

Lateral Wedging of the Foot

A Scoping Review

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Lateral wedges are a common intervention used to alter biomechanical function of the lower limb. Although there is evidence investigating the use and impact of lateral wedges in individuals with medial knee osteoarthritis, knowledge of how these wedges affect foot function in healthy adults is limited. Therefore, this study intends to investigate how lateral wedging affects foot function in healthy adults and, furthermore, how wedge design influences the outcome. The framework outlined by Arksey and O'Malley was used for this scoping review. To ensure methodologic quality and transparent reporting, the study adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews preferred reporting guidelines. A systematic search was conducted using MEDLINE by means of EBSCO; SPORT Discuss; CINAHL; AMED by means of OVID; and Scopus. The initial search yielded 252 articles in total; 21 studies were included in the final analysis. Significant incongruence exists in descriptions of wedge length among the 21 included studies. Thirteen studies (61%) reported using full-length wedges, five studies did not report wedge length, and only one study analyzed more than one wedge length. Ethylene vinyl acetate was the most common material, and reporting of hardness was inconsistent. A broad range of inclination angles were used, with limited explanation for why these values were selected. All but one study that analyzed ankle/subtalar joint frontal plane moments reported an increase in the external eversion moment. The review identified significant variation in the design of wedges used within this body of work and a lack of investigation into the influence of wedge design. Wedge design appears to be a secondary consideration, with very few studies examining multiple material types or wedge placements. All but one of the included studies reported a significant change in ankle/subtalar joint moments with lateral wedging. Unfortunately, further generalization was not possible because of the inconsistency and variation. (*J Am Podiatr Med Assoc* 113(5), 2023)

Lateral wedging, also known as valgus wedging, is a common conservative intervention used by health professionals as part of a management plan aimed at altering biomechanical function in the lower limb. Lateral wedges are created by sloping material so that the lateral side is thicker than the medial side and the gradient between is a uniform incline. These are

typically added to an orthotic, an otherwise flat insole, or on occasion to the midsole of a shoe,¹ with the goal being to change foot function. The biomechanical effect of lateral wedges has been most frequently examined by research investigating medial knee osteoarthritis (OA)^{2,3} and lateral ankle instability.^{4,5}

The seminal work from Merton Root and his colleagues, now known as Root theory, appears to have been the first theoretical explanation for lateral wedging.⁶ According to Root et al,⁶ abnormal alignment of the foot, such as forefoot valgus, leads to compensatory movement, which may increase an individual's risk of injury. In this example, Root theory would recommend clinicians build a wedge of equal size to the structural imbalance, and place this under the lateral aspect of the forefoot, thus "balancing" the rearfoot

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and forefoot and preventing compensation. Recently however, the concept of subtalar joint (STJ) neutral, a central theme discussed in Root theory, has been challenged.^{7,8} Many of the assessments within Root theory, including forefoot position, are static and non-weightbearing. Concerns have been raised over the value of these assessments when it comes to designing orthoses to be used dynamically.^{7,8} Given the paucity of other theoretical explanations, this leads us to question the conceptual reasons behind lateral wedge prescription in practice.

When designing and fabricating underfoot interventions such as orthoses or insole modifications, the materials used may impact kinematic and kinetic outcomes.⁹⁻¹² In healthy populations, material selection has been shown to affect plantar pressure, modify contact areas, and elicit mechanical change.⁹⁻¹² Therefore, appropriate choice of materials appears to be important for clinical interventions to be effective. In a recent systematic review on the effect of different orthotic materials on plantar pressures, Gerrard et al¹⁰ suggested that it is essential for all clinicians who prescribe orthoses to have access to robust evidence examining the effects of material selection.

Despite evidence reporting the effects of lateral wedging in individuals with medial knee OA, a systematic understanding of how lateral wedging affects foot function in healthy adults is lacking. Therefore, the purpose of this study was to investigate how lateral wedging affects foot function in healthy adults and, furthermore, how wedge design influences the outcome. Based on a precursory assessment of the evidence, a scoping review has been deemed the most suitable way to answer this question.

Methods

The framework outlined by Arksey and O'Malley¹³ was used for this scoping review: step 1, identifying the research question; step 2, identifying relevant studies; step 3, selecting the studies; step 4, charting the data; and step 5, collating, summarizing and reporting the results. To ensure methodologic quality and transparent reporting, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews preferred reporting guidelines were adhered to (Appendix 1).¹⁴ A comprehensive search was formulated and conducted by the first author (A.J.) in April of 2021 using MEDLINE by means of EBSCO; SPORT Discuss; CINAHL; AMED by means of OVID; and Scopus. Search strategy terms displayed in Table 1 were truncated using wildcard symbols to broaden

Table 1. Search Strategy Used for MEDLINE Through EBSCO^a

No.	Search
1	(MH "foot orthoses")
2	(MH "orthotic devices+") AND (foot OR feet OR ankle)
3	"lateral wedge" OR "valgus forefoot" OR "lateral forefoot" OR "valgus rearfoot" OR "valgus hindfoot" OR "lateral rearfoot post"
4	(orthotic* OR orthoses OR insole) n8 (foot OR feet OR ankle)
5	(MH "shoes")
6	3 AND 5
7	1 OR 2 OR 4
8	3 AND 7
9	6 OR 8

Abbreviation: MH, medical subject heading.

^aStrategy was modified for other databases.

the search and modified for each database. No limitation was placed on the date of publication.

At the outset of this review process, inclusion and exclusion criteria were developed to ensure that only relevant studies were included for analysis. As the search was developing and familiarity with the literature increased, these criteria were reviewed and refined. Studies were included if they measured kinetic or kinematic variables in the foot when a lateral wedge is placed under the foot, assessed the effect of lateral wedging during walking or running gait, used live human participants, and were published in English. Studies were excluded if they had no extractable data for "healthy" participants, involved participants younger than 18 years, measured the effect of lateral wedging during a sporting activity other than walking or running, or measured the effect of lateral wedging following a surgical intervention.

Reference management software EndNote version X9.3.1 (Clarivate Analytics, Philadelphia, Pennsylvania) was used for the screening and analysis phase of this review. Before screening, all duplicates were removed by EndNote and then checked, and manually completed by the principal investigator (A.J.). Two reviewers (A.J. and P.M.) independently screened all titles and abstracts against eligibility criteria. In cases of nonconsensus, a third author's opinion was planned for consultation (M.C.); however, this was not required. Reference lists of retrieved articles were searched for further potentially relevant studies. Following title and abstract screening, two reviewers (A.J. and P.M.) screened the full text of all remaining studies to compile a final list of included articles.

Data were charted using Microsoft Excel (Microsoft Corp, Redmond, Washington) to extract key information from the selected studies. This information included author(s), year of publication, study location, study population, wedge specifications (material, length, placement, and inclination), footwear conditions, gait type, outcome measures, and relevant findings. In some cases, studies compared a pathologic group to a healthy population. In these instances, only the relevant findings relating to the healthy group were extracted and charted.

Results

Selection and Characteristics of Studies

A total of 252 articles were retrieved for abstract review, with 21 studies satisfying the inclusion criteria included for final analysis (Fig. 1). Characteristics of these 21 included studies are presented in Table 2. Participant numbers ranged from eight to 50, with a mean age of 30.2 years. The date range of the publications spanned from 2003 to 2021, with 12 (57%) of the included studies

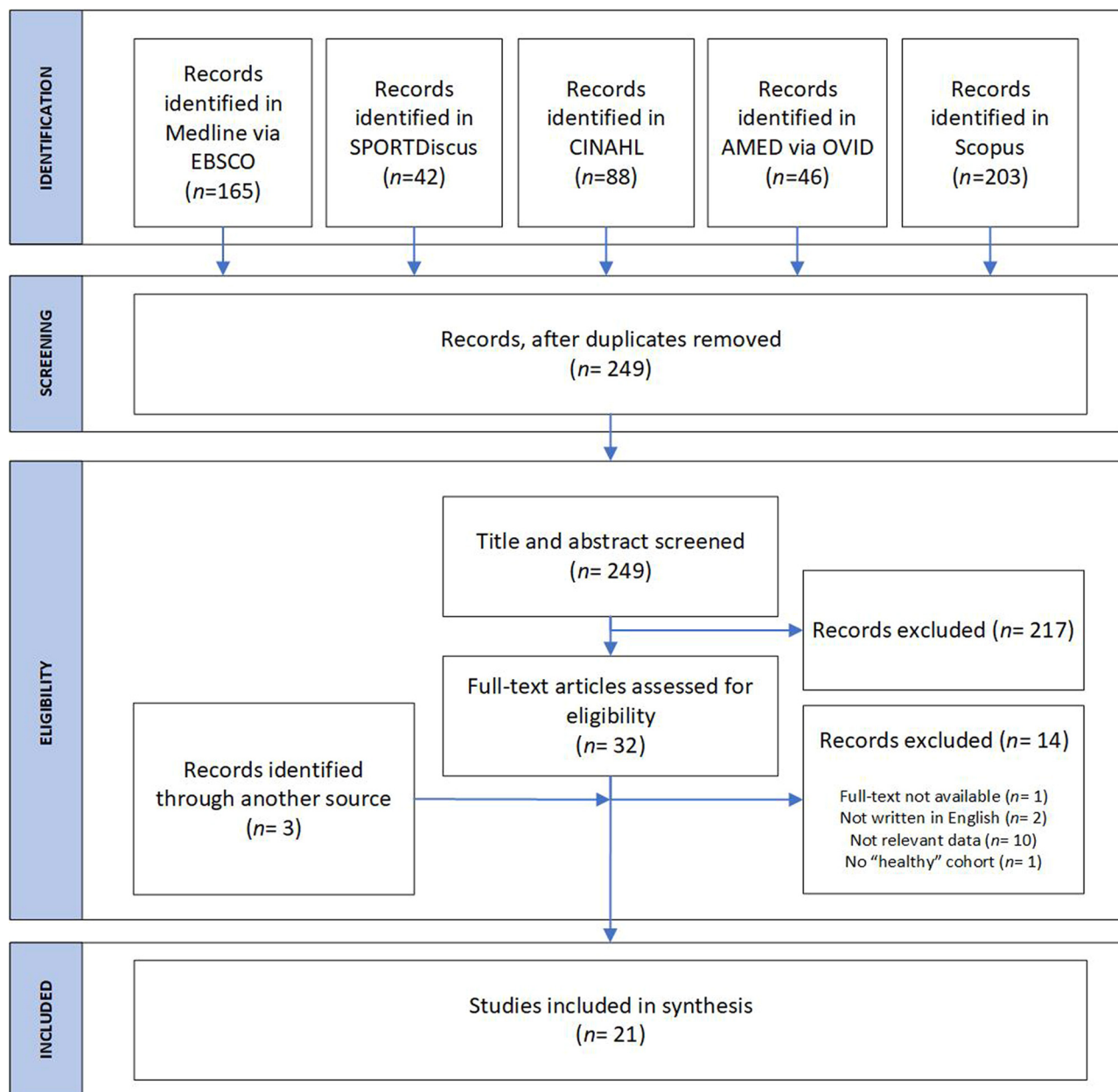


Figure 1. Flowchart diagram of literature search, screening, and selection.

Table 2. Demographic and Study Design Details of the Included Studies

Reference	No. of Participants	Comparison Group	Mean age ± SD	Female (%)	Gait Type	Gait Speed	Overground or Treadmill
Kakhiana et al ⁵	50	25 with lateral ankle instability 25 healthy controls	20.8 ± 1.3 20.7 ± 1.2	0 0	Walking	Self-selected	Overground
Kakhiana et al ¹⁵	26	13 with OA 13 healthy controls	63.3 ± 5.6 64.6 ± 2.3	100 100	Walking	Prescribed cadence (95 steps/min) Self-selected	Overground
Telfer et al ¹⁶	24	12 with pronated foot type and 12 controls with neutral feet	29.9 ± 8.7	50	Walking	Self-selected	Overground
Tse et al ¹⁷	40	FPI, pronated FPI, neutral FPI, supinated	26.0 ± 2.2 26.7 ± 2.8 27.3 ± 4.1	56.3 60 55.6	Walking	Self-selected	Overground
Fukuchi et al ¹⁸	21	No	25 ± 3.4	0	Walking	Prescribed 1.4 m/sec	Overground
Kluge et al ¹⁹	22	No	22.3 ± 2.2	86.3	Walking	Prescribed, 0.9 m/sec, 1.1 m/sec, 1.3 m/sec, and 1.5 m/sec	Treadmill
Lewinson et al ²⁰	9	No	25.2 ± 2.9	0	Running	Prescribed, 4.0 m/sec	Overground
Lilley et al ²¹	20	No	50.7 ± 5.6	100	Running	Prescribed, 3.5 m/sec	Overground
Møller Mølgaard and Kersting ²²	13	No	37.4 ± NR	30.8	Walking	Self-selected	Overground
Kakhiana et al ²³	10	No	25.2 ± NR	50	Walking	Self-selected	Overground
Forghany et al ²⁴	8	No	33.5 ± 4.5	0	Walking	Self-selected	Overground
Sawada et al ²⁵	15	No	22.5 ± 1.5	NR	Walking	Self-selected	Overground
Nester et al ²⁶	15	No	NR	46.6	Walking	Prescribed 108 steps/min	Overground
Weinhandl et al ²⁷	10	No	21.8 ± 0.6	100	Walking	Self-selected (mean 1.37 m/sec)	Overground
Pascual Huerta et al ²⁸	12	No	24.6 ± 5.6	50	Walking	Self-selected	Overground
Van Gheluwe and Dananberg ²⁹	23	No	22.2 ± 7.6	NR	Walking	Prescribed, 1.1 m/sec	Treadmill
Erhart et al ³⁰	15	No	28.6 ± 4	60	Walking	Self-selected and pre-scribed slow, normal and fast speeds (speeds NR)	Overground
Jin et al ³¹	30	No	21 ± 1	0	Walking	Self-selected	Overground
Jones et al ³²	15	No	30.5 ± 8.6	33.3	Walking	Self-selected	Overground
Rabiei et al ³³	50	No	21 ± 2.2	100	Running	Not specified	Overground
Schmalz et al ³⁵	10	No	34 ± 9	40	Walking	Self-selected	Overground

Abbreviations: FPI, Foot Posture Index; OA, osteoarthritis; NR, not reported; SD, standard deviation.

Table 3. Wedge Design Specifications as Reported in the Included Studies

Reference	Wedge Placement	Wedge Length	Wedge Material (Hardness or Density)	Wedge Inclination (Angle [°])	Footwear
Kakhana et al ⁵	Insole	Full length	EVA (elasticity of 100–300 kg/mm ²)	Lateral (6)	No footwear; insoles taped to the foot
Kakhana et al ¹⁶	Insole	Full length	EVA (elasticity of 100–300 kg/mm ²)	Lateral (6)	No footwear; insoles taped to the foot
Telfer et al ¹⁶	Insole	To the sulcus	Poly lactide (NR)	Lateral (6, 4, and 2) Medial (10, 8, 6, 4, and 2)	Standardized; details NR
Tse et al ¹⁷	Insole	To the sulcus	EVA (55, Shore A)	Lateral (5)	Standardized sandal; brand and model NR
Fukuchi et al ¹⁸	Insole	Full length	EVA (NR)	Lateral (6 and 9) Medial (6 and 9)	Standardized; Aidas, Aegis 2.0
Kluge et al ¹⁹	Insole	Full length	Cork (NR)	Lateral (4 mm approximately 4–5)	Standardized; Brooks, Green Silence
Lewinson et al ²⁰	Insole	Full length	EVA (NR)	Lateral (3, 6, and 9) Medial (3, 6, and 9)	Standardized; Adidas, Aegis 2.0
Lilley et al ²¹	Insole	Full length	NR (NR)	Lateral (4 and 5) Medial (4)	Standardized; Somnio, Pacemaker 2.0
Møller Mølgaard and Kersting ²²	Insole	Full length	NR (NR)	Lateral (10)	Standardized; three models: Klaveness new rehab; Klaveness Thor; and Nike, Air Pegasus
Kakhana et al ²³	Insole	Full length	EVA (elasticity of 100–300 kg/mm ²)	Lateral (6)	No footwear; insoles taped to the foot
Forghany et al ²⁴	Insole	To the sulcus	Vinyl acetate ("high density")	Lateral (5 and 8.5)	Standardized; New Balance, model NR
Sawada et al ²⁵	Insole	To the sulcus	High intensity silicone (40, Shore A)	Lateral (7 mm approximately 5.3)	No footwear; insoles strapped to the foot
Nester et al ²⁶	Insole	To the sulcus	EVA ("high density")	Lateral (10) Medial (10)	Participants' own footwear
Weinhandl et al ²⁷	Insole	Rearfoot	EVA (55, Shore A)	Lateral (9)	Participants' own footwear
Pascual Huerta et al ²⁸	Insole	Rearfoot	EVA (65, Shore A)	Lateral (7) Medial (7)	NR
Van Gheluwe and Dananberg ²⁹	Insole	Forefoot and/or rearfoot	EVA (70, Shore A)	RF lateral (4) RF medial (4 and 8) FF lateral (3) FF medial (3 and 6)	Standardized; Asics, Stratus
Erhart et al ³⁰	Midsole	NR	NR (Asker C; Durometer, 55)	Lateral (4 and 8)	Standardized; Nike, model NR
Jin et al ³¹	Insole	NR	Polyvinyl acetate (NR)	Lateral (6)	No footwear; insoles placed in socks
Jones et al ³²	Insole	NR	NR (70, Shore A)	Lateral (5)	Standardized; ECCO, Zen
Rabiei et al ³³	Insole	NR	Wood (NR)	Lateral (6)	Standardized; Nike, model NR
Schmalz et al ³⁴	Midsole	NR	NR (NR)	Lateral (14)	Standardized; Details NR

Abbreviations: EVA, ethylene vinyl acetate; FF, forefoot; NR, not reported; RF, rearfoot.

published since 2013. Four of the included studies used a comparator group, with two comparing healthy individuals to a pathologic cohort (medial knee OA and lateral ankle instability)^{5,15} and the other two compared groups with differing foot postures.^{16,17}

Wedge Length

Specifications of wedges used in the included studies are detailed in Table 3. Eight studies reported using full length wedges.^{5,15,18-23} Of these, two included images that show the wedge extending to the end of the insole.^{19,21} Also included in the eight studies to report full-length wedging were the Fukuchi et al¹⁸ and Lewinson et al²⁰ studies, both of which included an image showing wedges that extend just beyond the metatarsal heads to the sulcus of the foot. The remaining four studies in this group did not include an image of their wedge length, and as such, it was not possible to determine accuracy of the description “full length.”^{5,15,22,23}

Five studies added wedges extending to the sulcus of the foot.^{16,17,24-26} Only the Sawada et al²⁵ article included an image to provide visual clarification. The language used to describe length in this group was varied, with descriptions including: “3/4 length,”¹⁶ “graded to zero at the base of the fifth metatarsal,”²⁴ “the lateral wedge insoles had base heights equal to that of the fifth metatarsal,”²⁵ “just distal of the fifth metatarsal,”²⁶ and “sulcus length.”¹⁷

Studies by Weinhandl et al²⁷ and Pascual Huerta et al²⁸ were the only two to report looking solely at rearfoot wedges; however, neither included an image to confirm placement. The Pascual Huerta et al²⁸ study stated that the wedges used in their study were 14 cm long and 4 cm wide. The study by Van Gheluwe and Dananberg²⁹ was the only one to examine differences in wedge length. This was also the only study to use a forefoot wedge, which in this case was compared to a rearfoot wedge. This study used six different insole conditions with a range of rearfoot (4° valgus to 8° varus) and forefoot (3° valgus to 6° varus) wedges, all compared to a neutral, flat insole. No details regarding wedge length were reported by five studies.³⁰⁻³⁴ Despite not reporting length in the manuscript, three of these five provided images that showed wedges running the complete length of the insole or midsole.^{30,32,34}

Wedge Material Type and Hardness

There were a range of materials used, with the most common being ethylene vinyl acetate (EVA), used

in 10 studies (47%).^{5,15,17,18,20,23,26-29} Other materials used included vinyl acetate,²⁴ polyvinyl acetate,³¹ high-intensity silicon,²⁵ polylactide,¹⁶ cork,¹⁹ and wood.³³

The reporting of material used and the hardness of the material was inconsistent. Five studies did not define the type of wedge material used^{21,22,30,32,34} and nine studies provided no detail relating to material hardness of the wedge.^{16,18-22,31,33,34} Within those studies that did report durometer (measure of hardness), there was variation in terminology. Scales used included Shore A,^{17,25,27-29,32} which ranged from 40 to 70; Asker C³⁰; and kilogram per square millimeter.^{5,15,23} Two studies recorded the wedges simply as “high density.”^{24,26} Three studies provided no detail of both the material type and hardness or density.^{21,22,34}

Inclination Angle

A broad range of wedge inclination angles were used, ranging from 3° to 14° laterally wedged (6.21° ± 2.51°). The highest inclination angle, of 14°, was in the study by Schmalz et al,³⁴ where the wedge was placed in the midsole of a shoe. Considering only insole-based wedges, the range of inclinations were 3° to 10° laterally wedged (5.94° ± 2.10°). All studies in this review included an unwedged control condition as a comparison. Six studies compared more than one lateral wedge inclination.^{16,18,20,21,24,30} Telfer et al¹⁶ included the most comprehensive range of inclinations, extending from 6° laterally wedged through 10° medially wedged, in 2° increments. Although laterally wedged conditions were of interest to the current review, it was noted that seven studies also examined medial wedges.^{16,18,20,21,26,28,29}

Nineteen studies (90%) reported inclination in degrees, whereas two studies reported millimeter thickness of the lateral border. Kluge et al¹⁹ reported that using a 4-mm wedge is approximately equivalent to a 4° to 5° angle. Sawada et al²⁵ used a 7-mm wedge and noted that this was comparable to a 5.3° inclination angle. Neither study provided any further details about wedge dimensions such as foot or insole width.

Kinematic, Center of Pressure, and Kinetic Effect

Kinematic and kinetic outcomes of the included studies are displayed in Appendix 2. Interpretation of kinematic and kinetic variables was difficult

because of the varied terminology used across all studies.

STJ Moments

Eleven studies reported on ankle/STJ inversion, eversion, or valgus moments.^{5,15,17,18,20,23,28,30-32,34} A mix of internal and external joint moments were measured which, when not clearly outlined, can make results appear contradictory. The external moment includes the impact of ground reaction force and inertial forces, and therefore is equal and opposite to the internal joint moment.³⁵ There are consistent findings among all but one study in this review that lateral wedging effects the ankle/STJ by increasing the external eversion moment,^{17,30,32} increasing the internal inversion moment,^{18,20} increasing the external valgus moment,^{5,15,23,34} or decreasing the internal valgus moment.³¹ These findings were all statistically significant ($P < .05$). The only study included that did not reach statistical significance was the work of Pascual Huerta et al.²⁸ In this study, the authors compared a 7° lateral rearfoot wedge to a flat condition and found no significant change in net ankle inversion moments.

Ankle Abduction Moment

The study by Møller Mølgaard and Kersting²² was the only study to report ankle abduction moment. Looking at the effect of lateral wedging when used within three different types of footwear, the authors found a reduction in ankle abduction moment, across all conditions. Schmalz et al³⁴ used the steepest wedge included in this review (14°) and did not find statistically significant results. The insignificant findings are supported by Nester et al,²⁶ who analyzed a 10° insole-based lateral wedge, and also found no change with respect to rearfoot plantarflexion moments.

Center of Pressure

Centre of pressure (COP) was investigated by eight studies.^{5,15,18-20,25,29,32} Seven of these studies (87.5%) reported that COP was shifted laterally with the use of lateral wedges.^{5,15,18,20,25,29,32} Lewinson et al²⁰ noted that this effect was more pronounced as wedge inclination increased from 3° to 6° and 9°. Of these eight studies, the study by Kluge et al¹⁹ was the only one to report insignificant findings.

Kinematics

Kinematics were reported by 12 of the included studies.^{5,15,17,19,21,23-27,32,33} Nine studies discussed ankle/STJ eversion and, of these, five reported a significant increase.^{17,19,24,25,32} Of these 12 studies, only Forghany et al²⁴ analyzed multiple inclinations, reporting a significantly larger effect from their steeper wedge (8.5°) when compared to their less steep (5°) condition. Kluge et al,¹⁹ who assessed a range of walking speeds, reported that speed did influence the effect of lateral wedging on ankle eversion, with wedges making less of a difference at faster speeds. Three studies in this review showed insignificant effects of lateral wedging on ankle eversion. All three compared a single inclination to the control condition.^{5,15,27} Two studies reported rearfoot eversion, both finding that lateral wedging did not induce a significant change.^{21,25} Rabiei et al³³ analyzed “foot pronation” (measured as the combined movement in all three planes, frontal, sagittal, and transverse) in healthy female runners using a rearfoot lateral wedge. These findings indicated a significant increase in foot pronation, from 5% to 35% of stance phase ($P = .012$), compared to the control condition.

Discussion

Understanding of the effect exerted by lateral wedging on foot function is limited by inconsistency in reporting of lateral wedge length, minimal reporting of specific wedge properties, a wide variation in wedge inclination angles, and an array of kinematic and kinetic outcome variables used to assess their biomechanical effect. Interpretation of the kinematic and kinetic effect of wedging is also restricted by the use of inconsistent terminology.

This review found that full length or sulcus length wedges were used in the majority of included studies, rather than rearfoot or forefoot wedges. This finding may be explained by a dominance of literature that has investigated the relationship between lateral foot wedging and knee adduction moments (KAM).^{2,36-41} Sixteen studies (80%) included in this review analyzed frontal plane knee kinetics such as KAM. With the preposition that full-length wedges are considered optimal to reduce KAM, it is perhaps not surprising that this was the dominant design.^{42,43} Hinman et al⁴³ were the first authors to identify the impact of wedge length on KAM. Before this work, researchers interchangeably used rearfoot or full-length wedges. Initially Hinman et al,⁴³ and more recently Fischer et al,⁴² have compared multiple lengths of lateral wedge,

with both studies concluding that longer wedges (full length or sulcus length) elicited a larger reduction in KAM than a rearfoot-only wedge. Despite some evidence surrounding alteration to KAM with full length lateral wedges, there is currently very limited research indicating what is the optimal length and positioning of lateral wedging to elicit functional changes in foot biomechanics.

Kogler et al⁴⁴ have shown that lateral wedging under the forefoot is the most effective way to reduce strain in the plantar aponeurosis. This in vitro study analyzed nine different test conditions, considering all possible combinations of rearfoot lateral, forefoot lateral, rearfoot medial, and forefoot medial wedging. Results of this work showed that all configurations with a forefoot lateral wedge induced a greater reduction in plantar aponeurosis strain than those without, including a lateral rearfoot wedge. As the only study included in the current review to compare different wedge placements, Van Gheluwe and Dananberg²⁹ found that although rearfoot wedging had no impact on forefoot plantar pressures, lateral forefoot wedging shifted the COP laterally at the forefoot.

There has been limited investigation into the impact of material properties on lateral wedge function. A multitude of different materials were used in the included studies; the hardness of these was inconsistently reported. A recent systematic review has indicated that some orthotic materials can reduce peak plantar pressures during walking.¹⁰ Although Gerrard et al¹⁰ reported no clear consensus about the effects of EVA hardness on force modulation, they did note that softer EVA deforms to the shape of the foot, thus increasing the contact area with the foot and impacting plantar pressures. Soft materials are generally thought to be more suitable when cushioning or shock attenuation is the desired outcome, whereas firm materials are better suited to redistribution of load.¹² Gerrard et al¹⁰ suggested that the ability of a material to conform to the foot is a key factor in altering plantar pressures. Extrapolating the results of Gerrard et al¹⁰ to lateral wedging, it may be postulated that lateral wedges constructed from more firm material may induce a larger change in joint moments and kinematics because of their reduced compressibility. Conversely, wedges manufactured from softer materials may exert less kinetic and kinematic effect. Unfortunately, although a range of materials were used across all included studies, no studies analyzed more than one material type or hardness, therefore limiting our ability to draw

conclusions or make recommendations relating to optimal material selection.

Lateral wedge inclination angles applied in the included studies ranged from 3° to 14°, with no clear rationale provided as to why particular inclination angles were selected. Previous research has highlighted comfort as a factor that may determine the degree of wedge inclination to be investigated.⁴⁵⁻⁴⁷ Research has postulated that a threshold of between 5° and 7° exists and beyond this level comfort is adversely affected.⁴⁵⁻⁴⁷ Erhart et al³⁰ and Lewinson et al²⁰ were the only studies in the current review to discuss comfort, both reporting higher discomfort levels with their largest inclination angles (8° and 9°, respectively). All studies in the current review that compared multiple inclination angles reported that an increase in angulation is associated with a larger biomechanical change.^{16,18,20,21,24,30} Beyond the concept of comfort, the basis for using a particular material thickness or inclination angle appears to be guided by a limited evidence base. In light of this finding, we postulate that inclination angles used in lateral wedge research may relate to the properties of commercially available prefabricated materials (such as thickness), rather than what is known to be optimal. That is, convenience of available material may be a significant factor that determines inclination angle selection.

Despite significant variance in wedge design, and the mix of internal and external joint moments reported, lateral wedges were reported to modify frontal plane moments of the ankle/STJ in all but one included study. Although analyzed by a smaller number of studies, several reported that lateral wedging shifts the COP laterally, thereby lengthening the ankle joint eversion moment arm. This lateralization of COP and change in moment arm appear to explain the increase in external eversion (valgus) moment at the ankle/STJ. With respect to other outcome measures analyzed by the included studies, there is insufficient consistency to make generalizations or draw conclusions.

Inconsistent terminology in the description of lateral wedges was a major finding of this review. Consequently, based on definitions drawn from included studies, we propose the following standard definitions for lateral wedge length and placement that can be adopted in future work:

- Full length lateral wedge: Beginning from the most proximal aspect of the insole, under the calcaneus. Extending to the distal end of the insole, past the apex of the digits.

- Sulcus length (3/4 length) lateral wedge: Beginning from the most proximal aspect of the insole, under the calcaneus. Extending to the sulcus of the foot, just distal to the metatarsal heads and tapering to nothing at this point.
- Rearfoot lateral wedge: Beginning from the most proximal aspect of the insole, under the calcaneus. Extending to the styloid process full thickness and tapering to nothing before the midshaft of the fifth metatarsal.
- Forefoot lateral wedge: Beginning from the calcaneocuboid joint and extending distally to the sulcus of the foot.

Conclusions

The review has identified significant variation in the design of wedges used within this body of work and a lack of investigation into the influence of wedge design. Wedge design appears to be a secondary consideration, with very few studies examining multiple material types or wedge placements. All but one of the included studies reported a significant change in ankle/STJ joint moments with lateral wedging. Unfortunately, further generalization was not possible because of the inconsistency and variation. This dearth of evidence suggests that clinicians using lateral wedges in practice are most likely fabricating these without robust evidence-based guidance. We recommend that future work should seek to provide clinicians with an understanding of how best to manufacture and prescribe lateral wedges that will achieve their desired clinical and biomechanical outcomes.

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Conflict of Interest: None reported.

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Appendix 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) Checklist.

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE#
TITLE			
Title	1	Identify the report as a scoping review.	Page 1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	Page 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	Page 1
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	Page 1
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	NA
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	Page 5
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	Page 4
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Table 1
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	Page 5
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	Page 5
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	Page 5
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	NA
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	Page 5
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	Figure 1
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	Table 2 & 3
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	NA

continued

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE#
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Appendix 2
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Page 6-10
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	Page 10-13
Limitations	20	Discuss the limitations of the scoping review process.	NA
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	Page 13-14
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	Page 15

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

*Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

†A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med.* 2018;169:467–473. doi: 10.7326/M18-0850.

Appendix 2. Kinetic and Kinematic Outcome Measures of the Included Studies.

Reference	Intervention	Outcome
Kakahana et al ¹	2 conditions – Neutral, laterally wedged insole 6°	<ul style="list-style-type: none"> – STJ valgus moment increased in the laterally wedged condition ($p < 0.001$) – No significant change in STJ angle between conditions ($p = 0.215$) – COP shifted laterally in the wedged condition. The valgus moment arm of the STJ was greater in the wedged condition ($p < 0.001$)
Kakahana et al ²	2 conditions – Neutral, laterally wedged insole 6°	<ul style="list-style-type: none"> – STJ valgus moment increased in the laterally wedged condition ($p < 0.001$) – No significant change in STJ angle ($p = 0.142$) – COP shifted laterally in the wedged condition. The valgus moment arm of the STJ was greater in the wedged condition ($p < 0.001$)
Telfer et al ³	9 conditions - 6° lateral to 10° medial wedges, in 2° increments	<ul style="list-style-type: none"> – Mean lateral rearfoot plantar pressure is increased by lateral wedging ($p = 0.002$) – Midfoot peak and midfoot mean plantar pressure increased with lateral wedging ($p < 0.001$) – Lateral forefoot peak ($p = 0.042$) and mean ($p = 0.002$) plantar pressure decreased with lateral wedging – No significant change was found for the following plantar pressures: Peak medial rearfoot ($p = 0.231$); mean medial rearfoot ($p = 0.313$); peak lateral rearfoot ($p = 0.179$); peak 1st ray ($p = 0.796$); and mean 1st ray ($p = 0.337$)
Tse et al ⁴	6 conditions – Flat (control), 5° lateral wedge, variable stiffness contoured arch support, uniform stiffness contoured arch support, variable stiffness contoured arch support with 5° lateral wedge, uniform stiffness contoured arch support with 5° lateral wedge	<ul style="list-style-type: none"> – Ankle/STJ eversion moment and eversion moment impulse increased with lateral wedging ($p < 0.05$) – Ankle/STJ eversion angle peak was increased with lateral wedging ($p < 0.05$) – Ankle/STJ eversion excursion was not significantly changed ($p = 0.52$)
Fukuchi et al ⁵	5 conditions – Neutral, laterally wedged insoles 6° and 9°, medially wedged insoles 6° and 9°	<ul style="list-style-type: none"> – Lateral wedges increased the internal ankle inversion moments relative to the neutral condition (6° wedge, $p = 0.02$; 9° wedge, $p < 0.001$) – 9° lateral wedge increased the ankle inversion impulse, relative to the neutral condition ($p = 0.12$) – 9° lateral wedge shifted the COP laterally relative to the neutral condition ($p < 0.001$)
Kluge et al ⁶	2 conditions – Individualised arch support to STJ neutral, laterally wedged insole 4mm (4-5°)	<ul style="list-style-type: none"> – Ankle eversion increased in the wedged condition ($p < 0.001$) – No significant change in COP position ($p = 0.509$) – No significant change in either the vertical ($p = 0.151$) or medial ($p = 0.069$) components of GRF
Lewinson et al ⁷	6 conditions – laterally wedged insoles 3°, 6°, 9° and medially wedged insoles, 3°, 6° and 9°	<ul style="list-style-type: none"> – Ankle inversion moment was increased by lateral wedging ($p = 0.041$) – COP was also shifted laterally by lateral wedging ($p < 0.001$)
Lilley et al ⁸	4 conditions – Control, 4° medial or 4° lateral rearfoot wedge, 5° lateral wedge on a contoured insole (called here 'combined insole')	<ul style="list-style-type: none"> – Lateral wedging demonstrated no significant change in either the magnitude or velocity of rearfoot eversion, compared to control (p-value not reported) – The combined insole achieved the largest reduction in peak rearfoot eversion ($p < 0.05$)
Møller Mølgaard et al ⁹	7 conditions – barefoot walking (control), 3 different types of shoe each with and without a 10° full length lateral wedge	<ul style="list-style-type: none"> – The lateral wedge produced a significant reduction in ankle abduction moment ($p < 0.001$) – Lateral wedging increased ankle power during propulsion ($p = 0.001$)
Kakahana et al ¹⁰	2 conditions – Neutral, laterally wedged insole 6°	<ul style="list-style-type: none"> – STJ valgus moment increased in the laterally wedged condition (significance not reported) – The valgus moment arm of the STJ significantly increased with use of the lateral wedge. – Kinematics of the STJ displayed no significant change.

continued

Reference	Intervention	Outcome
Forghany et al ¹¹	3 conditions – Neutral, laterally wedged insoles 5° and 8.5°	– Lateral wedging increased ankle eversion ($p < 0.0001$)
Sawada et al ¹²	2 conditions – barefoot (control) and 7mm (approx. 5.3°) lateral wedge	– The lateral wedge significantly increased ankle eversion ($p < 0.05$) – No significant change in rearfoot eversion ($p = 0.49$) – COP offset shifted laterally when using the lateral wedge ($p < 0.01$)
Nester et al ¹³	3 conditions – Control, 10° lateral wedge, 10° medial wedge	– The lateral wedge increased the degree of rearfoot plantarflexion at heel strike ($p = 0.001$) – The lateral wedge decreased the first peak in the rearfoot external rotation moment (transverse plane) ($p = 0.04$) – No significant change was exhibited in frontal or sagittal plane moments at the rearfoot, with the use of lateral wedging.
Weinhandl et al ¹⁴	2 conditions – Neutral, 9° lateral wedge	– There was no effect on GRF except for an increase in vertical GRF at the point of peak knee adduction moment ($p = 0.01$) – No significant change in ankle eversion ($p = 0.14$)
Pascual Huerta et al ¹⁵	3 conditions – Control, 7° lateral wedge, 7° medial wedge	– No significant change was reported in net ankle inversion moments ($p = 0.147$)
Van Gheluwe et al ¹⁶	8 conditions – Forefoot wedging 3° valgus, flat, 3° varus or 6° varus. Rearfoot wedging 4° valgus, flat, 4° varus or 8° varus	– Lateral wedging increased peak pressure and maximal loading rate at the lateral forefoot and rearfoot (p -value not reported) – COP shifted laterally with lateral wedging and medially with medial wedging (p -value not reported) – No significant change was found in timing between initial impact and peak load for any of the wedge conditions (p -value not reported)
Erhart et al ¹⁷	3 conditions – Neutral, Laterally wedged midsoles 4° and 8°	– Ankle eversion moment increased by laterally wedged shoes ($p < 0.001$) – Both the 4° wedge ($p = 0.002$) and 8° wedge ($p < 0.001$) increased the maximum medial-to-lateral heel pressure ratio
Jin et al ¹⁸	3 conditions – No insole, Neutral insole, laterally wedged insole 6°	– Lateral wedges reduced the ankle valgus moment, at the first peak, as soon as they are placed in the shoe ($p < 0.05$)
Jones et al ¹⁹	3 conditions – Neutral, laterally wedged ‘supported’ insole 5°, laterally wedged ‘unsupported’ insole 5°	– Both supported ($p = 0.025$) and unsupported ($p = 0.022$) lateral wedges increased ankle/STJ complex eversion moments, compared to the control condition. No significant change was found between supported and unsupported ($p = 1.00$) – The unsupported lateral wedge increased maximum ankle/STJ eversion angle by more than both the supported lateral wedge ($p = 0.002$) and the control condition ($p = 0.004$). No significant change between supported and control ($p = 1.00$) – The supported lateral wedge increased lateral COP excursion during early ($p < 0.001$), mid ($p < 0.001$) and late stance ($p = 0.016$), compared to a control condition. The unsupported lateral wedge increased lateral COP excursion during early ($p < 0.001$) and midstance ($p < 0.001$), however not during late stance
Rabiei et al ²⁰	3 conditions – barefoot, shod and shod including a 6° laterally wedged insole	– The lateral wedge significantly increased foot pronation when compared with unwedged conditions, between 5 and 35% of stance phase ($p = 0.012$)
Schmalz et al ²¹	7 conditions – control (unwedged shoe), shoes with either a medial or lateral wedge (10mm, approx. 14°) built into the midsole. Both shoes tested with no additional bracing, an ankle brace or an AFO	– No significant change in plantarflexion moment immediately after weight acceptance (p -value not reported) – No significant change in the dorsiflexion moment during toe-off (p -value not reported) – Vertical component of GRF shifted laterally in laterally wedged conditions ($p < 0.05$) – Lateral wedging significantly increased the valgus moment at the ankle ($p < 0.01$)

COP, centre of pressure; STJ, subtalar joint; °, degrees; AFO, ankle foot orthotic; GRF, ground reaction force.

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