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Meta Analysis

The Footwear and Footwear Modifications for Reducing Biomechanical Risk Factor, External Knee Adduction Moment for Medial Knee Osteoarthritis Progression: A Systematic Review and Meta-Analysis

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ABSTRACT

Objective

- The purpose of this systematic study is to provide clear, patient-focused, recent, evidence-based, and consensus recommendations for footwear and footwear modifications with effects that are globally relevant in OA knee.
- The identification and quantitative rating of studies estimating 1st and 2nd KAM by wearing different types of footwear and insoles in patients with OA knee.

Method: Five databases were searched. A full search of 258 articles was found. To be included in this study, the population should be with OA of any grade without any ambulatory aids, male and female were included with age group above 54 years. For the intervention, all the types of shoes and any kind of modification in the shoes were included. The Primary outcome of interest relating to the biomechanical risk of disease progression was the 1st and 2nd Knee Adduction Moment. Eligible studies were pooled using meta-analysis.

Result: Twenty-three studies were included with a total population of 841. Variable stiffness shoe (Mean Difference MD: -0.27; 95% CI: -0.34, -0.21) and Moleca (Mean Difference MD: -0.25; 95% CI: -0.56, 0.05) (Mean Difference MD: -0.25; 95% CI: -0.56, 0.05) have a comparably large statistically significant reduction in KAM with low heterogeneity ($Ch^2 = 1.49$, $I^2 = 0\%$). The quality of all the studies is moderate (modified Downs and Black quality checklist) and low to moderate risk of bias (QUADAS 2).

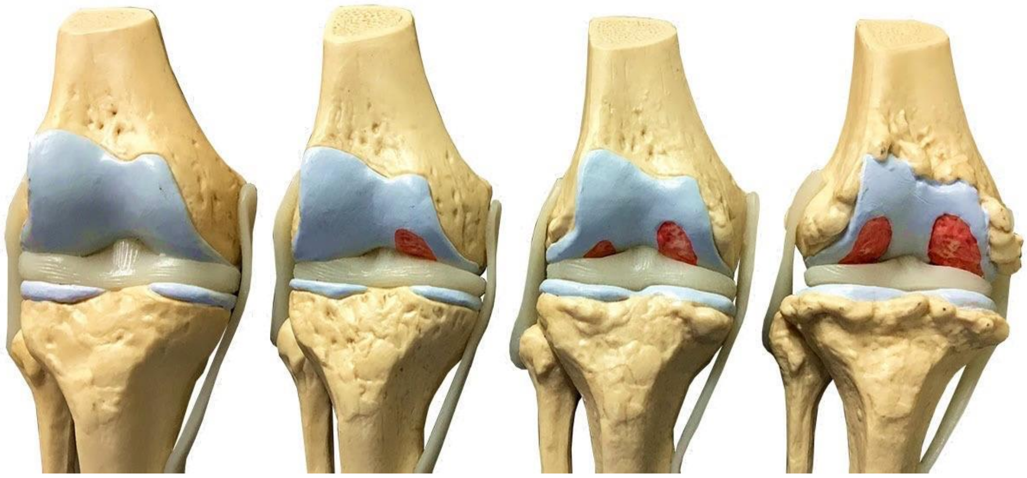
Conclusion: Biomechanical parameters related to the medial knee load, including first peak EKAM and second peak EKAM, were reduced with the use of footwears and footwear modification, apart from the mobility shoes in first peak KAM and MBT in second peak KAM in comparison with barefoot. VSS and Moleca show significant changes in KAM. Future studies need to consider in terms of height of arch in LWI, duration of footwear usage, material, and rigidity of insole, consider the grades of OA knee for baseline for disease specific recommendation. However, based on our study, the footwear and its modifications show an immediate reduction in EKAM. VSS and Moleca have greater effect in reducing EKAM.

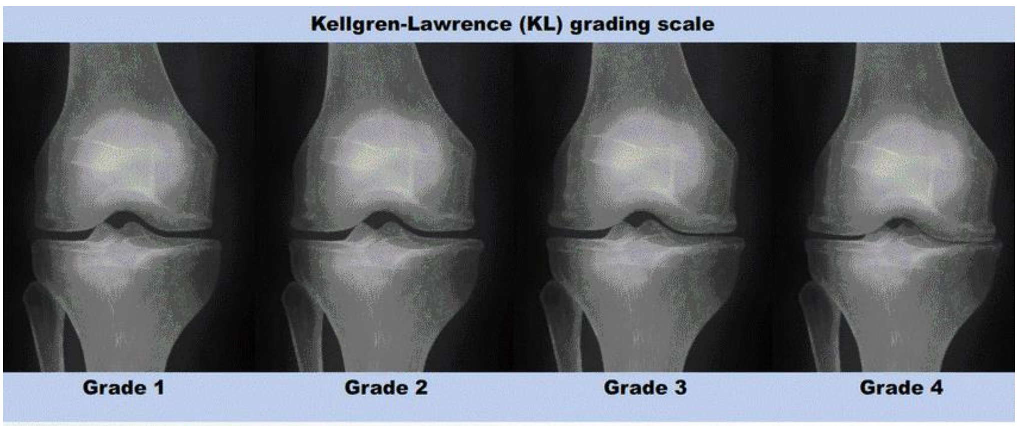
Keywords: Footwear, OA knee, Degenerative knee, Biomechanical knee, Knee adduction moment, Joint loading, Kinematic knee joint

INTRODUCTION

1.1. Definition of Osteoarthritis Knee

Articular cartilage degeneration is a characteristic of the degenerative joint disease known as knee osteoarthritis (OA) and the corresponding subchondral bone (4). Joint pain, functional impairment, and disability can result from OA knee (5). According to Kellgren and Lawrence in 1957, OA knee is classified into 4 grades, as shown in figure 1 and 2.





CLASSIFICATION	Normal	Doubtful	Mild	Moderate	Severe
DESCRIPTION	No features of OA	Minute osteophyte: doubtful significance	Definite osteophyte: normal joint space	Moderate joint space reduction	Joint space greatly reduced: subchondral sclerosis

Figures 1 and 2 shows KL grading for the severity of knee Osteoarthritis (6)

1.2. Prevalence and Risk factors of OA Knee

The overall global incidence of knee OA in people 20 and older was 203 per 10,000 person-years. Accordingly, there are 86.7 million people (20 years of age and older) with incident knee OA worldwide in 2020 (7). According to Van Der Pas et al (8) clinical knee OA affected 20.2% of adults living in the community aged 65 to 85 in certain European nations (Germany, Italy, the Netherlands, Spain, Sweden, and the UK).

Systemic and local biomechanical risk factors contribute to the development of knee OA, while the systemic are generally not modifiable (age, sex, hormones, bone density) (9), the biomechanical factor (medial knee loading, knee adduction moment (KAM), obesity, and muscle weakness) are modifiable (2). Knee joint loading is associated with discomfort and seriously damaging to gait cycle, occurs while walking. Individuals with knee OA have frequently been shown to have altered walking patterns when compared to controls (10).

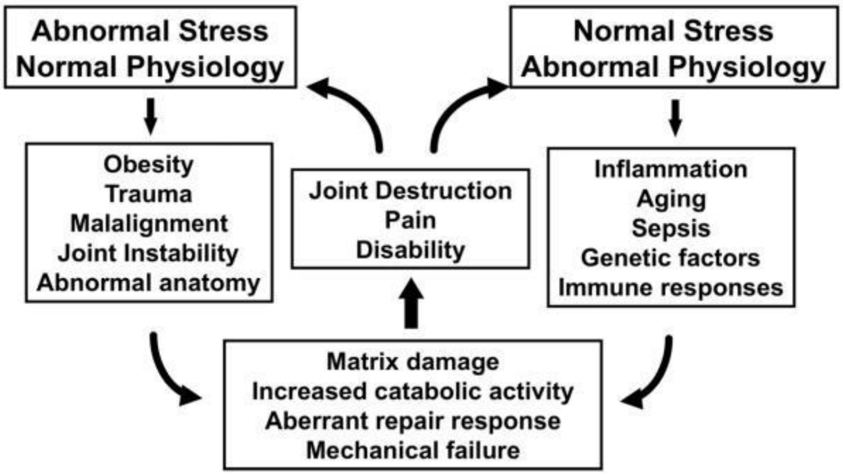


Figure 3 shows multiple hypotheses on the origins and pathophysiology of osteoarthritis have included biomechanical factors as contributing variables. These theories either explain how abnormal loading affects normal physiology or how normal loading affects abnormal physiology. The fact that many of these risk variables (such as obesity) have both physiologic and biomechanical effects should be recognised (2)

1.3. Biomechanical Factors of OA knee

According to Felson et al (11) and Ahlbäck (12), the lateral compartment of the knee is less likely to be affected by OA than the medial compartment, and this is because walking transmits between 60 and 80 percent of the compressive loading force to the medial side of the knee, hence weight bearing activity and gait assessing is a crucial tool for evaluating OA knee (13). External knee adduction moment (EKAM) and medial compartment load have a strong correlation (14). The relation shown in the figure 3. The EKAM correlates to knee pain and the severity of radiographic disease and is an effective and consistent surrogate for dynamic medial knee loading during walking(15).

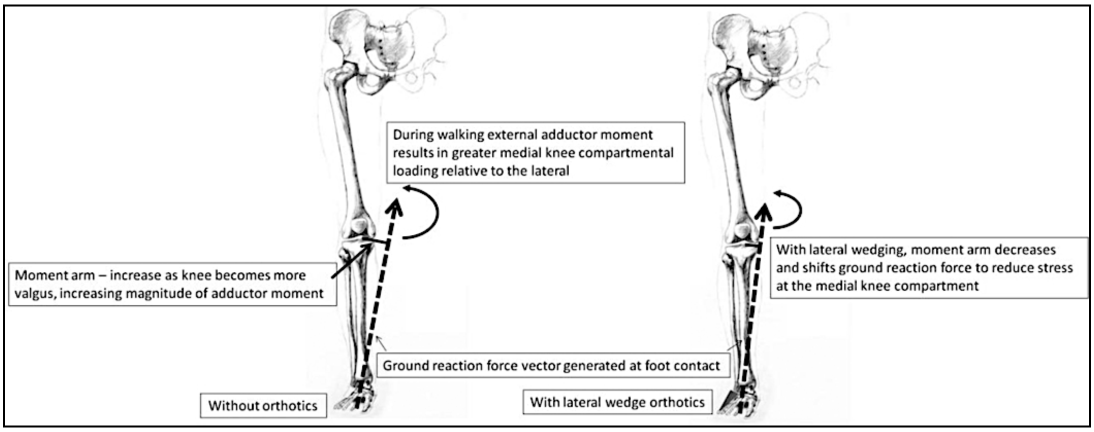


Figure 4 The representation of EKAM in relation with GRF (1). Normally, the KAM displays two peaks during the stance phase of gait. Every peak matches the corresponding peak in the vertical GRF. The first peak, which is greater, occurs in the load-acceptance phase of gait (0%–12% of the gait cycle), and the second, smaller peak, which is in late stance (50%–62% of the gait cycle), occurs during this phase (3) (figure 4).

During the swing phase of gait (62–100% of the gait cycle), the KAM is insignificant. Patients with medial compartment knee OA had previously been found to have a higher initial peak in KAM, and a larger KAM has been linked to a more severe radiographic condition (16, 17).

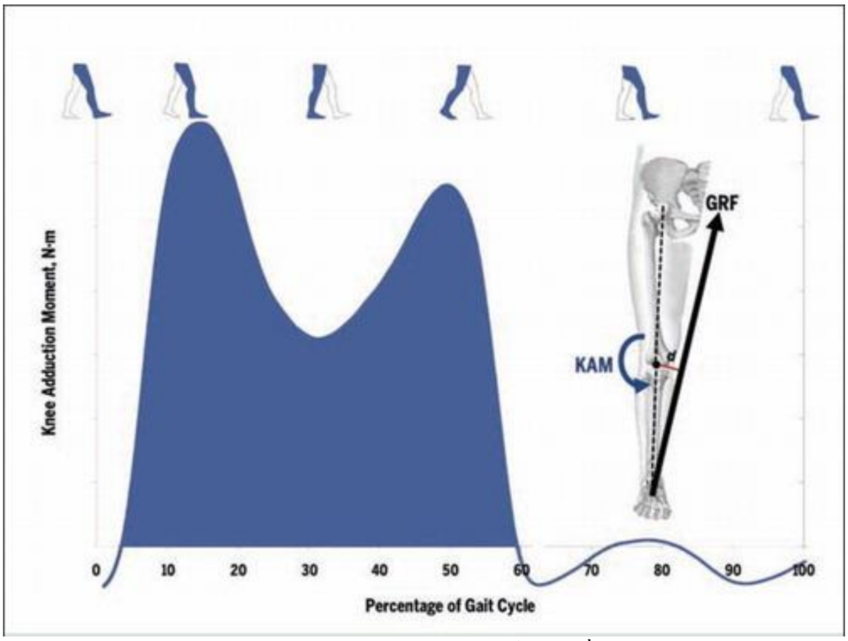


Figure 5 shows KAM in gait cycle of 1st and 2nd KAM (3).

1.4. Management of knee OA

Surgical intervention, such as high tibial osteotomy, arthroscopic surgery, Unilateral Knee arthroplasty and Total Knee Replacement (TKR) are effective and long-term management results in reduction of pain and improvement in function (18); however, the risk of this invasive procedure is high (19). Some of the conservative managements are patient education, muscle strengthening exercise, acupuncture, and using biomechanical load reducing treatments (20). The National Institute of Clinical Excellence (NICE) in 2014 and 2022 recommendations for the conservative therapy of knee OA include footwear and insoles (21).

1.5. Justification for the Review

Clinical guidelines, such as those issued by the American College of Rheumatology (ACR) recommend medial wedge insole for patients with valgus knee OA (22) and Osteoarthritis Research Society International (OARSI) (23) provide recommendations for the conservative management of knee OA such that footwear and its modifications. EULAR (The European Alliance of Associations for Rheumatology) guidelines recommend footwear with no raised heel, thick, shock-absorbing soles, support for the arches of the foot and a shoe size. Not recommending LWI (24).

Zafar et al (25) conducted a systematic study in the effectiveness of foot orthoses in knee OA, although study was unclear in the effects of EKAM in immediate effect, but study found the effects of LWI in long term effect. Therefore, the hypothesis of this study is that the footwear and footwear modifications reduce first and second peak KAM in patients with OA knee.

MATERIALS & METHODS

This systematic review methodology followed PRISMA guidelines incorporating the PRISMA-P checklist for Systematic review and meta-analysis. The "PIOD" framework, which stands for "Population, Intervention, Outcome, and Design," (26) used as the selection criteria, where the Population is patients with medial OA knee, Intervention is Footwears and its modifications, Outcome is biomechanical improvement in Knee Adduction Moment, Joint loading and Design used is experimental in quantitative data.

2.1. Research Question

A systematic review and meta-analysis to establish, what is the effects of footwear and its modifications on biomechanical risk factors, External Knee Adduction Moment for disease progression in patients with medial Knee Osteoarthritis?

2.2. Scoping Search

According to preferred guidelines, systematic review, and Meta-Analysis (PRISMA) used; to locate relevant papers, the following scientific databases were used, all associated with either biomechanics, gait analysis or health related are Cumulative Index to Nursing and Allied Health Literature (CINAHL), MEDLINE, AMED, EMBASE and Scopus database from established to October 2022. Furthermore, author search, 'NAJIA SHAKOOR (2006, 2008, 2010, 2013) and hand search will be used in Australian Journal of physiotherapy from 2002 to 2018. Moreover, a search for relevant unpublished works was done in the grey literature via Open Grey.

2.3. Data Extraction

Two reviewers retrieved and cross-checked point estimates of effects, which included descriptive (means, medians, standard deviations, change scores) and inferential statistical data (p-values, confidence intervals). When participants were assigned based on different criteria and raw data were available, the mean value was determined. When adequate data was provided, standardised mean differences were computed by dividing the mean difference in the biomechanical parameter by the pooled standard deviation after accounting for small sample sizes (27). Where not stated, the equivalent T-statistic was used to estimate the standard error of the mean difference and correlations between outcomes based on P-values. When this was not possible, a method known as imputation was used, in which the standard error of the mean difference was calculated using the lowest correlation estimate from other studies (28).

2.4. Inclusion and Exclusion Criteria

Table 1. Eligibility criteria

INCLUSION CRITERIA	EXCLUSION CRITERIA
STUDY	
RCT, prospective study, pre-post intervention design. Cohort study	Systematic review, study protocol, meta-analysis
POPULATION	
• Age above 54 (the prevalence of radiographic knee OA increased from 26.2% in people aged 55 to 64 to about 50% in people over 75) (29) • Medial OA knee participants • Female and male • Dropouts more than 25% of the total population	• Age below 54 • Healthy participants • Participants with ambulatory aid
INTERVENTION	
Any type of footwear and footwear modifications as experimental group and Control group with own shoe or comparing the modifications of footwear and different type of shoes.	Exercise or any other intervention
OUTCOME MEASURE	
Primary outcome should be first peak KAM With Immediate effect.	Any other outcome measures

2.5. Quality Assessment

A modified Downs and Black quality checklist were used because most of the biomechanical studies in this systematic review are laboratory-based investigations. The modified checklist contained 27 questions divided into the following sub-groups: reporting (1–10), external validity (11–13), internal validity–bias (items–15–20), internal validity–confounding (items–21–26), and power (item–27). Most of the studies are with different footwear conditions in one subject group, questions 5 and 27 will be modified (30). Walking speed, which is demonstrated to be associated with the EKAM and Joint load, are found to be the most significant major confounder. The quality of studies meeting ≥75% of the applicable criteria will be considered as high, 60–74% as moderate and 60% as low.

2.6. Data Synthesis and Analysis

Information from the data extraction form for each study was uploaded into Review Manager software (Revman Version 5.1, The Nordic Cochrane Centre, Copenhagen) to calculate the interventions' effects. The heterogeneity of the review assessed by I^2 and χ^2 static test. Each study was individually eliminated with the overall risk of bias during sensitivity analysis to evaluate the accuracy and consistency of the results. All potentially relevant titles and abstracts was assessed for inclusion criteria by two independent reviewers were blinded to authors and journals. The study with no abstract or not enough information in the title and abstract, the full articles were retrieved. There were no differences in opinion, if there was a difference of opinion, it would be resolved by conversation or full article evaluation.

Mean differences (95% confidence intervals, Cis) for the outcome of interest between footwear conditions were calculated for specific population groups (healthy subjects vs. symptomatic subjects). Forest plots are drawn for the effect sizes of the main footwear conditions and population groups. Clinical heterogeneities are assessed by examining the types of subjects and footwear interventions. A meta-analysis of the studies performed when 2 or more articles shows same interventions with same outcome measures in comparable manner.

RESULT

3.1. Search Result

The full search of 258 articles was found. To be excluded the duplicates, irrelevant titles and screening of abstracts articles was excluded after full assessment. The articles were selected using the search method from the databases CINAHL, MEDLINE, AMED, and Scopus. Due to duplications, 98 items were removed. The inclusion criteria were then applied to 258 titles and abstracts, and 80 papers were kept because they met the criteria for research design. The 57 articles were eliminated after being thoroughly read and evaluated using the inclusion criteria. Table 1 lists each rationale for discarding papers along with corresponding numbers. This review was completed with the remaining 23 studies.

3.2. Study Characteristics

The characteristics of included study and population and characteristics of population can be seen in table 2 and 3. The 23 eligible study were included with a total of 841 participants. All the studies with medial knee OA patients bilateral and unilateral irrespective of the compartments involved. 16 studies with bilateral OA knee, 4 with unilateral and 3 studies were unclear. All studies included radiographic measures of OA knee based on the classification of Kellgren and Lawrence grading in 1957. Out of 23 studies, 2 showed Variable stiffness shoe (31, 32) ,12 studies used Lateral Wedge Insole (33-43), 4 with Mobiltiy (43-46), 3 with Masai Barefoot Technology(47-49), 2 with Melbourne(50, 51) and 2 with Moleca (52, 53).

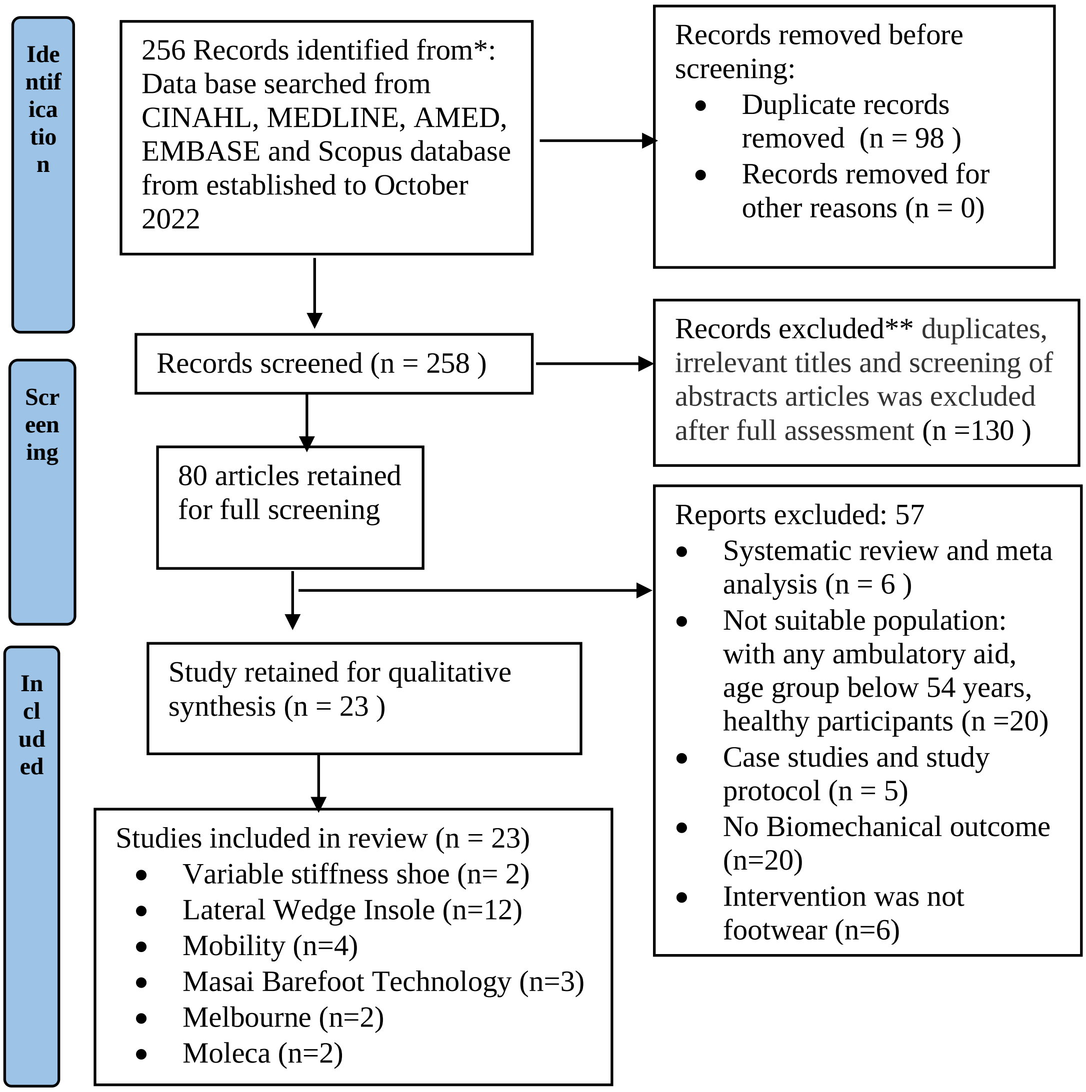


Figure 6. PRISMA Flow chart of study selection

3.3. Risk of bias and quality assessment of study

The risk of bias and quality of the study was assessed in 2 methods: The modified Downs and Black quality and QUADAS 2 tool (Quality Assessment and Diagnostic Accuracy) from Review Manager software (Revman Version 5.1, The Nordic Cochrane Centre, Copenhagen). The modified checklist contained 27 questions divided into the following sub-groups: reporting (1–10), external validity (11–13), internal validity–bias (items–15–20), internal validity–confounding (items–21–26), and power (item–27). The quality of studies meeting ≥75% of the applicable criteria will be considered as high, 60–74% as moderate and 60% as low. 11 studies are high quality, no studies were low, most of the studies are moderate quality. The overall risk of bias and quality of the studies are mentioned in the figure 5 and 6.

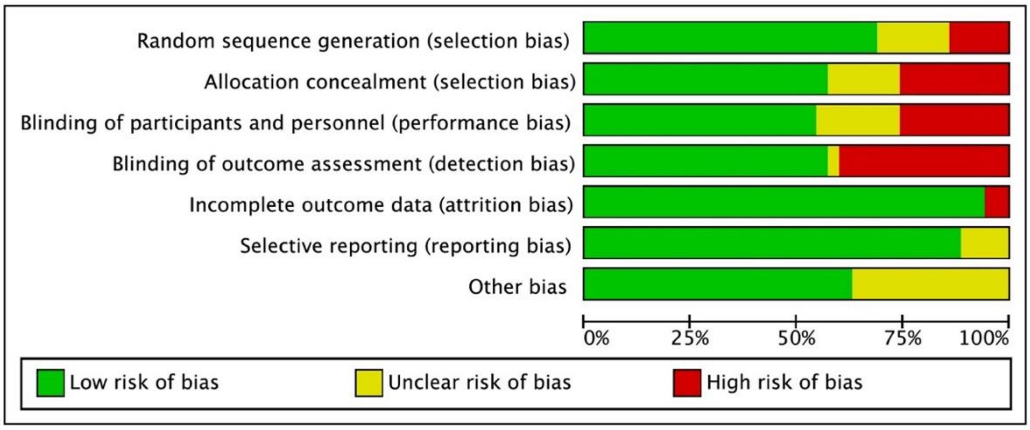


Figure 7. overall risk of bias and quality summary of the studies

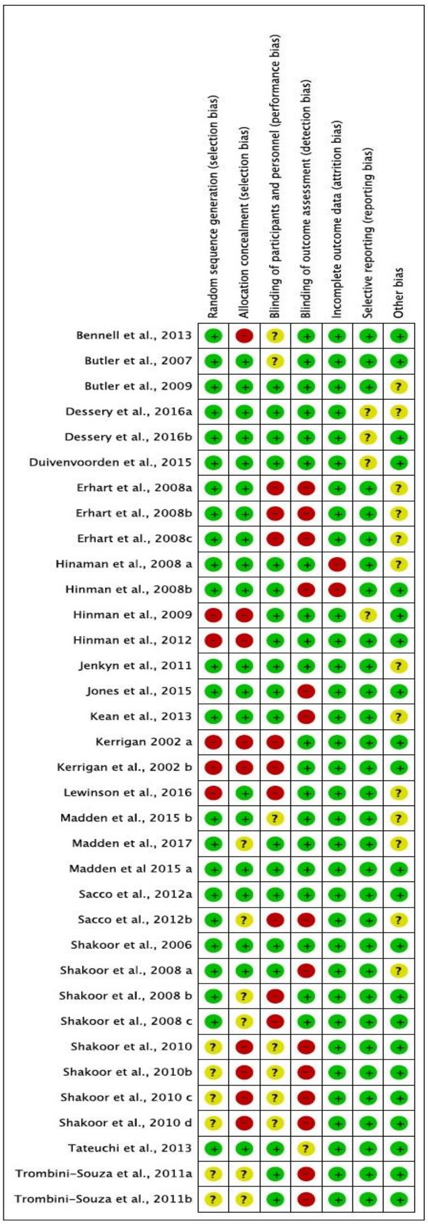


Figure 8. overall risk of bias and quality of the studies

Table 2. Characteristics of Included Study and Intervention						
AUTHOR	**COUNTRY**	**CLINICAL CRITERIA**	**INTERVENTION**	**OUTCOME MEASURE**	**APPLIED**	**QI SCORE**
VARIABLE STIFFNESS SHOE						
(Erhart et al., 2008) (32)	US	42 males+37 females with symptomatic medial knee OA	In two shoes— a constant-stiffness sole control shoe (durometer score of 55±2) a variable-stiffness sole durometer scores of 55±2 for medial sole and 70–76±2 for lateral sole. Each participant performed three walking trials at self-selected slow, normal, and rapid speeds for a total of 18 trials.	8-camera optoelectronic system for 3D motion analysis. 6-marker joint link system for Peak KAM	Unilateral, if subjects were bilateral then measures taken from more severe side	78%
(Jenkyn et al., 2011) (31)	Canada	20 Males + 12 Females with medial knee OA	A control shoe with an uniform sole stiffness and an intervention with Variable Stiffness Shoe with a construction similar to the control but a stiffer lateral sole than medial sole were both used. Each trial was 5 sec.	8-camera optoelectronic system for 3D motion analysis. Peak KAM	Bilateral	75%
LATERAL WEDGE INSOLE						
(Kerrigan et al., 2002) (33)	US	8 Males+ 7 Females with Medial compartment of OA knee	Control group with flat insole and non-wedged insole. Experimental with 5- and 10-degree Lateral Wedge Insoles (durometer score 55), made of Ameri foam, were fitted into subjects' own shoes.	Vicon 512 motion analysis system; 9 markers. Peak Knee Varus Torque	Unclear	65%
(Hinman et al., 2008a) (34)	Australia	7 females +6 males with medial knee OA	Control group with subject's own shoe without insole vs. Experimental group with full length 5^0 lateral wedge and rearfoot lateral wedge (calcaneus to mid-shaft of 5th metatarsal head) Insoles, made of high-density ethyl vinyl acetate, were fitted into subjects' own shoes	Vicon 8-camera motion analysis system. 8 markers (standard Plug-in-Gait set) Peak KAM	Bilateral	68%
(Hinman et al., 2008b) (34)	Australia	24 Females +16 Males with Medial Knee OA	Control group with subject's own shoe without insole. Experimental group with 5^0 lateral wedge, made of high-density ethyl-vinyl acetate, fitted into subject's own shoes	Vicon 8-camera motion analysis system. 8 markers (standard Plug-in-Gait set) Peak KAM	Bilateral	70%
(Hinman et al., 2009) (35)	Australia	12 Female + 8 Males with Medial Knee OA.	Control group is subject's own shoe without insole. Experimental with 5^0 lateral wedges, made of high-density ethyl-vinyl acetate, fitted into subjects' own shoes	Vicon 8-camera motion analysis system. 8 markers Peak KAM	Bilateral	71%
(Hinman et al.,	Australia	45 Female + 28	Control group is subject's own shoe without insole.	Vicon 8-camera motion	Bilateral	80%

2012) (36)		Males with Medial Knee OA.	Experimental with 5^0 lateral wedges, made of high-density ethyl-vinyl acetate, fitted into subjects' own shoes	analysis system. 8 markers Peak KAM		
(Butler et al., 2007) (38)	US	11 females + 9 males with medial knee OA	Control group with non-wedged orthotic. Experimental with 9^0 lateral wedges. Individually wedge degree determined orthotics (durometer score of 70) were fitted into New Balance Athletic shoe	Vicon motion analysis system; 21 markers Peak KAM	Unilateral	65%
(Butler et al., 2009) (39)	US	17 females+13 males with medial knee OA	Control group with non-wedged orthotic. Experimental with 10^0 lateral Wedge. Individually wedge degree determined orthotics (durometer score of 70) were fitted into New Balance Athletic shoe	Vicon 6-camera motion analysis system; 8 markers Peak KAM	Unilateral	70%
(Duivenvoorden et al. 2015) (40)	The Netherlands	28 Females + 14 Males with medial knee OA	Control group with own shoes Experimental group with 6^0 Lateral Wedge Insole	The patients' gait at baseline and after 6 weeks with and without the orthosis; 8 markers Peak KAM	Unclear	71%
(Lewinson et al. 2016) (41)	Canada	13 Females + 6 Males with medial knee OA	Control group with own shoes Experimental group with 6^0 Lateral Wedge Insole	Peak KAM	Bilateral	80%
(Dessery et al., 2016) (42)	Canada	10 Females + 8 Males with medial knee OA	Control group with own shoes Experimental group with $6^0$and 10^0 Lateral Wedge Insole	13 camera and 42 reflective markers: 26 were attached to anatomical landmarks and four rigid marker clusters. Peak KAM	Bilateral	70%
(Jones et al., 2014) (43)	UK	27 females + 43 males with medial knee OA	control vs typical wedge	16 Qualisys motion analysis system cameras with 3D analysis. Peak KAM	Bilateral	75%
MOBILITY SHOES						
(Shakoor et al. 2006) (44)	US	59 females+16 males with medial knee OA	Control group with subject's own walking shoe. Experimental group with barefoot	Multicamera optoelectronic system; 6 markers. Peak KAM	Bilateral	76%
(Shakoor et al. 2008) (45)	US	Experiment A: 24 females+4 males with medial knee OA Experiment B: 16 females+4 males with medial knee	Experiment A: Control group is subject's own walking shoe. Experimental group is barefoot walking, mobility shoe, a flexible and lightweight shoe to mimic barefoot walking. Experiment B: Control group is stability shoe (Brooks Addiction	4 Qualisys optoelectronic cameras. 6 markers Peak KAM	Bilateral	80%

		OA	Walker) Experimental group is barefoot walking and mobility shoe.			
(Shakoor et al. 2010) (46)	US	21 females +10 males with medial knee OA	Control group with barefoot walking Experimental group with clogs vs stability shoes vs flat walking shoes vs flip-flops	4 Qualisys optoelectronic cameras. 6 markers Peak KAM	Bilateral	84%
(Jones et al., 2014) (43)	UK	27 females + 43 males with medial knee OA	control vs mobility shoe	16 Qualisys motion analysis system cameras with 3D analysis. Peak KAM	Bilateral	75%
MASAI BAREFOOT TECHNOLOGY						
(Tateuchi et al., 2013) (47)	Japan	17 females + 0 males with medial knee OA	Control group with own shoes Experimental with Masai Barefoot Technology	7 Camera Vicon motion system, 6 markers Peak Knee Load	Unclear	70%
(Madden et al., 2017) (48)	Australia	15 females + 15 males with medial knee OA	Control group with own shoes Experimental with Masai Barefoot Technology	12 Camera Vicon motion system, 3 floor plate, 5 trials. Peak Knee Load	Unilateral	65%
(Madden et al., 2015) (49)	Australia	15 females + 15 males with medial knee OA	Control group with own shoes Experimental with Masai Barefoot Technology	12 Camera Vicon motion system, 3 floor plate, 5 trials. Peak KAM	Unilateral	70%
MELBOURNE SHOES						
(Kean et al., 2013) (50)	Australia	17 females + 13 males with medial knee OA	Control group with own shoes Experimental with Modified shoes (Gel Melbourne OA, ASICS Oceania Pty. Ltd.)	12 Camera Vicon motion system, plug in gait marker set. 5 trials of 10-meter walk. Peak KAM	Bilateral	85%
(Bennel et al., 2013) (51)	Australia	17 females + 13 males with medial knee OA	Control group with own shoes Experimental with Modified shoes (Gel Melbourne OA, ASICS Oceania Pty. Ltd.)	12 Camera Vicon motion system, plug in gait marker set. 5 trials of 10-meter walk. Peak KAM	Bilateral	87%
MOLECA SHOES						
(Sacco et al., 2012) (52)	Brazil	34 elderly women with medial knee OA	Flexible non heeled shoes (Moleca) vs modern heeled shoe vs barefoot	3D marker displacements with 6 infrared cameras Peak KAM	Bilateral	76%
(Trombini-Souza et al., 2011) (53)	Brazil	45 elderly women with medial knee OA	Moleca vs modern heeled shoe vs barefoot	3D marker displacements with 6 infrared cameras Peak KAM	Bilateral	75%

Table 3. Characteristics of Participants in included studies.

Authors	No.	Sex M: F	Age; years	Height; cm	Body Mass; Kg	BMI; Kg/m^2	Radiographic Feature	K/L grade, no.				Study Design	Follow up
								1	2	3	4		
VARIABLE STIFFNESS SHOES													
(Erhart et al., 2008) (32)	79	42:37	60.2 years (±9.8)	167 cm (±10)	62.8 kg (±9.8)	<35 kg/m^2	Not mentioned about KL grading but medial knee OA	unclear				Pre post intervention design: all the participants were applied to both shoes.	Immediate
(Jenkyn et al., 2011) (31)	32	20:12	58.7 years (±9.3)	162 cm (±80)	81.3 kg (±14.6)	<35 kg/m^2	Not mentioned about KL grading but medial tibiofemoral knee OA	unclear				Pre post intervention design: all the participants were applied to both shoes.	Immediate
LATERAL WEDGE INSOLE													
(Kerrigan et al., 2002) (33)	15	8:7	69.7 years (±7.6)	167 cm (±70)	83.9 kg (±11.9)	Not mentioned	KL grade ≥ 3 Presence of osteophytes and medial knee OA	0	0	10	5	Pre post intervention design: all the participants were applied to both shoes.	Immediate
(Hinman et al., 2008a) (34)	13	6:7	59.7 years (±6.2)	169 cm (±140)	81.0 kg (±20.4)	Not mentioned	KL grade 2 and 3 and medial knee OA	0	7	6	0	Pre post intervention study	Immediate
(Hinman et al., 2008b) (34)	40	16:24	64.7 years (±9.4)	169 cm (±90)	79 kg (±12)	29.6 (±4.2) kg/m^2	Medial tibiofemoral osteophytes	3	10	11	16	Pre post intervention study; RCT	Immediate
(Hinman et al., 2009) (35)	20	8:12	63.5 years (±9.4)	169 cm (±70)	83.1 kg (±12)	<36 kg/m2	Medial tibiofemoral osteophytes	0	8	12	0	Pre post intervention study; RCT	12 months
(Hinman et al., 2012) (36)	73	28:45	63.3 years (±8.4)	167 cm (±90)	77.2 kg (±14.5)	27.7 kg/m^2 (±3.6)	KL grade ≥ 3 Presence of osteophytes and medial knee OA	0	41	32	0	Pre post intervention study; RCT	12 months
(Butler et al., 2007) (38)	20	9:11	63.0 years (±6)	Not mentioned	Not mentioned	33.4 kg/m^2 (±7.8)	KL grade ≥ 2 Presence of osteophytes and medial knee OA	0	7	6	7	Pre post intervention study	2 weeks to accommodate the device and 1 week follow up
(Butler et al., 2009) (39)	30	13:17	63.1 years (±6.8)	Not mentioned	Not mentioned	33.8 kg/m^2 (±6.9)	KL grade ≥ 2 Presence of osteophytes and medial knee OA	0	9	0	11	Pre post intervention study	1 week

(Duivenvoorden et al. 2015) (40)	42	14:28	54.1 years (±7.4)	Not mentioned	Not mentioned	30 kg/m^2 (±1.0)	KL grade ≥ 1 Presence of osteophytes and medial knee OA	15	8	18	1	RCT	42 hours per week (7 days times 6 hours, or 75% of the working day)
(Lewinson et al. 2016) (41)	19	6:13	59.9 years (±7.4)	167 cm (±90)	93.3 Kg (±1.0)	32.5 kg/m^2 (±8.0)	KL grade ≥ 1 Presence of osteophytes and medial knee OA	5	2	3	9	single-blind, parallel groups, randomized controlled trial	3 months
(Dessery et al., 2016) (42)	18	8:10	54.5 years (±8.6)	170 cm (158–186)	83.5 Kg (57.8–98.5)	28.9 Kg/m^2 (22.3–36.0)	KL grade 2 and 3; Presence of osteophytes and medial knee OA; 4.5^0±2.8 varus alignment	0	15	3	0	Randomized single-blinded study	Immediate
MOBILITY SHOES													
(Shakoor et al. 2006) (44)	75	16:59	59 years (±10)	170 cm (±10)	78.9 Kg (±14.4)	28.4 kg/m^2 (±4.1)	KL grade 2 and 3; Presence of osteophytes and medial knee OA;	0	57	18	0	Double blind randomised control trial	Immediate
(Shakoor et al. 2008) (45)	Experimental A												
	28	4:24	59 years (±9)	170 cm (±10)	80 kg (±17)	28.4 kg/m^2 (±5.1)	KL grade 2 and 3;	Unclear				Double blind randomised control trial	Immediate
	Experimental B												
	20	4:16	57 years (±9)	170 cm (±10)	83 kg (±16)	29.6 kg/m^2 (±4.7)	KL grade 2 and 3;	Unclear				Double blind randomised control trial	Immediate
(Shakoor et al. 2010) (46)	31	10:21	59 years (±10)	Not mentioned	Not mentioned	29.3 kg/m^2 (±4.8)	KL grade 2 and 3;	0	20	11	0	Comparative study	Immediate
(Jones et al., 2014) (43)	70	43:27	60.3 years (±9.6)	169 cm (±90)	87.3 kg (±18.5)	30.5 kg/m^2 (±4.9)	KL grade 2 and 3; medial OA > Lateral OA knee	0	17	25	0	RCT, comparative study	Immediate
MASAI BAREFOOT TECHNOLOGY													
(Tateuchi et al., 2013) (47)	17	0:17	63.6 years (±7.9)	156.7 cm (±57)	56.5 kg (±6.5)	23.0kg/m^2 (±2.6)	KL grade ≥ 1 Presence of osteophytes and medial knee OA	1	9	2	5	Pre post intervention design: all the participants were applied to both shoes.	Immediate

(Madden et al., 2017) (48)	30	15:15	61.0 years (±7.3)	167 cm (±70)	79.5 kg (±12.7)	28.3kg/m² (±3.7)	KL grade ≥ 1 Presence of osteophytes and medial knee OA	0	9	10	11	Pre post intervention design: all the participants were applied to both shoes.	Immediate
(Madden et al., 2015) (49)	30	15:15	61.0 years (±7.3)	167 cm (±70)	79.5 kg (±12.7)	28.3kg/m² (±3.7)	KL grade ≥ 1 Presence of osteophytes and medial knee OA	0	9	10	11	Pre post intervention design: all the participants were applied to both shoes.	Immediate
MELBOURNE SHOES													
(Kean et al., 2013) (50)	30	17:13	63.3 years (±9.7)	Not mentioned	Not mentioned	28.6kg/m² (±3.6)	KL grade ≥ 1 Presence of osteophytes and medial knee OA	0	11	9	10	Pre post intervention design	Immediate
(Bennel et al., 2013) (51)	30	17:13	63.3 years (±9.7)	Not mentioned	Not mentioned	28.6kg/m² (±3.6)	KL grade ≥ 1 Presence of osteophytes and medial knee OA	0	11	9	10	Pre post intervention design	Immediate
MOLECA SHOES													
(Sacco et al., 2012) (52)	34	0:34	65.0 years (±6.0)	156 cm (±50)	70.9 kg (±8.0)	29.2kg/m² (±3.3)	KL grade ≥ 2 Presence of osteophytes and medial knee OA	Unclear				Pre post intervention design: all the participants were applied to both shoes.	Immediate
(Trombini-Souza et al., 2011) (53)	45	0:45	65.0 years (±5.0)	154 cm (±50)	68.9 kg (±7.8)	Not mentioned	KL grade ≥ 1 Presence of osteophytes and medial knee OA	Unclear				Pre post intervention design: all the participants were applied to both shoes.	Immediate

Table 4. Summary of result across 23 study in the analysis of 1st peak KAM, 2nd Peak KAM						
Author	**Information Available**	**Unit of Measure**	**Experimental**	**Control**	**Mean difference. (CI 95%)**	**P value**
			Mean ± SD	**Mean ± SD**		
FIRST PEAK KAM						
VARIABLE STIFFNESS SHOES						
(Erhart et al., 2008) (32)	ANOVA test and t-test was used for hoc analysis	%BW x Ht	Slow: 0.46±0.28 Normal: 0.57±0.36 Fast: 0.66±0.50	Slow: 0.70±0.36 Normal: 0.85±0.40 Fast: 1.01±0.49	Slow: -0.240 (-0.34 to -0.14) Normal: -0.28 (-0.40 to	(P<0.01)

					-0.16) Fast: -0.35 (-0.50 to -0.20)	
(Jenkyn et al., 2011) (31)	P value (t test)	%BW x Ht	2.57 ±1.00	2.76 ±1.07	-0.19 (-0.70 to 0.32)	(P<0.01)
LATERAL WEDGE INSOLE						
(Kerrigan et al., 2002a) (33)	P value (t test)	Nm/Kg*m	5° LWI: 0.375±0.090	Control insole (3.2mm): 0.390±0.085	-0.02 (-0.08 to 0.55)	(P<0.01)
(Kerrigan et al., 2002b) (33)	P value (t test)	Nm/Kg*m	10° LWI: 0.363± 0.083	Control Insole (6.35-mm): 0.395± 0.087	-0.03 (-0.09 to 0.03)	(P<0.01)
(Hinman et al., 2008a) (34)	P value (t test)	%BW x Ht	5° full wedge: 3.17± 0.61	No Insole: 3.60±0.90	-0.430 (-1.02 to 0.16)	(P<0.01)
(Hinman et al., 2008b) (34)	P value (t test)	%BW x Ht	5° rare foot wedge: 3.33± 0.69	No Insole: 3.60±0.90	-0.27 (-0.89 to 0.35)	(P<0.01)
(Hinman et al., 2009) (35)	Correlation assumed	%BW x Ht	3.67 ± 0.78	3.83±0.79	-0.16 (-0.64, 0.32)	(P<0.001)
(Hinman et al., 2012) (36)	Pearson r correlation coefficient	%BW x Ht	3.60 ± 0.75	3.82 ±0.78	− 0.22 (− 0.46, −0.02)	(P< 0.001)
(Butler et al., 2007) (38)	P value (t test)	Nm/Kg*m	0.346± 0.122	0.379 ±0.1280	-0.03 (-0.1130 to 0.0470)	(P<0.01)
(Butler et al., 2009) (39)	P value (t test)	Nm/Kg*m	-0.057±0.052	-0.030± 0.034	-0.03 (-0.05 to -0.00)	(P<0.01)
(Duivenvoorden et al. 2015) (40)	Correlation assumed.	Nm/kg	48.96±16.2	51±18	-2.04 (-9.36, 5.28)	(P=0.035)
(Lewinson et al. 2016) (41)	P value (t test)	Nm	60.2±18.6	68.1±21.6	-7.90 (-20.72, 4.92)	(P<0.01)
(Dessery et al., 2016a) (42)	P value (t test)	%BW*Ht	Insole >5^0 and <9^0 0.317 ± 0.078	Control insole 0.352 ±0.084	-0.03 (-0.09, 0.02)	(P<0.01)
(Dessery et al., 2016b) (42)	P value (t test)	%BW*Ht	Insole >9^0 0.332 ± 0.088	Control insole 0.352±0.084	-0.02 (-0.07, 0.03)	(P<0.01)
(Jones et al., 2015) (43)	Group difference/ correlation assumed	Nm/kg	Control shoe 0.39±0.16	Typical Lateral wedge Insole 0.37±0.15	-0.02 (-0.07, 0.03)	(P<0.01)
MOBILITY SHOES						
(Shakoor et al. 2006) (44)	P value (t test)	%BW*Ht	2.94± 0.77	2.59 ± 0.75	0.350 (0.11 to 0.59)	(P<0.001)
(Shakoor et al. 2008a) (45)	Newman-keuls method	%BW*Ht	Mobility 2.49 ± 0.80	Conventional 2.71 ± 0.84	-0.220 (-0.65 to 0.21)	(P<0.05)
(Shakoor et al. 2008b) (45)	Newman-keuls method	%BW*Ht	Mobility 2.66 ± 0.69	Stability 3.07 ± 0.75	-0.47 (0.08 to 0.85)	(P<0.05)
(Shakoor et al. 2008c) (45)	Newman-keuls method	%BW*Ht	Mobility 2.66 ± 0.69	Barefoot 2.71 ± 0.67	-0.05 (-0.47 to 0.37)	(P<0.05)
(Shakoor et al. 2010a) (46)	Correlation assumed.	%BW*Ht	Mobility 2.8 ± 0.7	Barefoot 0.7 ± 0.01	2.10 (1.85 to 2.35)	(P<0.05)
(Shakoor et al. 2010b) (46)	Correlation assumed.	%BW*Ht	Mobility 2.8 ± 0.7	Clog 3.1 ± 0.7	-0.30 (-0.65 to 0.05)	(P<0.05)

(Shakoor et al. 2010c) (46)	Correlation assumed.	%BW*Ht	Mobility 2.8 ± 0.7	Stability 3.0 ± 0.7	-0.20 (-0.55 to 0.15)	(P<0.05)
(Shakoor et al. 2010d) (46)	Correlation assumed.	%BW*Ht	Mobility 2.8 ± 0.7	Flip-fop 2.7±0.8	0.1 (-0.27 to 0.47)	(P<0.05)
(Jones et al., 2015) (43)	Paired t test; Correlation assumed.	Nm/kg	Mobility 0.39 ± 0.16	Barefoot 0.36 ±0.15	0.030 (-0.021 to 0.081)	(P<0.001)
MASAI BAREFOOT TECHNOLOGY						
(Tateuchi et al., 2013) (47)	Paired t test	Nm/kg m	0.44±0.09	0.45±0.08	-0.010 (-0.07 to 0.05)	(P=0.549)
(Madden et al., 2017) (48)	Paired t test	Nm	48.6 ± 18.1	54.1 ± 19.3	-5.50 (-14.97 to -3.97)	(P<0.001)
(Madden et al., 2015a) (49)	ANOVA test	Nm/BW Ht%	MBT 3.76 ± 1.31	Control shoe 4.04 ± 1.33	-0.280 (-0.95 to 0.39)	(P<0.001)
(Madden et al., 2015b) (49)	ANOVA test	Nm/BW Ht%	MBT 3.76 ± 1.31	Barefoot 3.56 ± 1.29	0.20 (-0.46 to 0.86)	(P<0.001)
MELBOURNE SHOES						
(Kean et al., 2013) (50)	Pearson r correlations	Nm/BW Ht%	3.73± 1.30	4.02 ± 1.35	−0.29 (−0.39, −0.19)	(P<0.001)
(Bennell et al., 2013) (51)	ANOVA test	%BW*Ht	Modifies shoe. 3.73± 1.30	Barefoot 3.54 ± 1.27	0.190 (-0.474 to 0.854	(P<0.05)
MOLECA SHOES						
(Sacco et al., 2012a) (52)	Newman-keuls method	%BW*Ht	Moleca 3.45 ± 1.23	Barefoot 3.40 ± 1.37	0.050 (-0.57 to 0.62)	(P<0.001)
(Sacco et al., 2012b) (52)	Newman-keuls method	%BW*Ht	Moleca 3.45 ± 1.23	Heeled 4.08 ± 1.28	-0.40 (-1.00 to 0.20)	(P<0.001)
(Trombini-Souza et al., 2011a) (53)	ANOVA test and t test	%BW*Ht	Moleca 2.5 ± 1.45	Barefoot 2.5 ± 1.53	0.00 (-0.62 to 0.62)	(P<0.001)
(Trombini-Souza et al., 2011b) (53)	ANOVA test and t test	%BW*Ht	Moleca 2.5 ± 1.45	Heeled 2.9 ± 1.43	-0.400 (-0.10 to 0.2	(P<0.001)
SECOND PEAK KAM						
LATERAL WEDGE INSOLE						
(Kerrigan et al., 2002a) (33)	P value (t test)	Nm/Kg*m	5° LWI: 0.317±0.076	Control insole (3.2mm): 0.331±0.083	-0.01 (-0.07 to 0.04)	(P<0.01)
(Kerrigan et al., 2002b) (33)	P value (t test)	Nm/Kg*m	10° LWI: 0.312± 0.078	Control Insole (6.35-mm): 0.335± 0.071	-0.02 (-0.08 to 0.03)	(P<0.01)
(Hinman et al., 2008a) (34)	P value (t test)	%BW x Ht	5° full wedge: 1.70 ± 0.76	No Insole: 1.98±0.82	-0.28 (-0.63 to 0.07)	(P<0.01)
(Hinman et al., 2008b) (34)	P value (t test)	%BW x Ht	5° rare foot wedge:1.84 ± 0.76	No Insole: 1.98±0.82	-0.14 (-0.49 to 0.21)	(P<0.01)
(Hinman et al., 2009) (35)	Correlation assumed	%BW x Ht	2.22 ± 0.79	2.39±0.79	-0.17 (-0.66, 0.32)	(P<0.001)
(Hinman et al., 2012) (36)	Pearson r correlation coefficient	%BW x Ht	1.18 ± 0.38	1.26 ±0.37	− 0.08 (− 0.20, 0.04)	(P< 0.001)

(Butler et al., 2007) (38)	P value (t test)	Nm/Kg*m	0.240± 0.071	0.245 ±0.078	-0.01 (-0.05 to 0.04)	(P=5.4)
(Dessery et al., 2016a) (42)	P value (t test)	%BW*Ht	Insole >5^0 and <9^0 0.260 ± 0.084	Control insole 0.284±0.092	-0.02 (-0.08, 0.03)	(P<0.01)
(Dessery et al., 2016b) (42)	P value (t test)	%BW*Ht	Insole >9^0 0.254 ± 0.087	Control insole 0.284±0.092	-0.03 (-0.09, 0.03)	(P<0.01)
(Jones et al., 2015) (43)	Group difference/ correlation assumed	Nm/kg	Control shoe 0.33±0.14	Typical Lateral wedge Insole 0.30±0.13	-0.03 (-0.07, 0.01)	(P<0.01)
MOBILITY SHOES						
(Shakoor et al. 2006) (44)	P value (t test)	%BW*Ht	0.66± 0.34	0.69 ± 0.30	-0.03(-0.13 to 0.07)	(P<0.001)
(Shakoor et al. 2008a) (45)	Newman-keuls method	%BW*Ht	Mobility 0.87 ± 0.45	Conventional 0.93 ± 0.46	0.02 (-0.19 to 0.23)	(P<0.05)
(Shakoor et al. 2008b) (45)	Newman-keuls method	%BW*Ht	Mobility 0.96 ± 0.42	Stability 1.07 ± 0.42	-0.06 (-0.34 to 0.22)	(P<0.05)
(Shakoor et al. 2008c) (45)	Newman-keuls method	%BW*Ht	Mobility 0.96 ± 0.42	Barefoot 0.94 ± 0.40	-0.11 (-0.33 to 0.11)	(P<0.05)
MASAI BAREFOOT TECHNOLOGY						
(Tateuchi et al., 2013) (47)	Paired t test	Nm/kg m	0.35±0.08	0.33±0.09	0.02 (-0.04 to 0.08)	(P=0.549)
(Madden et al., 2015a) (49)	ANOVA test	Nm/BW Ht%	MBT 1.21 ± 0.52	Control shoe 1.24 ± 0.49	-0.03 (-0.29 to 0.23)	(P<0.001)
(Madden et al., 2015b) (49)	ANOVA test	Nm/BW Ht%	MBT 1.21 ± 0.52	Barefoot 1.09 ± 0.48	0.12 (-0.13 to 0.37)	(P<0.001)
MOLECA SHOE						
(Sacco et al., 2012a) (52)	Newman-keuls method	%BW*Ht	Moleca 3.45 ± 1.23	Barefoot 3.40 ± 1.37	0.050 (-0.57 to 0.67)	(P<0.001)
(Sacco et al., 2012b) (52)	Newman-keuls method	%BW*Ht	Moleca 3.45 ± 1.23	Heeled 4.08 ± 1.28	-0.63 (-1.23 to -0.03)	(P<0.001)
(Trombini-Souza et al., 2011a) (53)	ANOVA test and t test	%BW*Ht	Moleca 2.5 ± 1.45	Barefoot 2.5 ± 1.53	-0.40 (-1.00 to 0.20)	(P<0.001)
(Trombini-Souza et al., 2011b) (53)	ANOVA test and t test	%BW*Ht	Moleca 2.5 ± 1.45	Heeled 2.9 ± 1.43	0.00 (-0.62 to 0.62)	(P<0.001)

SD = standard deviation
Mean Difference is the % of reduction of External knee adduction moment in experimental group (A) compared to control group(B); (A-B).
CI= Confidence interval; KAM= Knee Adduction Moment; NR= Not Reported; %BW*Ht = % body weight * Height

1st Peak Knee Adduction Moment in Variable stiffness shoe

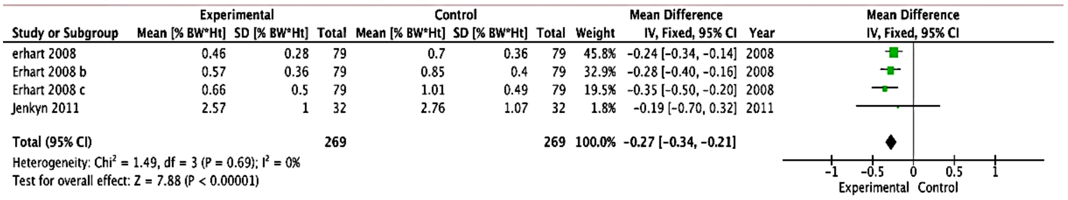


Figure 9a. summarized 1st peak EKAM in VSS shows, overall reduction in EKAM.

1st Peak Knee Adduction Moment in Lateral Wedge Insole (Footwear Modification)

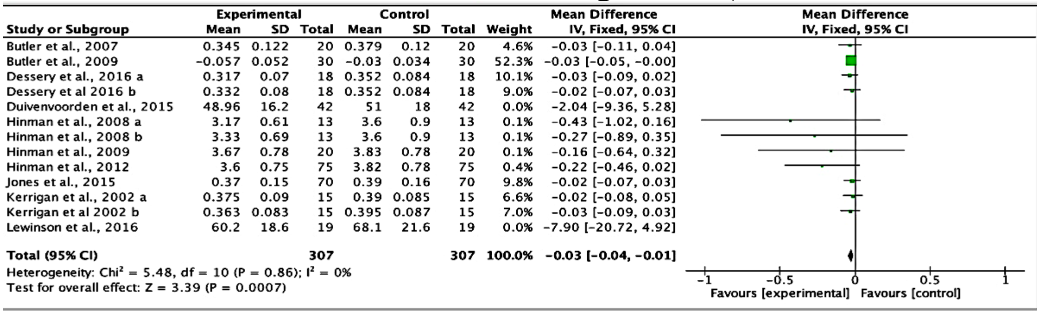


Figure 9b. summarized 1st peak EKAM in LWI shows, overall reduction in EKAM.

1st Peak Knee Adduction Moment in Mobility shoe

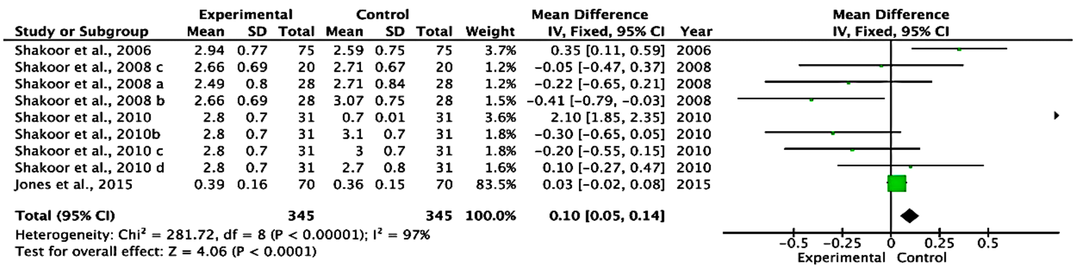


Figure 9c. summarized 1st peak EKAM in Mobility Shoe, shows overall increase in EKAM.

1st Peak Knee Adduction Moment in Masai Barefoot Technology

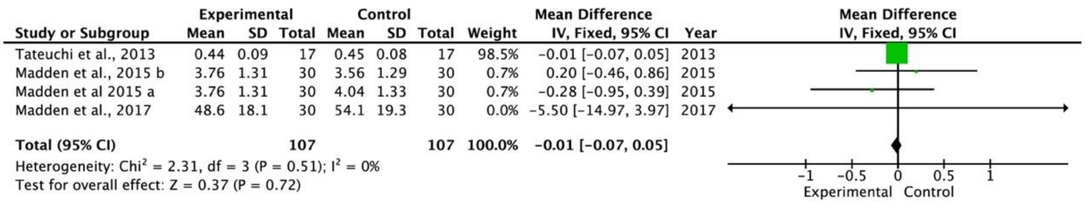


Figure 9d. summarized 1st peak EKAM in MBT, shows overall reduction in EKAM.

1st Peak Knee Adduction Moment in Melbourne Shoe

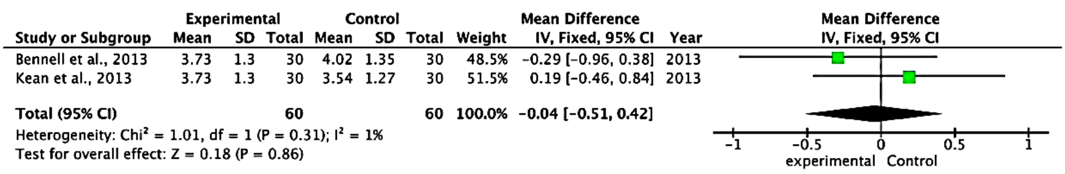


Figure 9e. summarized 1st peak EKAM in Melbourne, shows overall reduction in EKAM.

1st Peak Knee Adduction Moment in Moleca Shoe

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI	Year
Trombini-Souza et al., 2011a	2.5	1.45	45	2.5	1.53	45	24.2%	0.00 [−0.62, 0.62]	2011
Trombini-Souza et al., 2011b	2.5	1.45	45	2.9	1.43	45	26.0%	−0.40 [−1.00, 0.20]	2011
Sacco et al., 2012a	3.45	1.23	34	3.4	1.37	34	24.0%	0.05 [−0.57, 0.67]	2012
Sacco et al., 2012b	3.45	1.23	34	4.08	1.28	34	25.8%	−0.63 [−1.23, −0.03]	2012
Total (95% CI)			**158**			**158**	**100.0%**	**−0.25 [−0.56, 0.05]**	

Heterogeneity: $Chi^2 = 3.34$, df = 3 (P = 0.34); $I^2 = 10\%$
Test for overall effect: Z = 1.65 (P = 0.10)

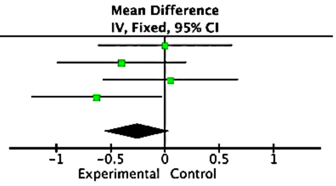


Figure 9f. summarized 1st peak EKAM in Moleca, shows overall reduction in EKAM.

Figure 9. Forest Plot of data pooling for the first peak Knee Adduction Moment (KAM). Solid square indicates the effect size, and the horizontal bar indicates the 95% Confidence Interval (CI). Solid diamond represents the pooled estimates. SD is standard Deviation.

2nd Peak Knee Adduction Moment in Lateral Wedge Insole

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI	Year
Kerrigan et al., 2002 a	0.317	0.076	15	0.331	0.083	15	13.4%	−0.01 [−0.07, 0.04]	2002
Kerrigan et al 2002 b	0.312	0.078	15	0.335	0.071	15	15.2%	−0.02 [−0.08, 0.03]	2002
Butler et al., 2007	0.24	0.071	20	0.245	0.078	20	20.3%	−0.01 [−0.05, 0.04]	2007
Hinman et al., 2008 a	1.7	0.76	40	1.98	0.82	40	0.4%	−0.28 [−0.63, 0.07]	2008
Hinman et al., 2008 b	1.84	0.76	40	1.98	0.82	40	0.4%	−0.14 [−0.49, 0.21]	2008
Hinman et al., 2009	2.22	0.79	20	2.39	0.79	20	0.2%	−0.17 [−0.66, 0.32]	2009
Hinman et al., 2012	1.18	0.38	73	1.26	0.37	73	2.9%	−0.08 [−0.20, 0.04]	2012
Jones et al., 2015	0.3	0.13	70	0.33	0.14	70	21.6%	−0.03 [−0.07, 0.01]	2015
Dessery et al., 2016 a	0.26	0.084	18	0.284	0.092	18	13.1%	−0.02 [−0.08, 0.03]	2016
Dessery et al 2016 b	0.254	0.087	18	0.284	0.092	18	12.7%	−0.03 [−0.09, 0.03]	2016
Total (95% CI)			**329**			**329**	**100.0%**	**−0.02 [−0.04, −0.00]**	

Heterogeneity: $Chi^2 = 4.56$, df = 9 (P = 0.87); $I^2 = 0\%$
Test for overall effect: Z = 2.26 (P = 0.02)

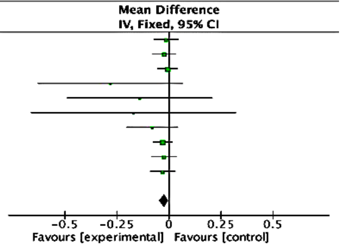


Figure 10a. summarized 2nd peak EKAM in LWI, shows overall reduction in EKAM.

2nd Peak Knee Adduction Moment in Mobility Shoe

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI	Year
Shakoor et al., 2006	0.66	0.34	75	0.69	0.3	75	63.4%	−0.03 [−0.13, 0.07]	2006
Shakoor et al., 2008 b	0.87	0.45	20	0.93	0.46	20	8.4%	−0.06 [−0.34, 0.22]	2008
Shakoor et al., 2008 c	0.96	0.42	28	1.07	0.42	28	13.8%	−0.11 [−0.33, 0.11]	2008
Shakoor et al., 2008 a	0.96	0.42	28	0.94	0.4	28	14.5%	0.02 [−0.19, 0.23]	2008
Total (95% CI)			**151**			**151**	**100.0%**	**−0.04 [−0.12, 0.05]**	

Heterogeneity: $Chi^2 = 0.74$, df = 3 (P = 0.86); $I^2 = 0\%$
Test for overall effect: Z = 0.87 (P = 0.38)

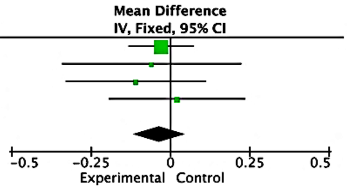


Figure 10b. summarized 2nd peak EKAM in Mobility shoe, shows overall reduction in EKAM.

2nd Peak Knee Adduction Moment in Masai Barefoot Technology

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI	Year
Tateuchi et al., 2013	0.35	0.08	17	0.33	0.09	17	90.8%	0.02 [−0.04, 0.08]	2013
Madden et al., 2015 b	1.21	0.52	30	1.09	0.48	30	4.6%	0.12 [−0.13, 0.37]	2015
Madden et al 2015 a	1.21	0.52	30	1.24	0.49	30	4.6%	−0.03 [−0.29, 0.23]	2015
Total (95% CI)			**77**			**77**	**100.0%**	**0.02 [−0.03, 0.08]**	

Heterogeneity: $Chi^2 = 0.74$, df = 2 (P = 0.69); $I^2 = 0\%$
Test for overall effect: Z = 0.80 (P = 0.42)

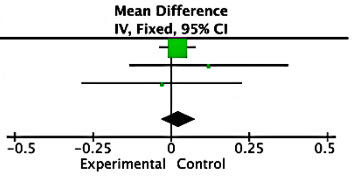


Figure 10c. summarized 2nd peak EKAM in MBT, shows overall increase in EKAM.

2nd Peak Knee Adduction Moment in Moleca shoe

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI	Year
Trombini-Souza et al., 2011b	2.5	1.45	45	2.5	1.53	45	24.2%	0.00 [−0.62, 0.62]	2011
Trombini-Souza et al., 2011a	2.5	1.45	45	2.9	1.43	45	26.0%	−0.40 [−1.00, 0.20]	2011
Sacco et al., 2012a	3.45	1.23	34	3.4	1.37	34	24.0%	0.05 [−0.57, 0.67]	2012
Sacco et al., 2012b	3.45	1.23	34	4.08	1.28	34	25.8%	−0.63 [−1.23, −0.03]	2012
Total (95% CI)			**158**			**158**	**100.0%**	**−0.25 [−0.56, 0.05]**	

Heterogeneity: $Chi^2 = 3.34$, df = 3 (P = 0.34); $I^2 = 10\%$
Test for overall effect: Z = 1.65 (P = 0.10)

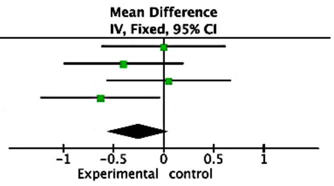


Figure 10d. summarized 2nd peak EKAM in Moleca shoe, shows overall reduction in EKAM.

Figure 10. Forest Plot of data pooling for the second peak Knee Adduction Moment (KAM). Solid square indicates the effect size, and the horizontal bar indicates the 95% Confidence Interval (CI). Solid diamond represents the pooled estimates. SD is standard Deviation.

3.4. Footwear

3.4.1. Variable Stiffness Shoe

The overall pooled effect estimated suggest that the Variable Stiffness Shoe have resulted in a statistically significant reduction in the first peak KAM in both the studies (31, 32) with low level of statistical heterogeneity (Ch^2= 2.31; I^2 = 0%) (figure 7). This represents small effect size hence an absolute change in peak KAM. Erhart et al (32) have done the study in varied speed. At medium speeds, the intervention shoe reduced knee adduction moment on average by 2.4% (P<0.01), whereas at fast speeds reduced knee adduction moment by 6.2% (P<0.001). In another study, KAM was reduced in the experimental group by 6.64% (31). The comparison yielded similar result in both study (MD: -0.27; 95% CI: -0.34, -0.21).

3.4.2. Mobility Shoe

Four studies have reported the effects of KAM in OA knee. Stability shoe walking was shown to have significantly greater initial peak EKAM than barefoot walking (mean values ranging from 3.7 to 14.81%). Comparing the "mobility" shoe to a conventional shoe, the peak EKAM was reduced by 8.1%. As opposed to flat walking shoes, flip-flops, and being barefoot, "stability" shoes and clogs increased the EKAM by roughly 10% to 15% (45, 46).

The overall pooled effect estimated suggest that the barefoot have resulted in a statistically significant reduction in the first peak KAM compared to mobility shoe (43-45). The overall MD is pooled to 0.10; 95% CI (0.05, 0.14) with a substantial heterogeneity, I^2 of 97%. However, the overall pooled effect estimated suggest that there is a statistically significant reduction in the second peak KAM in the same studies (44, 45) with low level of statistical heterogeneity (Ch^2= 0.74; I^2 = 0%) (MD= -0.04; 95% CI= -0.12, 0.05) (figure 8).

3.4.3. Masai Barefoot Technology

Three studies have reported effect in first and second KAM in OA knee, studies have compared MBT with own shoe showed statistically significant reduction in first peak KAM (MD= -0.01; 95% CI= -0.07, 0.05) whereas no reduction in second peak KAM (MD= 0.2; 95% CI= -0.03, 0.08) with a low-level heterogeneity in both (I^2 = 0%). The pooled effects equate to absolute change in both (47-49).

3.4.4. Melbourne Shoes

Two studies have done study to compare Melbourne shoe with own shoe and barefoot, where with own shoe have significant reduction of KAM in Melbourne shoe (MD= -0.29; 95% CI= -0.39, -0.19) and with barefoot, increase of KAM in Melbourne shoe (MD= 0.19; 95% CI= -0.470, -0.854). The overall pooled estimates indicated a significant reduction in KAM in Melbourne shoe (50, 51).

3.4.5. Moleca Shoes

Two studies with four subgroups have reported effect in first and second KAM in OA knee with comparison own shoe and barefoot showed statistically significant reduction in first peak KAM (MD= -0.25; 95% CI= -0.56, 0.05) whereas no reduction in second peak KAM (MD= -0.25; 95% CI= -0.56, 0.05) with a low-level heterogeneity in both (I^2 = 10%). The pooled effects equate to absolute change in both (52, 53).

3.5. Footwear Modifications

3.5.1. Lateral Wedge Insole

The primary result mentioned in the research was the first peak EKAM. The first peak EKAM was reported in all 10 studies(33-36, 38-43). The meta-analysis for the first peak EKAM included a total of 12 comparisons because several research did multiple analyses with other insole variables (<5^0 and >5^0 to <$9^{0)}$, such as the arch support or the length of the wedge. The overall effect suggests that LWI resulted in a statistically significant reduction in the first peak EKAM (n = 307, SMD –0.03 [95% CI –0.04, –0.01], *P* <0.001), with a low level of statistical heterogeneity (Chi^2 = 5.48, *P* = 0.86, I^2 0%). The overall effect suggests that LWI resulted in a statistically significant reduction in the second peak EKAM (n = 329, SMD –0.02 [95% CI –0.04, 0.00], *P* = 0.02), with a low level of statistical heterogeneity ($x2$ = 4.56, P = 0.87, I^2=0%).

DISCUSSION

The main objective of this review was to determine the biomechanical effects of first and second peak KAM of footwear and footwear modifications in patients with medial knee OA. This meta-analysis confirms that footwears and footwear modification cause an immediate reduction on knee load in conservative treatment for people with medial knee OA. Hinman et al (34-36) have taken same population in long term and short term to determine the effects of LWI in medial knee OA, hence have taken these studies in count. Biomechanical parameters related to the medial knee load, including first peak EKAM and second peak EKAM were reduced with the use of a footwears and footwear modification, apart from the mobility shoes in first peak KAM and MBT in second peak KAM in comparison with barefoot.

To our knowledge, there is no meta-analysis have done on footwear and footwear modifications to know the effects of KAM in medial knee OA. The previous meta-analysis (54-56) regarding these issues did not focus on the effects of footwear in people with OA. These studies focused only on insoles; hence these studies did not compare different footwear for medial knee OA patients. In our study, the comparison of footwear was undertaken to find the appropriate footwear for Medial knee OA. In these two meta-analyses, a small SMD was verified in the reduction of the first and second peak of EKAM. For the EKAM, was found an SMD = –0.19 ([95% CI –0.23, –0.15], P <0.001) in the meta-analysis of Arnold et al (54) an SMD = –0.22 ([95% CI –0.37, –0.07], P = 0.001) in the meta-analysis of Xing et al (55). In our study, the estimated pooled effect has found that the Moleca (MD= -0.25; 95% CI= -0.56, 0.05) and Variable Stiffness Shoe (MD: -0.27; 95% CI: -0.34, -0.21) have shown significant reduction in KAM compared to other shoes with low heterogeneity.

4.1. Variable Stiffness Shoe

We have used two studies (31, 32), both have shown similar effect in reducing KAM, the studies are representative. A "variables-stiffness" shoe with a lateral sole that is stiffer than the medial side has had effects on patients with medial knee OA comparable to a 5° lateral wedge. As a result, this shoe may be an alternate load-reducing solution for patients who might feel uncomfortable using insoles or who may not benefit from orthotics (32). Both the studies were limited with indicating only first peak KAM and studies were unclear about the distribution of OA knee based upon KL grading in control and experimental group and 2nd peak KAM hence it shows lack of clarity; therefore, studies with both 1st and 2nd peak KAM and an equal distribution are needed to draw a reliable complete conclusion.

4.2. Lateral Wedge Insole

Overall, twelve studies used in our review. Various factors contributed toward clinical heterogeneity of the included studies, preventing pooling of data. Although the EKAM was used as a primary outcome measure in all included studies, different unit measures were used in different study (Nm/Kg*m; %BW * Ht and Nm/kg).

Different studies have used different grades of OA knee of KL grading (0 to 4). Kerrigan et al (33) included people with Grades 3 or 4 on the K-L scale, in contrast to Hinman et al (34, 35) who included participants with Grades 1 to 4. A greater 95% CI (reported by Hinman et al.) may have resulted from including participants who represented a wider spectrum of severity. In contrast, Jones et al, in his study found that the initial part of the stance phase was substantially decreased by both barefoot walking and lateral wedge insoles, whereas the latter stages of the stance phase were significantly reduced with lateral wedge insoles with equal distribution of population with medial OA knee. (43).

The use of various wedging and control footwear also had an impact on clinical heterogeneity. The amount of wedging varied from 5^0 to 15^0, with most studies employing a lateral wedge of between 5^0 and 7^0. Further difference was found in the control settings, which either used non-wedged insoles or none.

There were variations in the insoles' design and their material characteristics, particularly those reported densities. For example, Butler et al (38) used orthotics with durometer scores of 70 while Kerrigan et al (33) tested insoles with a durometer score of 55. Because the peak EKAM is affected by the density or stiffness of the sole and the wedges, this could have an impact on the final measure. Subjects in the other studies wore their own shoes, although in two research (38, 39) researchers provided a standard shoe. This might alter how participants walk, which might affect the results. Overall, the insole with 6^0 wedges has higher reduction in KAM in 2 studies have included all 4 KL grades OA (40, 41).

4.3. Mobility Shoe

We have taken four studies, two studies have compared flip flop, walking shoe, barefoot, stability shoe and clogs (46) and barefoot with mobility shoe (43). Jones et al (43) have found that barefoot have reduced EKAM with a mean difference of 0.030 compared to mobility shoe. In comparison to walking barefoot, patients with medial knee OA reported high first peak EKAMs 7.4 % and 11.9% while wearing their own comfortable shoes (44).

However, in another study reported that there were no statistically significant differences for EKAM between wearing flip-flops and going barefoot, however the P values were not stated. Thus, it may be advised for individuals with medial knee OA to wear flat shoes and, whenever possible, walk barefoot (46).

4.4. Masai Barefoot Technology

We have used 2 studies, according to Taniguchi et al (47), Masai Barefoot technology significantly reduced the knee flexion moment by 16.7% while maintaining KAM and GRF unchanged. Moreover, the limited papers related to MBT and the insufficient number of populations in the Taniguchi's study left unclear. The overall pooled estimated effect shows no significant change in both studies. More studies are needed to make a conclusion.

4.5. Melbourne Shoes

Two studies have compared the Melbourne shoe, Kean et al (50), have compared with control shoes have reduction in KAM; whereas Bennell et al (51) have showed significant reduction in KAM in barefoot when compared to Melbourne.

4.6. Moleca Shoes

Sacco et al (52) compared the Moleca shoe with a heeled shoe and walking barefoot and concluded that knee OA patients could results in reduced knee loading when descending stairs while wearing the Moleca shoe. The use of Moleca shoe reducing the first peak KAM by 12% and the second peak of KAM during terminal stance by 12% when compared to heels (53). The same study revealed that compared to bare feet, heels enhance the first and second KAM peaks. However, both studies have limited by including only female patients and the KL grading of included patients in both studies are unclear, hence the conclusion need more studies with equal distribution and both male and female patients.

CONCLUSION AND FUTURE RECOMMENDATIONS

This is the first meta-analysis to look at the effects of footwear and its modification in biomechanical effectiveness in OA knee. Overall, all the studies have shown effectiveness in the reduction of KAM except mobility and MBT compared to barefoot. VSS and Moleca shoe shows significant changes in KAM compared to other footwears and modifications. The studies were limited to show equal distribution. Our study has limitation in the inclusion criteria, that the study is not specific in grades of OA because of fewer articles. Hence more studies with higher population and equal distribution considering KL grading, an equal ratio of female to male, and wedge customization concerning KL grading is needed to draw a valid recommendation of footwear in disease specific population with medial knee OA. However, based on our study, the footwear and its modifications show an immediate reduction in EKAM, hence effects in change of biomechanics. VSS and Moleca have greater effect in reducing EKAM.

Declaration by Authors

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