"), TITLE-ABS-KEY("laterally wedged" AND knee), TITLE-ABS-KEY("foot orthoses" AND "knee osteoarthritis"), TITLE-ABS-KEY("knee adduction moment" AND (insole OR orthoses OR wedge)) and TITLE-ABS-KEY("valgus insole" AND knee), each combined with the publication year filter. Supplementary searches for contextual and methodological literature used the terms "medial knee osteoarthritis", "knee adduction moment", "meta-analysis" and "biomechanics" without a lower date limit.

One reviewer extracted, for each included study, the design, country, sample size, population, intervention, comparator, outcomes and the main result with its estimate, using the full text when it was openly accessible and the abstract otherwise. Data were recorded in a structured table and were not re extracted independently, so extraction errors cannot be excluded.

The extraction form recorded first author and year, country, design, sample characteristics, the insole or orthosis specification including wedge angle, arch support, subtalar strap and manufacturing method, the comparator, the outcome measures and their time points, and the main quantitative result. Percentage changes in the adduction moment and in pain scores were transcribed as reported by the authors and were not recalculated. When a study reported several outcome domains, the pain, function and knee adduction moment results were prioritised for the narrative synthesis.

Randomised trials were assessed with the revised Cochrane risk of bias tool, RoB 2.⁽¹⁶⁾ Crossover and quasi experimental biomechanical studies, cohorts and cross sectional analyses were assessed with a domain based checklist derived from the JBI appraisal instruments, covering selection, confounding, measurement and completeness of outcome reporting. Each study received an overall judgement of low, some concerns or high risk of bias. No study was excluded solely for risk of bias.

RESULTS

Study selection

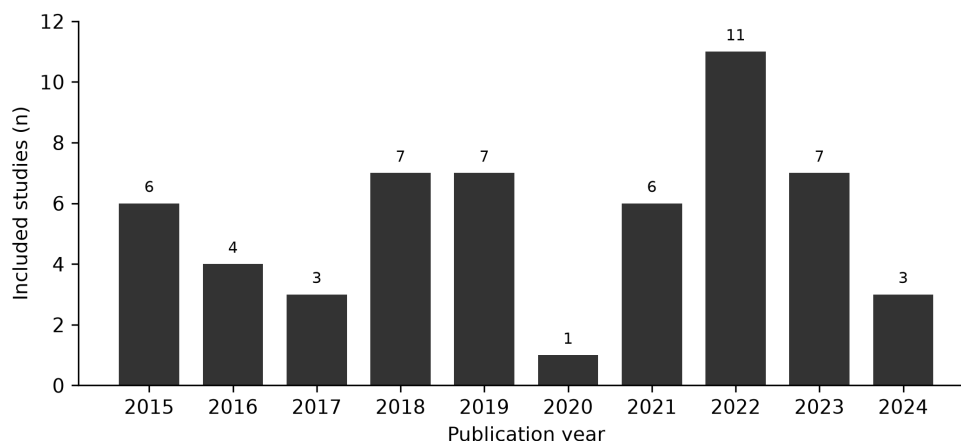
The database searches identified 630 records, distributed across Scopus, PubMed, OpenAlex and Crossref, and 285 duplicate records were removed. Of the 345 records screened by title and abstract, 267 were excluded, most because they evaluated a different population, a different intervention such as a knee brace or a gait modification, or because they were reviews or protocols. The eligibility of 78 reports was then assessed in detail and 23 were excluded: seventeen because no usable outcome data were accessible in the abstract, four because they were duplicate reports of the same study, one because it lacked a verifiable identifier and one because the population was not described. Fifty five studies met the inclusion criteria and were carried forward to the synthesis.

Characteristics of the included studies

The 55 included studies were published between 2015 and 2024, with the largest number appearing in 2022 (Figure 1). The designs comprised twelve parallel group randomised trials, six randomised crossover trials, sixteen repeated measures biomechanical laboratory experiments, eleven quasi experimental or single arm studies, four prospective cohorts and six case control or cross sectional analyses. Sample sizes ranged from 8 to 90 participants, and most studies enrolled

fewer than 40.

Figure 1. Included studies by publication year.



Note: The largest number of included studies was published in 2022. Source: Elaboration from the data extraction.

The settings reported in the largest numbers were Iran (8 studies), Japan(7), Pakistan(4), Germany (3) and the United Kingdom(3), with additional studies from Brazil, Canada, India, Italy and Taiwan (2 each) and single studies from the United States, Egypt, Bangladesh and Hong Kong; sixteen studies did not state the country. Outcome instruments varied widely. Pain was measured with a visual analogue scale, the WOMAC pain subscale or the KOOS pain subscale in the majority of the clinical studies, whereas the biomechanical studies reported the first and second peaks and the impulse of the external knee adduction moment, normalised to body weight and height in most cases. Medial meniscus extrusion was quantified by ultrasound in a subset of Japanese studies, and balance was quantified with centre of pressure variables, the Timed Up and Go test or static posturography. Lateral wedge insoles varied in inclination from 2 to 11 degrees and were combined in different studies with a medial arch support, a subtalar strap or a valgus knee brace, whereas the foot orthoses ranged from prefabricated wedges to custom and three dimensional printed devices (Table 1). The comparator conditions were correspondingly diverse, including neutral or flat insoles, barefoot or shoe only walking, valgus knee braces, ankle foot orthoses, conventional physiotherapy and no treatment, which complicates direct comparison across studies.

Risk of bias of the included studies

One double blind randomised trial was judged at low risk of bias. The remaining randomised and crossover trials carried some concerns, driven by absent or unclear blinding, small samples and selective reporting, and twenty studies, chiefly quasi experimental and cohort designs without a randomised comparator, were judged at high risk of bias (Table 2). In the biomechanical crossover experiments, masking of the gait assessor to the insole condition was not reported, and many analyses presented immediate laboratory outcomes rather than patient centred end points. Attrition and pre specified primary outcomes were described inconsistently across the abstracts, and few studies justified their sample size. Reporting heterogeneity also limited quantitative synthesis: studies expressed the adduction moment in different units, some as an external moment normalised to body weight and height and others as an internal contact force estimated from musculoskeletal models, and pain was reported on visual analogue, numerical and WOMAC or KOOS scales with follow up ranging from a single session to six months, so effect sizes could not be harmonised across the evidence base.

Lateral wedge insoles versus neutral insoles on knee pain and function

The contrast between a lateral wedge insole and a neutral or flat insole was tested most directly in randomised trials, and the symptomatic advantage was small or absent. The trial that first excluded patellofemoral osteoarthritis and biomechanical non responders found that the lateral wedge reduced pain on a 0 to 10 scale by 0.7 points compared with the neutral insole (95% confidence interval 0.1 to 1.2), an effect its authors judged clinically relevant in only a minority of patients.(14)By contrast, a twelve week trial of insoles tailored by gait analysis found no between group difference in pain intensity (mean difference -12.5 mm, 95% confidence interval -29.4 to 4.4) or in the knee adduction moment, and only the KOOS subscale of other symptoms favoured the

wedge.(17)A trial of lateral wedge insoles with subtalar strapping improved symptoms and function over twenty four weeks but was not superior to a placebo insole at any time point.(18)Studies without a placebo comparator reported more favourable results. Lateral wedges added to physiotherapy reduced pain and improved quality of life over six weeks, with a KOOS pain score that rose from 79.95 to 91.5 in the wedge group against 79.95 to 81.8 in the control group.(19)A double blind trial of 90 participants found that a soft lateral wedge arch support insole improved KOOS pain ($P = 0.008$), stair ascent time, daily living function and quality of life more than a rigid insole over three months.(20)Adding a wedge insole to routine physiotherapy produced a between group difference of 1.55 points on the numeric pain scale and 5.53 points on the WOMAC at three weeks in favour of the wedge.(21)An Egyptian study of 48 knees found that a lateral wedge insole and a subtalar strapped wedge both improved the WOMAC and plantar pressure peaks relative to physiotherapy alone over four months.(22)A Pakistani single blind comparison reported a large effect of the wedge on the KOOS pain subscale (eta squared 0.559), although conventional physiotherapy improved functional domains more.(23)In a quasi experimental comparison of two orthoses, pain decreased immediately after walking with either device ($P < 0.001$) and remained improved at one month, without a difference in the external adduction moment between the two devices.(24)A randomised trial that added a lateral wedge insole to pharmacotherapy and quadriceps exercise in Bangladesh reported a greater improvement in the WOMAC physical function subscale at eight weeks than pharmacotherapy and exercise alone.(25)Quasi experimental and pre post studies from Iran, Pakistan, India and Bangladesh likewise reported reductions in pain and improvement in the WOMAC or KOOS after two to eight weeks, although most lacked a neutral insole control. (22,23,25-29)In a four week study restricted to early radiographic disease, the insole reduced pain and shortened the Timed Up and Go and one leg balance times relative to baseline (all $P < 0.001$). (29)In a crossover comparison, the lateral wedge improved pain by 17 percent and function by 11 percent, both less than a biaxial ankle foot orthosis.(30)A secondary analysis of a crossover study quantified the insole pain effect as a median change of -0.5 points (range -5 to +6) on a numerical rating scale, and showed that greater varus malalignment predicted smaller pain relief, with a response cut off at a mechanical axis deviation of roughly 14 to 15 mm.(31)A six month randomised comparison reported that an unloader brace improved KOOS pain ($P = 0.002$) and symptoms more than a lateral wedge insole, whereas the insole produced better quality of life subscale scores.(32)Within subject comparisons that combined a lateral wedge with a knee brace showed that pain relief was driven largely by the brace rather than by the insole, and that the insole alone produced no significant pain change in some experiments.(33-36)A six week comparison found that the combination of a custom lateral wedge insole and a valgus brace reduced pain and improved walking velocity, cadence and satisfaction more than either device used alone.(35)

Knee adduction moment and medial compartment load

Biomechanical unloading was the most consistent finding. Compared with walking without an insole, lateral wedge insoles reduced the first peak of the external knee adduction moment in most studies, with reported reductions that ranged from 4 to 25 percent.(30,37-41)The effect was dose dependent. Increments from 2 to 10 degrees produced progressively larger reductions in the first and second peaks and in the impulse, and angles greater than 2 degrees were sufficient to induce statistically significant change in 38 patients.(42)In a personalised series of three dimensional printed orthoses, full length devices unloaded the knee more than three quarter length designs, and higher posting angles reduced the first and second peaks and the impulse in a graded fashion (all $P < 0.001$). (43)A randomised comparison of five walking conditions in 70 participants confirmed that lateral wedge insoles reduced the early stance adduction moment and the angular impulse relative to a control shoe, whereas a mobility shoe had no effect on loading but did reduce immediate pain.(38)When a lateral wedge was combined with a valgus knee brace, the concurrent use of the two devices reduced the first peak vertical ground reaction force by 6 percent and the peak external adduction moment by 25 percent in 24 men with varus medial knee osteoarthritis.(39)Single visit experiments reported that adding a wedge to a brace and a toe out or toe in gait modification produced the largest first and second peak reductions, in the range of 7 to 26 percent, although the combinations also increased fall risk and reduced comfort on dynamic balance platforms.(36,44)One crossover reported that the insole alone produced no change in pain during these short term tests.(36)In a six week follow up of older adults with bilateral disease, the immediate reduction in the adduction moment with a seven degree wedge was accompanied by improved WOMAC pain and physical function, and a gait adaptation persisted when the insoles were removed.(37)Three dimensional printed orthoses shifted the

centre of pressure laterally by 2.71 mm and reduced the first and second peak moments by 4.08 percent and 9.09 percent.(41)The magnitude was nonetheless small and highly variable between participants, and two independent analyses quantified a minority of non responders in whom the moment increased rather than decreased. An ancillary analysis of a randomised trial found that 33 percent of participants increased their adduction moment with the insole while 67 percent decreased it,(45)and subject specific musculoskeletal models reported changes in medial contact force ranging from -12 to +10 percent without a consistent dose response.(46)The unloading also decayed over time in one secondary analysis, which observed a 4 percent reduction in the peak moment at baseline but no biomechanical effect after six weeks of wear.(47)Responsiveness was related to participant characteristics. Biomechanical responders walked faster, were female, and had less varus and less severe radiographic disease in a predictive analysis of 53 patients,(48)and greater hindfoot and frontal plane ankle mobility attenuated the insole effect, with a moderate negative correlation between hindfoot valgisation and adduction moment reduction.(49,50) Static foot structure alone did not predict the biomechanical response in 30 patients.(51)Wearable sensor studies added a clinical correlate of the same unloading signal: the lateral wedge reduced lateral thrust and improved gait variability over one month of use, aligning the free living measurements with the laboratory adduction moment data.(52)Studies that looked beyond the external moment to internal joint parameters gave a similar picture. In weight bearing MRI, lateral wedge insoles increased the medial tibiofemoral contact area relative to a flat control ($P \leq 0.012$) without changing the lateral compartment,(53)and a kinematic chain analysis in eight patients found that the reduction in lateral thrust with a wedge correlated with the hindfoot to lower leg kinematic chain ratio ($r = 0.74$). (50)

Foot orthoses with arch support, straps and custom designs

Adding a medial arch support to a lateral wedge did not nullify the unloading effect in most experiments, although one randomised study reported that a customised arch support without a lateral wedge increased the adduction moment during loading response by 7 percent, which cautions against prescribing arch support alone in medial knee osteoarthritis.(54) Arch supported wedges reduced the second peak of the adduction moment by more than 6 percent without a measurable change in pain or comfort.(54,55) Unilateral eleven degree wedges reduced and delayed the impact ground reaction force, whereas bilateral use at the same angle increased impact loading, a distinction that has practical implications for patients with bilateral disease.(56)A subtalar strap added to a wedged insole produced no additional kinetic change in mild disease,(57)and one piece and two piece custom foot orthoses were biomechanically equivalent in their effect on knee loading and ankle eversion.(55)In comparisons against an ankle foot orthosis, the insole unloaded the knee less than the orthosis: the insole reduced the first maximum of the external adduction moment by 6 percent and the angular impulse by 5 percent, whereas the orthosis reduced them by 18 percent and 11 percent.(40)Both devices improved the Oxford Knee Score, and no clinical superiority of either could be shown.(30,40) Greater varus malalignment predicted smaller pain relief with the insole, with a response cut off at a mechanical axis deviation of about 14 to 15 mm.(31)

Medial meniscus extrusion and postural control

Several Japanese ultrasound studies used medial meniscus extrusion as a surrogate of medial compartment stress. Lateral wedge insoles reduced weight bearing extrusion immediately and during gait, and the reduction correlated with immediate pain relief.(58,59) The effect was confined to early radiographic disease and to patients who wore the insole for more than five hours per day, a subgroup that also showed less radiographic progression at one year, with extrusion falling from 3.9 to 2.6 mm in long duration wearers compared with 3.8 to 3.6 mm in short duration wearers.(60,61) In a real time ultrasound study, the insole reduced extrusion and walking pain simultaneously (both $P < 0.01$), and the participants whose pain improved showed larger reductions in extrusion than the non responders.(58)Studies of postural control were generally favourable in the medium term. Static balance and gait variability improved after four weeks to six months of insole use, whereas immediate effects on balance were small, and a lateral wedge reduced the lever arm of the ground reaction force in quiet standing by 12.8 mm, an effect that a medial arch support partly attenuated.(26,32,52,62)A six month randomised comparison found that both a lateral wedge and an unloader brace improved balance, although the brace improved balance and pain more than the insole.(32)In a case control study of gait initiation in early knee osteoarthritis, the insole increased the length and velocity of the centre of pressure trajectory during the locomotor phase relative to barefoot walking,(63)and a Japanese study of gait initiation reported improved anterior

displacement of the centre of pressure with the insole in the medial knee osteoarthritis group.(64)

DISCUSSION

The expectation that a demonstrable reduction in the knee adduction moment would translate into a proportionate reduction in knee pain was only partly confirmed. Lateral wedge insoles and foot orthoses unload the medial compartment of the knee reliably and in a dose dependent manner in the laboratory, but the magnitude of unloading is small, it is not reproduced in every participant and it does not translate into a consistent symptomatic benefit. This contrast between a robust biomechanical signal and a weak clinical signal is the central finding of the review, and it is the same contrast that the field has been trying to reconcile since the first randomised trials of wedged insoles were published.(12,13)

The biomechanical results agree with earlier meta analyses, which estimated small immediate reductions in the first peak of the adduction moment of roughly 5 to 8 percent with lateral wedge insoles,(5,71) and with studies showing that arch supported and higher angle wedges augment the effect.(7,72) The absence of a consistent relationship between static foot posture and the biomechanical response, observed in the included studies, agrees with the broader literature on footwear and insoles, which has repeatedly failed to find simple anthropometric predictors of unloading.(51)The present review adds the observation, derived from studies published after 2015, that the dose response extends to custom and three dimensional printed orthoses,(41,43) and that a sizable minority of patients are biomechanical non responders in whom the moment increases rather than decreases.(45,46) This heterogeneity is not random. Responders tend to walk faster, to be female, to have less varus and less severe disease, and to have limited frontal plane ankle mobility, whereas participants with greater hindfoot flexibility unload the knee more with an ankle foot orthosis than with an insole.(48,49) The same individualisation was anticipated by early work that titrated the wedge angle to the patient(73)and by comparisons showing that braces and insoles do not unload the knee equally.(74)These modifiers explain part of the discrepancy between laboratory efficacy and the null results of clinical trials. A further source of inconsistency lies in the comparison condition and the duration of follow up. Studies that used a neutral insole sham found smaller effects than those that compared the wedge with no treatment, and immediate laboratory measurements, which are insensitive to habituation and to clinical relevance, overstate the benefit relative to measurements taken after weeks of wear. The outcome instrument matters as well. The adduction moment responds to a wedge within minutes, whereas pain and function integrate loading, inflammation, central sensitisation and expectation over time, so a concordance between the two is not guaranteed and was in fact rarely observed in the included studies.(3)The finding that the unloading effect can disappear after six weeks while symptoms remain stable illustrates how the early biomechanical response cannot be read as a proxy for clinical outcome.(47)

The pain findings align with the conclusion of the Cochrane review and of the largest meta analysis that a lateral wedge insole does not confer a clinically meaningful average pain benefit over a neutral insole,(4,10) and with a systematic review restricted to placebo controlled comparisons.(9)They also extend the negative result of the twelve month Bennell trial, in which a lateral wedge was no better than a control insole, to the smaller trials published over the past decade.(11,17,18)The one prescreened trial that reported a statistically significant advantage found a between group difference of only 0.7 points on a 0 to 10 scale, an effect that its authors considered clinically relevant in only a minority of patients.(14)Across the placebo controlled comparisons, the point estimates for pain clustered around zero to one point on the numerical scales, and none of the differences reached the commonly proposed minimal clinically important difference for knee osteoarthritis. Studies that lacked a neutral insole control reported larger and more optimistic improvements,(20,26) which illustrates how the absence of a sham comparator inflates the apparent benefit of a device whose main effect may be contextual. Whereas the neutral insole arms of the randomised trials also improved, the uncontrolled studies could not separate the wedge from attention, expectation and the passage of time. The narrative reviews and year in review summaries of the period reached broadly the same reading of this literature.(6,75,76)Taken together, the certainty of the evidence for an average pain benefit is low, because the randomised comparisons are few, mostly unblinded and imprecise, whereas the certainty of the biomechanical evidence is moderate, because the direction of the adduction moment reduction is reproducible across independent laboratories even though its magnitude is modest. This asymmetry in certainty between the biomechanical and the clinical questions is itself informative: it indicates that the failure of the device is not primarily a failure to unload the knee, but a failure of unloading, at the magnitude

that is achieved, to translate into symptom relief. A similar reading emerges from the studies that tested the insole and a valgus knee brace head to head, in which the brace generally unloaded the knee and relieved pain more than the insole,^(32,74,77) which suggests that the marginal clinical value of the insole is real but small relative to other unloader devices.

For future trials, three design features would materially improve the evidence. First, the comparator should always be a neutral insole of identical appearance, because uncontrolled and brace comparison designs overstate the benefit. Second, the outcome set should pair a patient reported pain measure with the adduction moment measured before and after a habituation period, so that the biomechanical and clinical responses can be examined together in the same participants. Third, the analysis should be stratified by the baseline variables that predict response, particularly varus alignment, hindfoot mobility and gait speed, rather than reporting only the group mean. Trials designed in this way would answer the question that the current literature only begins to address, which is not whether the average patient benefits but which patient benefits.

For clinical practice, the findings support a cautious and selective use of lateral wedge insoles. The devices are inexpensive and safe, and they can be offered to patients who understand that the expected pain relief is small, that benefit is more likely in early disease and in less varus knees, and that a proportion of patients will not unload the knee at all. The prescription should favour a full length wedge of at least 5 degrees, with an arch support when comfort requires it, and should avoid arch support alone, which can increase loading in some patients.⁽⁵⁴⁾ Unilateral use should be preferred when the contralateral knee is less symptomatic, given the adverse impact loading observed with bilateral eleven degree wedges.⁽⁵⁶⁾ The dose response to wedge angle also suggests that the angle should be titrated to the individual rather than applied as a fixed prescription, a principle that was proposed in early studies of subject specific wedging⁽⁷³⁾ and that the more recent predictive work on responders now makes actionable.⁽⁴⁸⁾ For research, the priority is to replicate the prescreening approach, in which a gait based confirmation of unloading precedes randomisation, and to test whether predicted responders achieve clinically meaningful pain relief in adequately powered trials.^(14,45) The same logic applies to the newer custom and three dimensional printed designs, which promise personalisation but have not yet been shown to outperform standard wedges on symptoms.^(41,43) Because the expected benefit is modest and the devices are low cost and low risk, shared decision making is appropriate, with the patient informed that the wedge is a trial of therapy whose value should be judged against individual symptoms after a few weeks rather than assumed in advance.

CONCLUSIONS

The available evidence indicates that lateral wedge insoles and foot orthoses reduce the knee adduction moment and medial knee load immediately and in a dose dependent manner in adults with medial knee osteoarthritis, although the effect is small, variable and not maintained in every participant. These devices provide only a small and inconsistent reduction in knee pain and no consistent advantage in physical function over neutral insoles, and the symptomatic benefit appears confined to identifiable subgroups. Unloading of the medial meniscus and improvements in postural control are reported mainly in early disease, which supports the selective, personalised use of these orthoses rather than their routine prescription.

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SUPPLEMENTARY MATERIAL

Table 1. Characteristics of the 55 included studies.

Study	Design	Country	Sample	Intervention and comparator	Main finding
Hsu <i>et al.</i> , 2015 ⁽³⁷⁾	prospective pre-post (6 weeks)	Taiwan	n = 22	7-degree laterally wedged insoles with arch support; barefoot; baseline	Insole reduced KAM immediately; after 6 weeks pain and function improved and a barefoot gait adaptation persisted.
Duivenvoorden <i>et al.</i> , 2015 ⁽⁴⁷⁾	secondary analysis of randomised trial	Not stated	n = 80 analysed	laterally wedged insole; valgus knee brace	Insole reduced peak KAM by 4% at baseline (95% CI -0.147 to -0.03) but showed no biomechanical effect after 6 weeks.
Fu <i>et al.</i> , 2015 ⁽⁶⁵⁾	prospective cohort (sequential interventions)	Hong Kong	n = 10	lateral-wedged insole with or without strap/arch support; flat insole	Lateral-wedged insole reduced WOMAC pain 19.1% ($p = 0.04$) and peak/mean KAM versus flat insole; arch-support version reduced VAS 24.1%.
Chapman <i>et al.</i> , 2015 ⁽⁴⁵⁾	ancillary analysis of randomised trial (silk)	UK	n = 70	lateral wedge insole; control shoe	67% decreased EKAM with the insole; ankle eversion at peak EKAM predicted the biomechanical response.
Jones <i>et al.</i> , 2015 ⁽³⁸⁾	randomised trial (within-subject conditions)	UK	n = 70	lateral wedge insoles (typical and supported); control shoe; mobility shoe; barefoot	Lateral wedge insoles significantly reduced early-stance EKAM and KAAI versus control shoe; mobility shoe reduced pain.
Campos <i>et al.</i> , 2015 ⁽¹⁸⁾	randomised clinical trial	Brazil	n = 58	lateral wedge insole with subtalar strapping; neutral insole with strapping	Both groups improved WOMAC at weeks 8 and 24; lateral wedge was not superior to the neutral insole.
Dessery <i>et al.</i> , 2016 ⁽⁵⁵⁾	repeated-measures	Italy	n = 17	two-piece vs one-piece lateral foot orthoses; without orthosis	One- and two-piece orthoses had equivalent effects on knee loading and ankle eversion versus no orthosis.
El Megeid Abdallah <i>et al.</i> , 2016 ⁽⁵⁶⁾	within-subject	Not stated	n = 33	laterally wedged insoles with arch supports (unilateral/bilateral, 6/11 degrees); without insole	Unilateral 11-degree insoles reduced and delayed impact loading; bilateral 11 degrees increased impact force.
Hsieh <i>et al.</i> , 2016 ⁽²⁰⁾	double-blind randomised controlled trial	Taiwan	n = 90	rigid vs soft lateral wedge arch support insoles; between insole types	Soft lateral wedge arch support insoles improved KOOS pain ($p = 0.008$), function and quality of life more than rigid at 3 months.
Akbari <i>et al.</i> , 2016 ⁽⁶²⁾	quasi-experimental	Iran	n = 13	lateral wedge, medial arch support and their combination; barefoot	Lateral wedge reduced the knee lever arm significantly versus barefoot ($p = 0.005$); adding arch support attenuated the effect.
Dessery <i>et al.</i> , 2017 ⁽⁵⁴⁾	randomised single-blind study	Italy	n = 18	laterally wedged insoles (6 and 10 degrees) with arch support;	Wedge conditions reduced second peak KAM by more than 6% ($p < 0.001$);

				customised foot orthosis without wedge	arch support alone increased loading-response KAM by 7%.
Ishii <i>et al.</i> , 2017 ⁽⁵⁹⁾	case-control plus intervention	Japan	n = 18 (31 knees)	lateral wedge insole; standing without insole; controls	Insole significantly reduced meniscus extrusion in standing knee OA patients, not in controls.
Allan <i>et al.</i> , 2017 ⁽⁴³⁾	repeated-measures (randomised conditions)	UK	n = 10 (plus 10 controls)	3d-printed foot orthoses (full/three-quarter, 5-10-degree posting); 0-degree neutral orthosis	Full-length orthoses and higher wedging reduced first and second peak KAM and impulse; responses were heterogeneous.
Khan <i>et al.</i> , 2018 ⁽³⁶⁾	repeated-measures	Not stated	n = 20	full-length 5-degree laterally wedged insole, alone or combined; no intervention	Insole alone did not change pain; combined with toe-in it reduced second peak KAM 12% but decreased dynamic balance.
Mirzaei <i>et al.</i> , 2018 ⁽⁶⁶⁾	quasi-experimental (3 groups)	Not stated	n = 18	lateral wedge insole; valgus knee brace; combined	Insole alone significantly reduced KAM; combined insole plus brace produced the greatest KAM reduction.
Esfandiari <i>et al.</i> , 2018 ⁽²⁹⁾	quasi-experimental pre-post (4 weeks)	Iran	n = 20 (plus 19 controls)	5-degree lateral wedge insole; baseline; healthy controls	Insole reduced pain and fall risk and increased quality of life after four weeks ($p < 0.001$).
Lewinson <i>et al.</i> , 2018 ⁽⁵¹⁾	cross-sectional plus intervention	Not stated	n = 30	medial and lateral wedge footwear insoles; between-wedge conditions	Static foot structure was not associated with KAM or with the biomechanical response to wedged insoles.
Jafarnezhadgero <i>et al.</i> , 2018 ⁽³⁹⁾	repeated-measures	Iran	n = 24	lateral foot wedges, alone or with valgus knee brace; no device	Combined wedges plus brace reduced first peak vertical GRF 6% and peak external KAM 25% ($p = 0.019$).
Khan <i>et al.</i> , 2018 ⁽²⁵⁾	randomised prospective trial	Bangladesh	n = 65	lateral wedge shoe insole added to pharmacotherapy and exercise; pharmacotherapy and exercise alone	Adding the lateral wedge insole produced greater WOMAC physical function improvement at 8 weeks.
Zangi <i>et al.</i> , 2018 ⁽²⁶⁾	quasi-experimental pre-post (4 weeks)	Iran	n = 18	lateral wedged insole; barefoot; shoes without insole	No immediate balance effect; after 4 weeks pain and mediolateral balance improved ($p < 0.001$).
Felson <i>et al.</i> , 2019 ⁽¹⁴⁾	randomised crossover trial (prescreened)	USA	n = 62 analysed	lateral wedge insole; neutral insole	Insole reduced knee pain by 0.7 points (95% CI 0.1 to 1.2; $p = 0.02$) versus neutral insole; small effect.
Salam <i>et al.</i> , 2019 ⁽¹⁹⁾	randomised controlled trial	Pakistan	n = 40	lateral wedge with conventional physiotherapy; conventional physiotherapy alone	Lateral wedge plus physiotherapy reduced pain and symptoms and improved quality of life over 6 weeks.
Mannisi <i>et al.</i> , 2019 ⁽⁴⁶⁾	repeated-measures with musculoskeletal modelling	Not stated	n = 7 (plus 8 controls)	subject-specific 3d-printed lateral wedge insoles (5 and 10 degrees); 0-degree shell	Insoles did not significantly reduce medial contact force; inter-subject variability ranged from -12% to +10%.

Esfandiari <i>et al.</i> , 2019 ⁽⁵⁷⁾	repeated-measures	Iran	n = 17	lateral wedge insole with arch support, with and without subtalar strap; no insole	No immediate kinetic changes except a small knee flexion angle increase early in stance.
Khan <i>et al.</i> , 2019 ⁽⁴⁴⁾	repeated-measures (single visit)	Not stated	n = 24	laterally wedged insole, alone or with brace and toe-out gait; natural gait	Insole contributed to first-peak KAM reduction; triple combination reduced second peak KAM 25.55% but increased fall risk.
Katoh <i>et al.</i> , 2019 ⁽⁶⁴⁾	case-control plus intervention	Japan	n = 10 (plus 10 controls)	lateral wedge insole; barefoot; healthy controls	Insole improved anterior centre-of-pressure displacement at gait initiation in knee OA.
Hamed <i>et al.</i> , 2019 ⁽²²⁾	quasi-experimental (3 groups)	Egypt	n = 48 knees	lateral wedge insole with or without subtalar strap; conventional physiotherapy	Both insole groups improved WOMAC and plantar pressure versus physiotherapy after 4 months.
Esfandiari <i>et al.</i> , 2020 ⁽⁶³⁾	case-control plus intervention	Iran	n = 21 (plus 19 controls)	lateral wedge insole (immediate and 4 weeks); barefoot; healthy controls	Insole increased centre-of-pressure length and velocity during the locomotor phase versus barefoot.
Ferreira <i>et al.</i> , 2021 ⁽¹⁷⁾	randomised single-blind controlled trial	Brazil	n = 38	tailored lateral wedge insole (2-10 degrees); neutral (0-degree) insole	No significant between-group differences after 12 weeks (pain difference -12.5 mm, 95% CI -29.4 to 4.4).
Lin <i>et al.</i> , 2021 ⁽⁴¹⁾	repeated-measures	Not stated	n = 15	3d-printed foot orthoses; standard shoes alone	3D-printed orthoses reduced first and second peak KAM by 4.08% and 9.09% with lateral COP shift.
Khosravi <i>et al.</i> , 2021 ⁽³⁵⁾	randomised controlled trial (3 groups)	Not stated	n = 21	full-length custom lateral wedge insole with arch support; valgus knee brace; combined	Combined insole plus brace reduced peak KAM more (30%) and improved pain and gait parameters at 6 weeks.
Ishii <i>et al.</i> , 2021 ⁽⁶⁰⁾	prospective cohort (non-randomised groups)	Japan	n = 39	lateral wedge insole for 3 months; control without insole	Weight-bearing meniscus extrusion decreased at 3 months only in early OA (KL grade 2).
Schwarze <i>et al.</i> , 2021 ⁽⁴⁰⁾	block-randomised crossover trial	Germany	n = 39	laterally wedged insole; ankle-foot orthosis	Insole reduced both eKAM peaks by 6% and KAAI by 5%; both aids improved OKS with no clinical superiority.
Pandey <i>et al.</i> , 2021 ⁽⁶⁷⁾	cross-sectional study	India	n = 56	lateral wedge insole, alone or with valgus knee brace; barefoot	No significant change in vertical GRF or varus angle; only maximum GRF during initial stance differed.
Ishii <i>et al.</i> , 2022 ⁽⁵⁸⁾	prospective cohort	Japan	n = 25	lateral wedge insole; with vs without insole	Insole reduced meniscus extrusion and walking pain ($p < 0.01$); responders had larger extrusion reductions.
Ferreira <i>et al.</i> , 2022 ⁽⁴²⁾	repeated-measures (randomised order)	Not stated	n = 38	lateral wedge insoles 2-10 degrees; 0-degree control insole	Incremental first-peak KAM reduction with wedging; angles above 2 degrees produced significant changes.

Robert-Lachaine <i>et al.</i> , 2022 ⁽³³⁾	repeated-measures	Canada	n = 10	7-degree lateral wedge foot orthoses with knee braces; brace alone; no treatment	Foot orthoses added little to the valgus-external rotation brace; pain relief was not significant in any modality.
Dwarakanathan <i>et al.</i> , 2022 ⁽³²⁾	randomised controlled trial	Not stated	n = 66	full-length 6-degree lateral wedge insole; unloader knee brace	Both improved balance and function; the brace improved balance and pain more than the insole over 6 months.
Falahatgar <i>et al.</i> , 2022 ⁽²⁴⁾	quasi-experimental pretest-posttest	Iran	n = 29	lateral wedge with subtalar strap (barefoot) vs wedged insole in sandal; between-orthosis comparison	Pain decreased immediately with both orthoses ($p < 0.001$); no EKAM difference; both improved at one month.
Barati <i>et al.</i> , 2022 ⁽³⁰⁾	randomised crossover trial	Iran	n = 31	lateral wedge insole; biaxial ankle-foot orthosis	Insole improved pain 17%, function 11%, first-peak KAM 15.7% and KAM impulse 14.8%; AFO improved more.
Bartsch <i>et al.</i> , 2022 ⁽⁴⁹⁾	randomised crossover trial	Germany	n = 20	laterally wedged insole; ankle-foot orthosis	KAM reduction with the insole correlated negatively with hindfoot valgisation ($r = -0.31$); insole suited patients with limited frontal-plane ankle mobility.
Bartsch <i>et al.</i> , 2022 ⁽³¹⁾	secondary analysis of randomised crossover study	Germany	n = 28	5-mm laterally wedged insole; ankle-foot orthosis; baseline	Insole reduced pain versus baseline (median change -0.5); greater varus predicted smaller pain relief ($p = 0.003$).
Riaz <i>et al.</i> , 2022 ⁽²³⁾	single-blind pretest-posttest comparison	Pakistan	n = 40	lateral wedge insole; conventional physical therapy	Insole improved all KOOS domains (pain eta-squared 0.559); physical therapy improved more.
Kumar <i>et al.</i> , 2022 ⁽²⁷⁾	pretest-posttest	India	n = 20	10-degree lateral wedge sole; baseline (pre-post)	Pain improved significantly after the wedge; gait speed did not change.
Mohammad Shah <i>et al.</i> , 2022 ⁽²¹⁾	randomised controlled trial	Pakistan	n = 80	routine physiotherapy plus wedge insole; routine physiotherapy alone	Adding wedge insoles improved pain (mean difference 1.55; $p = 0.05$) and WOMAC (5.53; $p < 0.001$) at 3 weeks.
Hunt <i>et al.</i> , 2023 ⁽⁴⁸⁾	cross-sectional exploratory (predictor analysis)	Not stated	n = 53	standalone and arch-supported lateral wedge insoles; responders vs non-responders	Responders walked faster, were female, and had less varus and less severe radiographic OA.
Okamoto <i>et al.</i> , 2023 ⁽⁶⁸⁾	repeated-measures	Japan	n = 25	lateral wedge insoles with or without toe-out gait; normal gait	All interventions reduced the meniscus extrusion increase and second KAM peak versus normal gait, without synergy.
Jaques <i>et al.</i> , 2023 ⁽⁶⁹⁾	repeated-measures	Not stated	n = 10	four different insoles; between-insole conditions	Insole changes affected six gait variables with high inter-patient heterogeneity; $\geq 36.7\%$ of changes were medium-to-large.

Ishii <i>et al.</i> , 2023 ⁽⁵²⁾	prospective single-arm with healthy control	Not stated	n = 15 (plus 13 controls)	lateral wedge insole; baseline; healthy controls	Stance-duration variability and lateral thrust decreased after one month, matching control values.
Hsu <i>et al.</i> , 2023 ⁽⁷⁰⁾	randomised controlled trial	Not stated	n = 40	lateral-wedge insole; ordinary (flat) insole	Lateral-wedge insoles kept plantar pressure stable over 20 weeks, whereas the ordinary insole shifted load to the forefoot.
Edo <i>et al.</i> , 2023 ⁽⁵⁰⁾	repeated-measures (small)	Japan	n = 8	lateral wedge insoles (5 and 10 degrees); barefoot; neutral insole	Kinematic chain ratio correlated with lateral thrust reduction with the insole (r = 0.74).
Faim <i>et al.</i> , 2023 ⁽²⁸⁾	cross-sectional survey	Pakistan	n = 62	lateral heel wedge; pre-post clinical survey	Lateral heel wedge showed symptomatic effectiveness, with higher use among women and older adults.
Robert-Lachaine <i>et al.</i> , 2024 ⁽³⁴⁾	randomised crossover trial (level i)	Canada	n = 22	lateral wedge foot orthoses, alone or with a valgus-external rotation brace; knee brace; combined	Foot orthoses reduced pain and KAM less than the brace after 3 months; all modalities improved function (ES > 0.2).
Ishii <i>et al.</i> , 2024 ⁽⁶¹⁾	prospective cohort	Japan	n = 23	lateral wedge insole by daily wear duration; short (<5 h) vs long (>5 h) wear	Long-duration wear maintained medial meniscus extrusion reduction at 1 year (3.9 to 2.6 mm) and slowed OA progression.
Tse <i>et al.</i> , 2024 ⁽⁵³⁾	repeated-measures biomechanical (mri weightbearing)	Not stated	n = 15	lateral wedge insole with and without arch support; flat control insole	Medial contact area increased with both lateral wedge conditions versus control (P ≤ 0.012).

Note: KAM = knee adduction moment; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index; KOOS = Knee injury and Osteoarthritis Outcome Score; VAS = visual analogue scale; MME = medial meniscus extrusion.

Source: Elaborated from the data extraction of the included studies.

Table 2. Risk of bias of the included studies.

Study	Design	Overall risk of bias
Hsu <i>et al.</i> , 2015 ⁽³⁷⁾	prospective pre-post (6 weeks)	some concerns
Duivenvoorden <i>et al.</i> , 2015 ⁽⁴⁷⁾	secondary analysis of randomised trial	some concerns
Fu <i>et al.</i> , 2015 ⁽⁶⁵⁾	prospective cohort (sequential interventions)	high
Chapman <i>et al.</i> , 2015 ⁽⁴⁵⁾	ancillary analysis of randomised trial (silk)	some concerns
Jones <i>et al.</i> , 2015 ⁽³⁸⁾	randomised trial (within-subject conditions)	some concerns
Campos <i>et al.</i> , 2015 ⁽¹⁸⁾	randomised clinical trial	some concerns
Dessery <i>et al.</i> , 2016 ⁽⁵⁵⁾	repeated-measures	some concerns
El Megeid Abdallah <i>et al.</i> , 2016 ⁽⁵⁶⁾	within-subject	some concerns
Hsieh <i>et al.</i> , 2016 ⁽²⁰⁾	double-blind randomised controlled trial	low
Akbari <i>et al.</i> , 2016 ⁽⁶²⁾	quasi-experimental	high
Dessery <i>et al.</i> , 2017 ⁽⁵⁴⁾	randomised single-blind study	some concerns
Ishii <i>et al.</i> , 2017 ⁽⁵⁹⁾	case-control plus intervention	high
Allan <i>et al.</i> , 2017 ⁽⁴³⁾	repeated-measures (randomised conditions)	some concerns
Khan <i>et al.</i> , 2018 ⁽³⁶⁾	repeated-measures	some concerns
Mirzaei <i>et al.</i> , 2018 ⁽⁶⁶⁾	quasi-experimental (3 groups)	high
Esfandiari <i>et al.</i> , 2018 ⁽²⁹⁾	quasi-experimental pre-post (4 weeks)	high
Lewinson <i>et al.</i> , 2018 ⁽⁵¹⁾	cross-sectional plus intervention	some concerns
Jafarnejhadgero <i>et al.</i> , 2018 ⁽³⁹⁾	repeated-measures	some concerns
Khan <i>et al.</i> , 2018 ⁽²⁵⁾	randomised prospective trial	some concerns
Zangi <i>et al.</i> , 2018 ⁽²⁶⁾	quasi-experimental pre-post (4 weeks)	high
Felson <i>et al.</i> , 2019 ⁽¹⁴⁾	randomised crossover trial (prescreened)	some concerns
Salam <i>et al.</i> , 2019 ⁽¹⁹⁾	randomised controlled trial	some concerns
Mannisi <i>et al.</i> , 2019 ⁽⁴⁶⁾	repeated-measures with musculoskeletal modelling	some concerns
Esfandiari <i>et al.</i> , 2019 ⁽⁵⁷⁾	repeated-measures	some concerns
Khan <i>et al.</i> , 2019 ⁽⁴⁴⁾	repeated-measures (single visit)	some concerns
Katoh <i>et al.</i> , 2019 ⁽⁶⁴⁾	case-control plus intervention	high
Hamed <i>et al.</i> , 2019 ⁽²²⁾	quasi-experimental (3 groups)	high
Esfandiari <i>et al.</i> , 2020 ⁽⁶³⁾	case-control plus intervention	high
Ferreira <i>et al.</i> , 2021 ⁽¹⁷⁾	randomised single-blind controlled trial	some concerns
Lin <i>et al.</i> , 2021 ⁽⁴¹⁾	repeated-measures	some concerns
Khosravi <i>et al.</i> , 2021 ⁽³⁵⁾	randomised controlled trial (3 groups)	some concerns
Ishii <i>et al.</i> , 2021 ⁽⁶⁰⁾	prospective cohort (non-randomised groups)	high
Schwarze <i>et al.</i> , 2021 ⁽⁴⁰⁾	block-randomised crossover trial	some concerns
Pandey <i>et al.</i> , 2021 ⁽⁶⁷⁾	cross-sectional study	high
Ishii <i>et al.</i> , 2022 ⁽⁵⁸⁾	prospective cohort	high
Ferreira <i>et al.</i> , 2022 ⁽⁴²⁾	repeated-measures (randomised order)	some concerns
Robert-Lachaine <i>et al.</i> , 2022 ⁽³³⁾	repeated-measures	some concerns
Dwarakanathan <i>et al.</i> , 2022 ⁽³²⁾	randomised controlled trial	some concerns
Falahatgar <i>et al.</i> , 2022 ⁽²⁴⁾	quasi-experimental pretest-posttest	high

Barati <i>et al.</i> , 2022 ⁽³⁰⁾	randomised crossover trial	some concerns
Bartsch <i>et al.</i> , 2022 ⁽⁴⁹⁾	randomised crossover trial	some concerns
Bartsch <i>et al.</i> , 2022 ⁽³¹⁾	secondary analysis of randomised crossover study	some concerns
Riaz <i>et al.</i> , 2022 ⁽²³⁾	single-blind pretest-posttest comparison	high
Kumar <i>et al.</i> , 2022 ⁽²⁷⁾	pretest-posttest	high
Mohammad Shah <i>et al.</i> , 2022 ⁽²¹⁾	randomised controlled trial	some concerns
Hunt <i>et al.</i> , 2023 ⁽⁴⁸⁾	cross-sectional exploratory (predictor analysis)	high
Okamoto <i>et al.</i> , 2023 ⁽⁶⁸⁾	repeated-measures	some concerns
Jaques <i>et al.</i> , 2023 ⁽⁶⁹⁾	repeated-measures	some concerns
Ishii <i>et al.</i> , 2023 ⁽⁵²⁾	prospective single-arm with healthy control	high
Hsu <i>et al.</i> , 2023 ⁽⁷⁰⁾	randomised controlled trial	some concerns
Edo <i>et al.</i> , 2023 ⁽⁵⁰⁾	repeated-measures (small)	high
Faim <i>et al.</i> , 2023 ⁽²⁸⁾	cross-sectional survey	high
Robert-Lachaine <i>et al.</i> , 2024 ⁽³⁴⁾	randomised crossover trial (level i)	some concerns
Ishii <i>et al.</i> , 2024 ⁽⁶¹⁾	prospective cohort	high
Tse <i>et al.</i> , 2024 ⁽⁵³⁾	repeated-measures biomechanical (mri weightbearing)	some concerns

Note: Overall judgements follow the RoB 2 categories of low, some concerns and high risk of bias.

Source: Elaborated with the RoB 2 tool for randomised trials and a JBI derived checklist for the remaining designs.