Title: Effects of foot orthoses on the biomechanics of the lower extremities in adults with and without musculoskeletal disorders during functional tasks: a systematic review

Article type: Systematic review

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Abstract

Background: Foot orthoses are among the most commonly used external supports to treat musculoskeletal disorders. It remains unclear how they change the biomechanics of the lower extremities during functional tasks. This systematic review aimed to determine the effects of foot orthoses on primary outcomes (i.e., kinematics, kinetics and electromyography of the lower extremities) in adults with and without musculoskeletal disorders during functional tasks.

Methods: A literature search was conducted for articles published from inception to June 2021 in Medline, CINAHL, SPORTDiscus, Cochrane libraries and PEDro electronic databases. Two investigators independently assessed the titles and abstracts of retrieved articles based on the inclusion criteria. Of the 5 578 citations, 24 studies were included in the qualitative synthesis as they reported the effects of foot orthoses on the primary outcomes. Risk of bias of included studies was determined using the modified Downs and Black Quality Index.

Findings: During low impact tasks, foot orthoses decrease ankle inversion and increase midfoot plantar forces and pressure. During higher impact tasks, foot orthoses had little effects on electromyography and kinematics of the lower extremities but decreased ankle inversion moments.

Interpretation: Even though the effects of foot orthoses on the biomechanics of the lower extremities seem task-dependent, foot orthoses mainly affected the biomechanics of the distal segments during most tasks. However, few studies determined their effects on the biomechanics of the foot. It remains unclear to what extent foot orthoses features induce

different biomechanical effects and if foot orthoses effects change for different populations.

Keywords: Foot orthoses; Lower Extremity; Orthotic devices; Electromyography; Locomotion; Biomechanical Phenomena

1. Introduction

Foot orthoses (FOs) are among the most commonly used external supports to efficiently treat and/or prevent musculoskeletal disorders such as plantar heel pain (Whittaker et al., 2018), posterior tibialis tendon dysfunction (Kulig et al., 2009) and plantar forefoot pain (Arias-Martín et al., 2018). Previous systematic reviews have reported that FOs can provide therapeutic benefits via direct mechanical effects (Desmyttere et al., 2018; Hajizadeh et al., 2020), by inducing somatosensory changes (Aboutorabi et al., 2016) and by generating neuromuscular (Murley et al., 2009; Reeves et al., 2019) effects on the lower extremities. The outcome measures from experimental studies informed us about the neuromuscular and biomechanical effects of FOs under various tasks and conditions. Among these outcome measures, lower extremity kinematics (e.g., joint movements) (Chicoine et al., 2021; Telfer et al., 2013b), kinetics (e.g., joint moments and plantar pressure) (Telfer et al., 2013a; Telfer et al., 2013b) and electromyography (EMG) (e.g., amplitude) (Moisan et al., 2021; Murley and Bird, 2006) when wearing FOs are among the most widely studied to explain their mechanism of action.

Previous systematic reviews have mainly focused on walking, running, cycling and balance control tasks to determine the effects of FOs on lower extremity biomechanics (Aboutorabi et al., 2016; Desmyttere et al., 2018; Hajizadeh et al., 2020; Mills et al., 2010; Murley et al., 2009; Reeves et al., 2019; Yeo and Bonanno, 2014). However, in clinical contexts, FOs are also prescribed to address biomechanical deficits during sports, physical activities and other related functional tasks. A better understanding of how FOs change the biomechanics of the lower extremities during these functional tasks can inform us about their mechanism of action (i.e., understand how they work). Furthermore, by determining the task- and population-specific effects of FOs, future research can disseminate the results of experimental studies into the development of clinical trials, subsequently translate knowledge into clinical practice, and eventually yield better patients' outcomes.

Thus, the main objective of this study was to determine the effects of FOs on lower extremity biomechanics (i.e., kinematics, kinetics, electromyography), in adults with and without musculoskeletal disorders, completing functional tasks (excluding balance control, cycling, walking and/or running). We defined functional tasks as activities or acts that allows one to meet the demands of the environment and daily life. The secondary objective was to determine if FOs specificities (e.g., geometry, material and extrinsic additions) and population characteristics (e.g., musculoskeletal disorders and foot morphology) induce different effects on the biomechanics of the lower extremities.

2. Methods

This systematic review is informed by the framework outlined by the Cochrane handbook for systematic review of interventions (Chandler et al., 2019) and is reported according to the most recent guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021). The protocol was registered a priori on PROSPERO (Registration number: CRD42021259230).

2.1. Inclusion and Exclusion criteria

The inclusion and exclusion criteria for studies selected were based on PICO elements (Schardt et al., 2007). *Population:* individuals 18 years or older*; Intervention:* executing functional tasks (e.g., stair ambulation, jumping, landing) and wearing shoes with custom and/or prefabricated FOs; *Comparator:* only wearing shoes; *Outcomes:* biomechanical lower extremity outcome measures such as reported kinematics (e.g., displacement, speed and/or acceleration), kinetics (e.g., joint moment/power/impulse and/or plantar pressure) and/or electromyography (EMG) activation (e.g., amplitude, onset and/or duration).

Studies were excluded if they used finite element methods, included FOs which were not limited to the foot region (e.g., ankle-foot orthoses, knee-ankle-foot orthoses), investigated the effects of FOs by comparing data from two different data collection sessions, compared the effects of FOs with a barefoot condition and/or the biomechanics of the lower extremities was evaluated during cycling, balance control, running and/or walking (as many systematic reviews related to these tasks were previously published). Review articles, audits, case series, case reports, conference proceedings, and abstracts and communication papers were excluded research designs and publication types. Articles that were not published in French or English were also excluded.

2.2. Information sources and search strategy

Medline (via EBSCO), CINAHL (via EBSCO), SPORTDiscus (via EBSCO), Cochrane libraries and PEDro electronic databases were searched to identify relevant studies published from inception to June 11, 2021. Grey literature from Google Scholar, Science Direct, Clinicaltrial.gov, PROQUEST and reference lists of included articles, were also searched to identify other potential studies. The search strategy was developed by two reviewers (VB and GM) and validated by a librarian at our institution, using MeSH terms and keywords related to four concepts: (1) Foot orthoses, (2) Functional tasks, (3) Biomechanics and (4) Lower Extremity. Boolean Operators "AND" and "OR" were used to combine the four concepts. The literature search was developed for Medline and adapted to each database (Appendix A - supplementary material). References for screening were managed using EndNote version 20.1 (Thomson Reuters, New York, USA).

2.3.Data selection, extraction and management

After duplicates were removed, a training exercise which included random screening of 100 citations by both reviewers (GM and KR) was executed to validate the inclusion and exclusion criteria. As the interrater agreement (Cohen's kappa statistic) was over k = 0.6 threshold (Sim and Wright, 2005), they independently screened titles and abstracts according to the eligibility criteria. A consensus between both reviewers was sought and a third reviewer (VB) addressed discrepancies when required. Then, the full texts were reviewed and a consensus of inclusion was also reached. Data were extracted by a first reviewer (CM) and independently double-checked by another reviewer (KR). An extraction form was designed (GM) and validated by pilot-testing on five reference studies (KR and CM). Data extracted included authors and country, sample size, participants' characteristics (i.e., age, sex, mass, height, patient-related outcomes questionnaires, clinical tests and neuromusculoskeletal disorders of included participants if applicable), types of FOs (i.e., custom or prefabricated) and shoes, FOs' specificities (i.e., material, extrinsic/intrinsic additions), types of functional tasks, measurement tools and outcome measures (e.g., kinematics, kinetics and EMG). A narrative synthesis was performed to report major findings and no meta-analysis was planned as high diversity of interventions, comparators and outcomes was expected. When available, a measure of difference (i.e., mean difference (MD) or effect size (ES)) was included in the results section.

2.4. Risk of bias assessment

A modified version of the Downs and Black (1998) Quality index checklist was used to assess the risk of bias as some items were irrelevant to our systematic review. The details of the checklist modifications and our interpretation are included in Appendix B – Supplementary material. The risk of bias assessment was independently completed by two reviewers (KR and CM) and disagreements were resolved by a third one (GM). All scores were expressed as a percentage of the maximum score. Studies with quality scores of 60% or less were considered of low quality, those between 61 and 74 were considered of moderate quality, and those of 75% or greater were considered of high quality (Desmyttere et al., 2018).

3. Results

3.1. Literature search

Our initial search strategy yielded 5 578 potential articles (including one from the grey literature). A kappa of 0.61 was calculated between both reviewers which indicated a substantial agreement for the title and abstract screening review. Of these articles, 44 articles underwent a full-text review and 25 met the final eligibility criteria. Two of these studies had identical cohorts, data and results (Arastoo, 2010; Arastoo et al., 2014), thus, the most recent study (with the smallest risk of bias) remained in the review (Arastoo et al., 2014). A total of 24 studies were included for qualitative synthesis. A PRISMA flow chart detailing the selection process (Figure 1) and excluded studies' details is available in Appendix C - supplementary material.

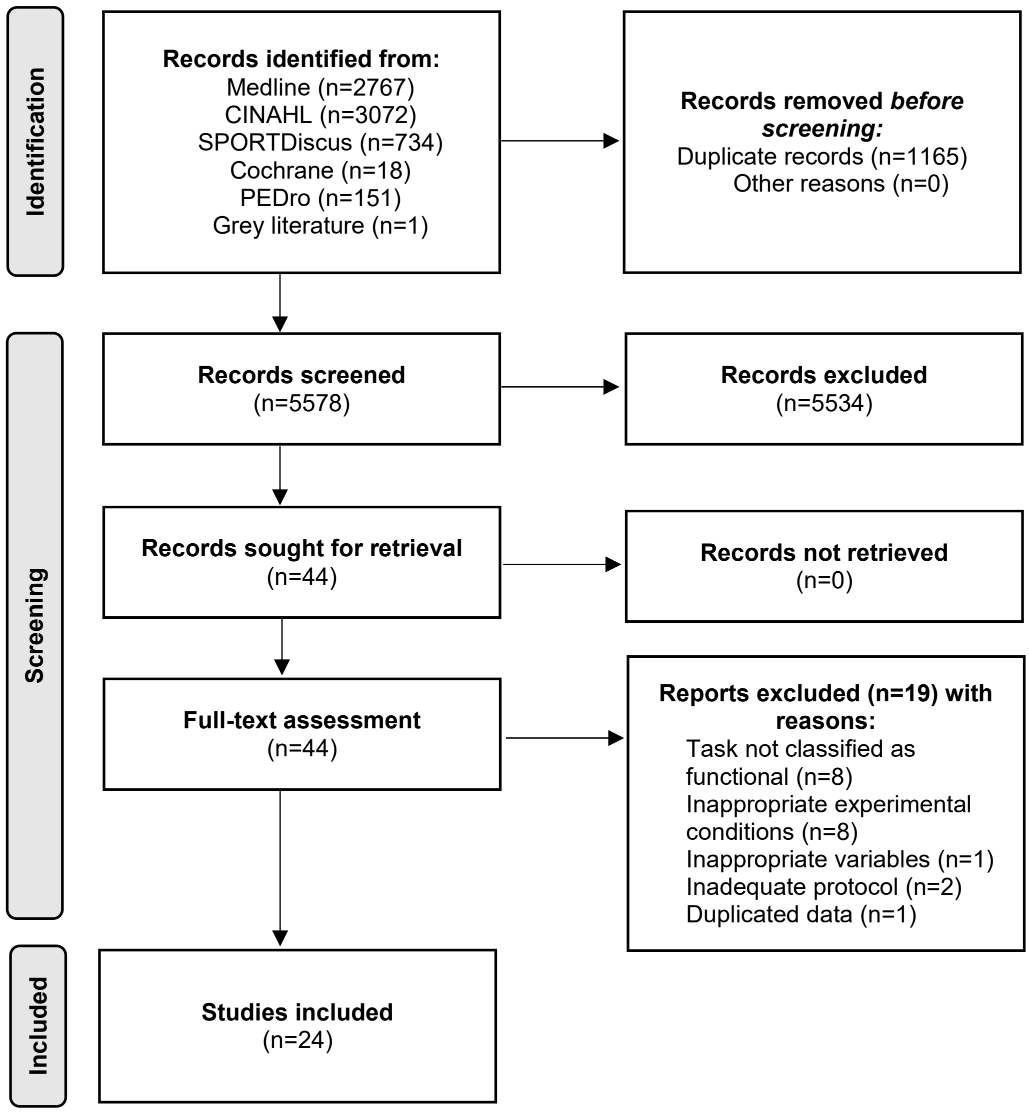

Figure 1. Flow chart of included studies

3.2. Characteristics of the included studies

Specific details regarding the main characteristics of the included studies are available in Table 1. All 24 included studies were published in English. We identified two articles from Canada (Moisan et al., 2019; Moyer et al., 2017), four from the United States of America (Carcia et al., 2006; Hertel et al., 2005; Jenkins et al., 2011; Yu et al., 2007), four from China (Ho et al., 2019; Lam et al., 2021; Lam et al., 2019; Wang et al., 2020), one from Denmark (Rathleff et al., 2016), two from Iran (Arastoo et al., 2014; Esfandiari et al., 2020), one from Italy (Caravaggi et al., 2016), two from Belgium (Dingenen et al., 2015a; Dingenen et al., 2015b), five from the United Kingdom (Alshawabka et al., 2014; Bonifácio et al., 2018; Burston et al., 2018; Lack et al., 2014a; Lack et al., 2014b), two from Australia (Hart et al., 2020; Tan et al., 2020) and one from Thailand (Nouman et al., 2017).

Publication years ranged from 2005 to 2021 with 16 articles published in 2015 to current (Bonifácio et al., 2018; Burston et al., 2018; Caravaggi et al., 2016; Dingenen et al., 2015a; Dingenen et al., 2015b; Esfandiari et al., 2020; Hart et al., 2020; Ho et al., 2019; Lam et al., 2021; Lam et al., 2019; Moisan et al., 2019; Moyer et al., 2017; Nouman et al., 2017; Rathleff et al., 2016; Tan et al., 2020; Wang et al., 2020).

Sample sizes ranged from 8 to 42 participants, for a total of 546 participants and mean age ranged from 20 to 58 years. Thirteen studies included healthy participants (Arastoo et al., 2014; Bonifácio et al., 2018; Burston et al., 2018; Carcia et al., 2007; Dingenen et al., 2015a; Hertel et al., 2005; Ho et al., 2019; Jenkins et al., 2011; Lack et al., 2014a; Lam et al., 2021; Lam et al., 2019; Wang et al., 2020), two included participants with chronic ankle instability (Dingenen et al., 2015b; Moisan et al., 2019), four with patellofemoral pain

(Burston et al., 2018; Hart et al., 2020; Lack et al., 2014b; Rathleff et al., 2016), three with medial knee osteoarthritis (Alshawabka et al., 2014; Esfandiari et al., 2020; Moyer et al., 2017), one with patellofemoral osteoarthritis (Tan et al., 2020), one with diabetes and neuropathy (Nouman et al., 2017) and one with an unknown musculoskeletal status (Caravaggi et al., 2016).

Among the included studies, the following functional tasks were studied: step-down (n=3) (Bonifácio et al., 2018; Burston et al., 2018; Hertel et al., 2005), step up (n=3) (Lack et al., 2014a; Lack et al., 2014b), stair ambulation (n=6) (Alshawabka et al., 2014; Caravaggi et al., 2016; Hart et al., 2020; Moyer et al., 2017; Nouman et al., 2017; Tan et al., 2020), unilateral drop jump landing (n=5) (Carcia et al., 2007; Jenkins et al., 2011; Lam et al., 2021; Moisan et al., 2019; Wang et al., 2020), jump (n=6) (Arastoo et al., 2014; Carcia et al., 2006; Hertel et al., 2005; Ho et al., 2019; Moisan et al., 2019; Rathleff et al., 2016), single-leg squat (n=2) (Hertel et al., 2005; Rathleff et al., 2016), weightlifting (n=1) (Caravaggi et al., 2016), basketball specific tasks (n=1) (Lam et al., 2019), transition from double to single leg stance (n=2) (Dingenen et al., 2015a; Dingenen et al., 2015b) and gait initiation (n=1) (Esfandiari et al., 2020).

Regarding FOs type, custom FOs were studied in seven protocols (Burston et al., 2018; Caravaggi et al., 2016; Dingenen et al., 2015b; Moisan et al., 2019; Moyer et al., 2017; Nouman et al., 2017; Rathleff et al., 2016) and prefabricated FOs in 18 (Alshawabka et al., 2014; Arastoo et al., 2014; Bonifácio et al., 2018; Carcia et al., 2006; Dingenen et al., 2015a; Dingenen et al., 2015b; Esfandiari et al., 2020; Hart et al., 2020; Hertel et al., 2005; Ho et al., 2019; Jenkins et al., 2011; Lack et al., 2014a; Lack et al., 2014b; Lam et al., 2021; Lam et al., 2019; Tan et al., 2020; Wang et al., 2020; Yu et al., 2007).

Authors and country	Risk of bias	n (M/F)	Cohort characteristics	Pathology characteristics	Functional tasks	Experimentation protocol	Shoes characteristics	Outcomes	FOs type	FOs specificities
Molnar et al. (2019) Canada	95	26 (9/15)	Adults with chronic ankle instability Age: 25.3 years (± 5.2), mass: 72.2 kg (± 13.2), height: 1.69 m (± 0.10)	Number of sustained sprains: 4.5 (± 3.9) Time since last sprain: 1.8 years (± 1.9) Foot posture index score: 4.7 (± 3.3) FAAM-ADL: 88.8% (± 8.5), FAAM-S: 61.2% (± 10.7) IPAQ: 3621 MET-min/week (± 3215)	1) Maximal single-leg side jump landing 2) Unilateral drop jump landing on an even surface 3) Unilateral drop jump landing on a 25deg. laterally inclined surface 4) Unilateral drop jump landing on an unstable surface	Five trials of each task with and without FOs Conditions (FOs and shoes only) were randomized	Model: Rupert, Athletic Works *Standardized	Kinematics Kinetics EMG	Custom	Non-weightbearing plaster cast, subtalar joint neutral, midtarsal in maximum pronation Shell: 3.2 mm polypropylene Posting: Ethylene-vinyl acetate rearfoot post, ethylene-vinyl acetate lateral bar Top Cover: 3mm multiform Length: full
Yu et al. (2007) United States of America	63	14 (14/0)	Healthy young adults, competitive basketball players (min. 3x/week) Age: 18 to 30 years	N/A	1) Simulated lay-up (Basketball) with single-leg landing 2) Shuttle run to maximum effort with 180° change of direction	Dominant leg for takeoff and landing Five trials of lay-up and shuttle run with and without FOs	Nike Basketball shoes with a medium midsole stiffness *Standardized	Kinematics Kinetics	Prefabricated (1st Step, Wrymark, Inc. St Louis, MO)	Shell: Semirigid medial arch support Length: full
Carda et al. (2006) United States of America	79	20 (0/20)	Age: 20.1 years (± 1.0), height: 1.69m (± 0.10), mass: 69.7 kg (± 9.7) Navicular drop < 8 mm (Pes planus)	Navicular drop scores by sport: Basketball (n=3): 10.4 mm (± 1.3) (9.6-12.0) Soccer (n=1): 9.8 mm (± 3.3) (8.0-19.3) Volleyball (n=6): 8.9 mm (± 0.7) (8.0-10.0) Mean: 9.6mm (± 2.5)	1) Single-leg forward hop 2) Drop landing	Hands on iliac crest Single-leg forward hop on a force plate from a distance equal to 45% of the participant height Drop landing on a force plate from 20 cm high wooden box positioned 11 cm on the edge of FP 3 trials of each task 15 seconds between trials	Model: New Balance neutral cross trainer *Standardized	Kinematics Kinetics	Prefabricated (Interpod, St Kilda, Australia)	Shell: Rigid Posting: extrinsic 6° rearfoot medial post
Lam et al. (2021) China	79	16 (16/0)	Active university basketball players Age: 24.6 years (± 3.9), height: 1.77 m (± 0.05), mass: 71.5 kg (± 6.4)	Normal foot arch (arch index between 0.21 and 0.28)	1) Drop landing	Look forward and place their arms across their chest Step off the elevated plateform leading with their right leg Landing with the right leg on the force plate and maintain balance after landing Five successful trials for each experimental condition 2 minutes and 10 minutes resting periods were administred between trials and between footwear sessions	Basketball shoes (Model Li Ning, ABPK021) 2 types: high and low collar with the same upper, midsole and outsole material *Standardized	Kinematics Kinetics	Prefabricated (Not mentionned)	Shell: Soft, durable, nonmoldable (rearfoot 6mm thick, forefoot 4mm thick) Posting: Polyurethane of 2mm thickness at forefoot 2 cm at medial longitudinal arch Additions: Longitudinal and metatarsal arch supports (3mm height)
Wang et al. (2020) China	90	19 (19/0)	College basketball players Age: 22.0 years (± 4.0), height: 1.80 m (± 0.03), mass: 75.1 kg (± 7.6)	Foot length of US size 9, normal foot arch, normal color vision	1) Drop landing	Standing on a raised platform (0.45m and 0.61m) Hands on the hips, landed on their right leg on a force plate 5 successful trials for each FOs and height conditions Trial was discarded if an obvious loss of balance 5 minutes rest period after each FOs condition Conditions were randomized	Basketball shoes Model: Wade 4.0, LiNing *Standardized	Kinematics Kinetics	Prefabricated (Arch support series - Universal 2, Dr. Kong footwear)	Red and white FOs: Shell: polyurethane, Top cover: identical except for the color (forefoot: 4mm thick, arch height: 25mm, rearfoot: 6mm thick) White flat: Shell: flat insole, same polyurethane materials of red and white FOs. Additions: no arch support (forefoot: 4mm thick, arch height: 5mm,
Rathleff et al. (2016) Denmark	84	23 (13/10)	Young adults with patellofemoral pain Age: 25.8 years (± 7.4), height: 176.4 cm (± 10.9), mass: 71.2 kg (± 14.0), Foot length: 25.3 cm (± 2.0) Average physical activity per week: 349.7 min (± 272.4). Average daily use of FOs during the 12-wk period:	Knee pain > 6 weeks, pain provocation and reproduction of their symptoms in this position (prolonged sitting, prolonged kneeling, squatting, running, hopping, stair walking) Patellofemoral pain severity assessed at baseline and follow up with PFP severity Scale	1) Drop jump 2) Maximal vertical jump 3) Single-leg squat	Drop jump from 20 cm high box followed by a maximal vertical jump Single-leg squat at a controlled speed (3 sec to go down) to 90° of knee flexion and 3 seconds to go up to 0 degree of knee flexion. 3 successful trials of each task with and without FOs	Model: Le coq Sportif *Standardized	Kinetics	Custom (Super-sole)	Not mentionned
Arastoo et al. (2014) Iran	84	30 (30/0)	Amateur soccer players Participants with normal feet: Age: 23.1 years (± 2.7), height: 1.76 m (± 0.05), mass: 69.5 kg (± 8.3) Participants with flexible flat feet: Age: 22.7 years (± 2.3), height: 1.75 m (± 0.04), mass: 69.9 kg (± 9.2)	Bilateral flexible flatfeet grades 2-3 (determined by Yagami mirror box flatfoot tester model (Flexible Flat-1) and Feiss line test) Previous experience of insole adoption	1) Two-legged vertical jump	Maximal two-legged vertical jump with two feet to head the suspended ball with and without FOs Participants were allowed to swing arms during data collection Five trials with 30 s rest period interval Last three successful jumps were analysed	*Standardized trainer shoes	Kinetics	Prefabricated (Not mentionned)	Shell: Soft, durable, nonmoldable Posting: Polyurethane of 2 mm thickness at forefoot 2 cm and at medial longitudinal arch Additions: Longitudinal and metatarsal arch supports
Jenkins et al. (2011) United States of America	74	36 (18/18)	Healthy physical therapy students Females: Age: 23.8 years (± 2.5), height: 1.65 m (± 0.07), mass: 58.8 kg (± 5.9) Males: Age: 24.6 years (± 2.0), height: 1.81 m (± 0.07), mass: 84.9 kg (± 9.9)	Healthy participants	1) Maximum vertical jump with single-leg landing	Standardized break-in for at least one week before participation FOs were worn for 1-2h/day and progressively increase to 8-10h/day Maximum jump in goff with two feet on FP (with elbows flexed to 90° and upper arm parallel to the floor) Land from their jump on the left foot on a force plate, 20 inches in front if the take off point Required to jump 75% of their maximal vertical jump height 12 trials Conditions were randomized Analysed from initial foot contact to 0.25 s after	Not mentionned	Kinematics	Prefabricated (Foot management inc. Pittsville, MD)	Medial longitudinal arch support with a 4° medial rearfoot post Length: Full length
Hertel et al. (2005) United States of America	63	30 (15/15)	Recreationally active young adults Age: 21.1 years (± 1.6), Height: 1.70 m (± 0.06), mass: 69.1 kg (± 13.9) Foot type: 5 men/5 women with pes planus, pes cavus, pes rectus	Healthy participants	1) Single-leg squat 2) Lateral stepdown 3) Maximum vertical jump	3 trials of each task under 4 orthotics conditions (no FOs, 7° medial rearfoot post, 4° lateral rearfoot post, neutral rearfoot post) Single-leg squat: stood on their testing and reached anteriorly with their nonstance leg Lateral stepdown: stood with their nontesting close to the edge of the 30 cm high wooden box. Bending their testing leg over 2 seconds, lightly touch the floor with nonstance leg and return to the starting position over 2 seconds Maximum vertical jump: Bilateral stance. Flex their knees and hips and swing their arms to jump as high	Low-top athletic shoes *Standardized	EMG	Prefabricated (Superfeet Footbed orthotics, Superfeet Worldwide)	Shell: rigid plastic Posting: contained 7° medial and 4° lateral rearfoot postings (with grinding wheel, medial and lateral postings were removed) Cover: Full-foot soft covering
Ho et al. (2019) China	79	26 (26/0)	Male basketball players Normal-arched group (n=15): age: 21.5 years (± 4.1), height: 1.80 m (± 0.03), mass: 74.1 kg (± 10.9) Flat-footed group (n=11): age: 23.0 years (± 4.7), height: 1.78 m (± 0.05), mass: 76.4 kg (±10.4)	Foot length from 8.5 to 11 US Normal-arched group: Years of playing experience: 7.20 (± 4.39), Chippaux Smirak index: 34.09% (± 6.59), Navicular drop: 5.10 mm (± 2.22), Resting calcaneal stance angle: 3.03° (± 2.70) Flat-footed group: Years of playing experience: 9.10 (± 4.14), Chippaux Smirak index: 45.51% (± 6.75), Navicular drop: 9.90 mm (± 2.22), Resting calcaneal stance angle: 5.95° (±1.88)	1) Vertical countermovement jump (CMJ) 2) Standing board jump (SBJ)	1): Standing upright on the force plate, squatted position with hips and knees flexed, before extending the legs to jump up vertically and off the ground with maximal effort, participant swing their arms, land within the force plate, maintaining balance after landing 2): Stand upright on the edge of the force plate, SBJ with maximum effort, by bending the hips and knees and going to squatted position with the arm swing, followed by extension of the legs and forward lean of the body for take-off For 1) and 2), five successful trials were recorded for each insole condition	Basketball shoes Model: Wade All Day 2, ABPM013 *Standardized shoes and socks	Kinematics Kinetics	Prefabricated (Firm Orthotic Insole, Salford Insole, UK)	1) FOs: Forefoot: thickness 6mm, hardness 40C; arch: height 31mm, hardness 55C; rearfoot: thickness 9mm, hardness 50C 2) Neutral flat insole, minimal arch support Forefoot: thickness 6mm, hardness 40C; arch: height 6mm, hardness 40C; rearfoot: thickness 9mm, hardness 35C
Caravaggi et al. (2016) Italy	79	17 (11/6)	Age: 45.1 years (± 5.2), body mass index: 26.7 kg/m² (± 4.5), shoe size: 42 Euro (± 3)	Manchester Oxford Foot questionnaire: 28.1 (± 11.9) Manchester Oxford Foot questionnaire sub-score: pain: 11 (± 4.3), walking/standing: 10.3 (± 6.3), social interaction: 6.8 (± 3.7)	1) Single and double leg standing 2) mass lifting 3) Stair ascent and descent	Single-leg and double-leg standing mass lifting: Bend knee and maintaining the back spine as straight. Stairs ascent and descent: Total of 3 steps were recorded Task was performed with custom and prefabricated FOs	Model: Base Protection, Italy Features: safety shoe, padded collar, puncture-resistant outsole and steel toe cap Standardized shoes	Kinetics	Custom and prefabricated (Not mentionned)	Prefabricated FOs: Fitted with thin, perforated and feature less prefabricated insole Shell: Polyurethane with perforated thermoplastic Top Cover: anti-slip material, full length Additions: heel pad, medial arch support, metatarsal pad Full length custom FOs shell: direct mill ethylene-vinyl acetate Cast: weightbearing laser scan
Dingenen et al. (2015a) Belgium	79	15 (8/7)	Age: 20.2 years (± 1.4), height: 1.75 m (± 0.12), mass: 65.7 kg (± 11.3), Foot length: 25.5 cm (± 2.0),	Healthy young adults Navicular drop dominant leg: 6.0 mm (± 2.9) Navicular drop non-dominant leg: 6.5 mm (± 3.1)	1) Transition from double-legged to single-legged stance eyes open/eyes closed	Stood on FP, feet separated by the width of the hips Transition task from double-leg stance to single-leg stance position (shifting the mass to the tested leg) Lift one leg on command of the examiner toward ≤60° of hip flexion within 1 s Tested in 4 conditions: 1) Barefoot, 2) Shoes only, 3) Shoes with standard FOs, 4) Shoes with custom FOs with eyes open/closed 3 trials for each conditions Test procedure was repeated for the non-tested leg during a separate testing session, scheduled the same week Testing leg was determined randomly Force plates and EMG data signals of the last trial was	Model: Saucony Grid Shadow 9 TR *Standardized	EMG	Prefabricated (Not mentionned) Custom	Prefabricated: Posting: ethylene-vinyl acetate, height of medial arch support was based on the correction of half the navicular drop Custom: participant already wore FOs before experimentation
Dingenen et al. (2015b) Belgium	79	15 (9/6)	Age: 21.8 years (± 3.0), height: 1.78 cm (± 0.10), mass: 72.0 (± 14.6), Foot length: 25.7 cm (± 1.8), MSK disorders: Chronic ankle instability Bilateral CAI: 8 participants Started FOs due to foot/ankle problem: 11, due to lower back pain: 1, due to combination of lower extremity problems: 3	Navicular drop of more affected extremity: 4.9 mm (± 3.3), Navicular drop of less affected extremity: 5.5 (± 2.7), Correction of navicular drop of more affected extremity with standard FOs: 3.7 mm (± 3.0), Correction of navicular drop of more affected extremity with custom FOs: 3.3 mm (± 3.1), Correction of navicular drop of less affected extremity with standard FOs: 4.4 mm (± 2.3), Correction of navicular drop of less affected extremity with custom FOs: 3.9 mm (± 2.3), Worn custom FOs: 15.7 months (± 21.3) Always wear FOs: 10 participants, FOs during sports activities: 4 participants, FOs sometimes: 1 participant	1) Transition from double-legged to single-legged stance eyes open/eyes closed	Stood on FP, feet separated by the width of the hips Transition task from double-leg stance to single-leg stance position (shifting the mass to the tested leg) Lift one leg on command of the examiner toward ≤60° of hip flexion within 1 s Tested in 4 conditions: 1) Barefoot, 2) Shoes only, 3) Shoes with standard FOs, 4) Shoes with custom FOs with eyes open/closed 3 trials for each conditions Test procedure was repeated for the non-tested leg during a separate testing session, scheduled the same week Testing leg was determined randomly Force plates and EMG data signals of the last trial was exported for analysis	Model: Saucony Grid Shadow 9 TR *Standardized	EMG	Prefabricated (Not mentionned) Custom	Prefabricated: Posting: Ethylene-vinyl-acetate, height of medial arch support was based on the correction of half the navicular drop Hardness of standard FOs (Shore A): 60.0 (±0.0) Custom: participant already wore FOs before experimentation
Esfandiari et al. (2020) Iran	68	40 (0/40)	Knee osteoarthritis group (n=21) Age: 53.1 years (± 7.4), 14 individuals had unilateral knee osteoarthritis Control group (matched) (n=19) Age: 47.5 years (± 11.2)	Knee osteoarthritis group: Kellgren-Lawrence scale ≤2, medial knee pain ≤3 on visual analog pain scale	1) Gait initiation	Heel and lateral border of the feet were identified with tapes Received verbal cue to initiate walking Walking until the end of walkway 3 trials for right and left extremity at baseline and four-week follow-up: 1) Barefoot, 2) Own shoes, 3) Lateral wedge FOs	Sneakers or orthopedic shoes without high heels or narrow toe boxes Non-standardized shoes	Kinetics	Prefabricated (Not mentionned)	Posting: 5° wedge from high density EVA Additions: Wedge was posted in lateral border of FOs, 10 mm medial longitudinal arch support (low density EVA) For individuals with unilateral osteoarthritis, neutral FOs without wedge for uninvolved extremity
Alshawabka et al. (2014) United Kingdom	63	8 (3/5)	Age: 47.4 years (± 3.0), height: 1.69 m (± 0.09), mass: 66.1 kg (± 11.5) MSK disorders: medial knee OA grade 1-3 (Kellgren-Lawrence scale)	Kellgren-Lawrence osteoarthritis grade scale Grade 2: 6, grade 3: 2	1) Stair ascent 2) Stair descent	Five trials at a self-selected speed ≠ handrails Started each trial with the same foot, ascended three stairs in step-over-step manner, turned around, descended steps in step-over-step manner	Model: ECCO ZEN *Standardized	Kinematics Kinetics	Prefabricated (SureStep-Control)	Shell: medium density, Shore A 70 Additions: medial arch Posting: 5 deg. lateral wedge Length: full
Hart et al. (2020) Australia	79	42 (22/20)	Age: 35.9 years (± 6.8), mass: 73.1 kg (± 12.1), height: 1.71 m (±0.09), body mass index: 24.9 kg/m2 Musculoskeletal disorders: Patellofemoral pain	Duration of patellofemoral pain (number (%)): 3-6 months: 4 (9.5), 6-12 months: 10 (23.8), 1-2 years: 4 (9.5), ≥2 years: 24 (57.1) Pain visual analogue scale (0-100mm): Usual pain: 19.9 (17.3), worst pain: 36.3 (22.4), average pain during most aggravating activity: 37 (21.1), maximum pain during walking: 15.7 (19.9), and during stair ambulation: 30.4 (25.1) Knee Injury and Osteoarthritis Outcome score (0-100): pain 77.4 (13.3), symptoms: 76.7 (12.4), activity of daily living: 84 (13.3), sports and recreation: 55 (28.9) Quality of life: 50 (19), Patellofemoral: 61.1 (16.8) Anterior knee pain scale (0-100): 74.9 (11) Radiographic PFOA (KL≥2), number (%): 9	1) Stair ascent 2) Stair descent	Stair ascent and descent Self-selected speed With and without FOs	Model: Nike Strap Runner Running sandals *Standardized	Kinematics Kinetics	Prefabricated (Vasyli, Labrador Australia)	Shell: Ethylene-vinyl-acetate, shore A70 Additions: medial arch support Posting: 6-deg medial wedge Length: full
Moyer et al. (2017) Canada		35 (22/13)	Age: 55 years (±6), height: 1.70 m (± 0.08), mass: 90.4 kg (± 19.6), body mass index: 30.0 kg/m2 (± 5.9), wedge size: 3 mm = 1, 6 mm = 17, 6 mm = 17 MSK disorders: confirmed medial knee osteoarthritis	Pain at rest (0-10): 0.9 (± 1.0) Knee injury and osteoarthritis score (0-100): Pain: 54.3 (± 16.2), symptoms: 43.5 (± 13.0), ADL: 62.0 (± 19.2), Sport and recreation: 26.1 (± 19.6), Quality of life: 31.3 (± 17.3) Mechanical axis angle (°): Kellgren and lawrence grade 1 (n=8): -2.5 (± 0.8) Kellgren and lawrence grade 2 (n=12): -4.4 (± 3.0) Kellgren and lawrence grade 1 (n=14): -7.1 (±	1) Stair ascent 2) Stair descent	Balanced latin square design was used to randomize testing conditions (Control, custom-made lateral wedge FOs and combined knee brace + FOs) Four trials of stair ascent and descent using a step-over-step manner at a self-selected speed in all testing conditions ≠ handrails	Model: New Balance *Standardized	Kinematics Kinetics	Custom (Sole-Science, London, CAN)	Full weightbearing plaster cast Length: Full Shell: 3 mm ROH500 shell with posting made from EVA with 55 shore A-durometer hardness, uniform thickness Additions: maximum wedge height while maintaining confort. 3 prefabricated FOs: Length: full, additions: lateral wedge of 3, 6 and 9 mm Unaffected extremity was fit with FOs
Nouman et al. (2017) Thailand	79	16 (9/7)	Age: 58 years (± 9), height: 1.58 m (± 0.08), mass: 73.3 kg (± 14.1), body mass index: 28.7 kg/m2 (± 4.8) MSK disorders: Neuropathic diabetic patients	Duration of diabetes: 8.4 years (± 4.5), Callus at big toe: 62.5% of patients, Callus at metatarsal heads: 81.3% of patients, Hallux valgus: 31.3% of patients	1) Walking on inclined surface 2) Stair walking (ascent and descent)	10 trials of stair ascent and descent with and without FOs ≠ walking aid or handrail 10 minutes to rest after each walking activity	Non-standardized shoes	Kinetics	Custom (Streifeneder ortho production GmbH, Emmering, Germany)	Cast: Positive plaster molds Foam: compressed to capture the foot and medial longitudinal arch with knee at 90 degrees and a neutral subtalar joint Top cover: multiform as the top layer, plastazole as second layer and microcellular rubber as the final stabilizing layer
Tan et al. (2020) Australia	74	21 (7/14)	Age: 58 years (± 8), body mass index: 27.0 kg/m² (± 4.8)	Duration of pain: 3-6 months = 2 (9.5%), 6-12 months = 0 (0%), 1-2 years = 2 (9.5%), > 2 years = 17 (81%), FPI: 3 (1 to 7), mass bearing ankle joint dorsiflexion ROM: 9.1 cm (± 3.2), Arch height difference: 8.8 mm (± 5.2), Midfoot width difference: 8.9 mm (± 3.1), Foot mobility magnitude: 14.8 mm (± 7.9), Usual pain VAS (0-100 mm): 40 mm (± 22), Worst pain VAS (0-100 mm): 55 mm (± 30), Anterior knee pain scale (0-100): 50 (±17)	1) Stair ascent 2) Stair descent	Stair ascent and descent at a self-selected speed Successful trials if total foot contact occur on one of the two embedded FP 6 successful trials for 3 tests conditions: FOs, flat insert, CON	Participant own shoes OR Neutral shoes: Mizuno Wave Rider	Kinematics Kinetics	Prefabricated (Vasyli Medical) Flat shoes insert	Prefabricated: Full length arch contoured FOs, Shell: high density, Posting: Ethylene-vinyl-acetate with inbuilt arch support, 6° medial wedge, Top cover: synthetic fabric (Cambrelle, Camtex Fabrics) Flat shoe inserts: Posting: high-density, Shell: uniform thickness, Length: full (3 mm), Top cover: same synthetic top cover (Cambrelle, Camtex Fabrics)
Bonifácio et al. (2018) United Kingdom	63	16 (10/6)	Age: 25.7 years (± 5.8), mass: 71.7 kg (± 10.6), height: 1.75 m (±0.09), body mass index: 23.3 kg/m2 (± 1.7), Mean FPI score: +5 (±4)	Healthy participants	1) Step-descent	6 repetitions of 20 step descents from a step at a self-selected speed Three randomized conditions	Model: Dr Comfort Winner Plus *Standardized	Kinematics Kinetics EMG	Prefabricated (Not mentionned)	1) Control flat insole 2) Posting: Medial longitudinal arch support with a 5° medial rearfoot post 3) Posting: Medial longitudinal arch support with 5° medial forefoot and rearfoot posts Posts: Standardized arch support, neutral heel, 5° posting material was ethylene-vinyl acetate
Burston et al. (2018) United Kingdom	79	30 (15/15)	Healthy participants: Age: 30.1 years (± 10.0), mean Foot Posture index score: 6.3 (+4 to +9) Patellofemoral pain participants: Age: 28.6 years (± 5.8), mean FPI score: 7.9 (+6 to +10)	Pain around the patella, visual analog pain score of at least 3 on a regular basis following sport or descent stairs Pronated feet, no history of knee surgery or back pain	1) Step-descent	Five repetitions of a step descent task for each condition (no FOs, 3/4 full length FOs, full-length FOs) at a self-selected speed Three steps of heights 20 cm, 40 cm and 20 cm were placed on the force plates	Own training shoes	Kinematics Kinetics	Custom Prefabricated (Slimflex)	Shell: heat molded, low density ethylene-vinyl acetate (Shore A 30) Posting: 5° medially wedged ethylene-vinyl acetate - 3/4 or full length post Length: 3/4 length FOs and full length FOs
Lack et al. (2014a) United Kingdom	79	18 (11/7)	Age: 29.2 years (± 3.7), height: 1.75 m (± 0.07), mass: 72.5 kg (± 11.8) MSK disorders: ≠ FPI score: normal (0-5) = 14, pronated (6-9) = 2, high-supinated (-5 - -12) = 1 Mean Knee bent Ankle dorsiflexion ROM: 50.2° ± 5.8°, values ranging from 42° to 62°	Physically active and asymptomatics individuals No history of lower-extremity or knee pain in the last 12 months. No lower back pain or neuro-musculoskeletal deficits	1) Step-up	Stepped up onto a 22 cm height (force plate + wooden step) Dominant leg was always the leading Five trials Conditions (FOs and shod) were randomized	Model: Asics Nimbus Neutral *Standardized	Kinematics EMG	Prefabricated (Vasyli Easy Fit)	Posting: 6° medial rearfoot post Length: 3/4
Lack et al. (2014b) United Kingdom	74	20 (9/11)	Age: 28.5 years (± 4.2), height: 1.72 m (± 0.07), mass: 64.8 kg (± 9.7) FPI score: normal (0-5) = 8, pronated (6-9) = 10, high-pronated (10-12) = 1, supinated (-1 - -5) = 1	Kujala patellofemoral score (median (IQR)): 80 (± 10.75) Orebro pain questionnaire score (median (IQR)): 63 (± 20.75) FPI: 5.4 (± 3.2) Knee straight ankle dorsiflexion: ± 39.4° (± 5.8) Knee bent ankle dorsiflexion: 45° (± 6.6) Hip abduction strength: 36.2 kg (±6.2)	1) Step-up	Stepped up onto a 22 cm height (force plate + wooden step) Dominant leg was always the leading Five trials Conditions (FOs and shod) were randomized	Model: Asics Nimbus Neutral *Standardized	Kinematics EMG	Prefabricated (Vasyli Easy Fit)	Posting: 6° medial rearfoot post Length: 3/4
Lam et al. (2019) China	79	13 (13/0)	Basketball players Age: 21.4 years (± 3.3), height: 1.80 m (± 0.06), mass: 72.0 kg (± 7.1) Average competition experience: 4.5 years (± 3.7)	Healthy participants	1) Basketball free-throw with a fatigue protocol (Yo-yo intermitted recovery protocol, consecutive maximal vertical jump)	20 free-throw shooting trials during the first FOs condition and 20 free-throw during the second FOs condition Participants performed the fatigue-inducing protocol (2 x 20m shuttle runs with a 10 s recovery period between set, 30 s rest standing, 10 consecutive maximal-effort vertical jumps) 20 free-throw shooting trials during one FOs condition The maximal consecutive jump protocol was repeated 20 free throw shooting during another FOs condition	High-top basketball shoes Model: Wade 6 *Standardized	Kinematics Kinetics	Prefabricated (CNC milling machine, Vulcan Series, Sensor medica, Italy)	2 types of FOs: 1) Medial-arch support (29mm) 2) Flat control (arch height =8mm) FOs had the same material, thickness and hardness (except for the medial-arch support) Hardness of FOs across forefoot, midfoot and rearfoot with type C durometer (1600 Asker SP-698 Rex Durometers)

Table 1. Cohort characteristics and type of FOs used in included studies

3.3. Biomechanical effects of FOs during functional tasks

A detailed summary of the studies' kinematic, kinetic and EMG outcome measures during functional tasks are included in Table 2, Table 3 and Table 4, respectively.

3.3.1. Step-up and down tasks

Three studies reported a step-down task (Bonifácio et al., 2018; Burston et al., 2018; Hertel et al., 2005), including a total of 61 healthy participants (Bonifácio et al., 2018; Burston et al., 2018; Hertel et al., 2005) and 15 with patellofemoral pain (Burston et al., 2018). Hertel et al. (2005) investigated the thigh muscle activity during a lateral step-down task from a 30 cm wooden box with and without three types of full-length prefabricated FOs (with a neutral, a 7º medially inclined and a 4º laterally inclined rearfoot post). The authors reported that regardless of the worn FOs, vastus medialis muscle activity increased and gluteus medius and vastus lateralis muscle activity remained unchanged. Bonifácio et al. (2018) reported the kinematic, kinetic and EMG effects of two full-length prefabricated FOs designs (with a 5º medial ethylene-vinyl acetate (EVA) rearfoot post or a 5º medial EVA rearfoot and forefoot posts) during a forward step-down task. Both types of FOs decreased the peak metatarsocalcaneal internal rotation angle (MD: 0.6 and 0.9º), peak ankle eversion angle (MD: 0.9 and 1.1º), peak ankle abduction angle (MD: 2.6 and 2.4º), peak knee internal rotation moment (MD: 0.031 and 0.034 Nm/kg) and abductor hallucis integral EMG (MD: 17.8 and 19.8%) as well as increased peak hip external rotation angle (MD: 1.4 and 1.7º) and knee adduction moment (MD: 0.061 and 0.058 Nm/kg) compared to a control condition. Furthermore, they reported that FOs with a rearfoot post generated a reduction in hip frontal range of motion (MD: 1.1 and 1.0º) and tibialis anterior integral EMG (MD: 13.1 and 10.2%) compared to FOs with rearfoot and forefoot posts and a control condition. Burston et al. (2018) reported that ¾ and full-length EVA FOs with a 5º medial wedge reduced knee frontal moments during the forward continuum phase compared to a control condition.

Two studies reported a step-up task which included 18 healthy participants (Lack et al., 2014a) and 20 participants with patellofemoral pain (Lack et al., 2014b). Lack et al. (2014a) reported that prefabricated FOs with a 6º medial heel wedge reduced hip adduction angles (MD: 1.6º) 100 ms after initial contact and knee internal rotation angles (MD: 1.3º) during initial contact. FOs had no effect on vastus medialis, vastus lateralis and gluteus medius muscle activity in healthy individuals during a step-up task onto a 22 cm platform. Lack et al. (2014b) reported that these prefabricated FOs reduced hip adduction angles (MD: 0.8º), knee internal rotation angles (MD: 0.5º) and gluteus medius peak amplitude (MD: 0.9 mV) compared to a control condition in individuals with patellofemoral pain.

3.3.2. Stair ascent and descent tasks

Six studies reported a stair ambulation task, including 43 participants with medial knee osteoarthritis (Alshawabka et al., 2014; Moyer et al., 2017), 21 with patellofemoral osteoarthritis (Tan et al., 2020), 42 with patellofemoral pain (Hart et al., 2020), 16 with diabetes and neuropathy (Nouman et al., 2017) and 17 with an unknown musculoskeletal status (Caravaggi et al., 2016). Tan et al. (2020) reported that full-length prefabricated EVA FOs with a 6º medial wedge did not change lower limb kinematics and kinetics during stair ascent and descent in individuals with patellofemoral osteoarthritis. Using identical FOs, Hart et al. (2020) reported a reduction in peak hip flexion (ES: 0.11), maximum ankle inversion (ES: 0.28), maximum ankle external rotation (ES: 0.24), hip external rotation angular impulse (ES: 0.29), as well as ankle dorsiflexion (ES: 0.56), eversion (ES: 0.89) and internal rotation (ES: 0.21) angular impulses compared to a control condition during stair ascent. They also reported greater peak knee flexion angle (ES: 0.14) and lower knee adduction angle excursion (ES: 0.23), maximum ankle inversion angle (ES: 0.26), hip adduction angular impulse (ES: 0.17) as well as ankle dorsiflexion (ES: 0.45) and eversion (ES: 0.45) angular impulses when wearing these prefabricated FOs during stair descent.

Caravaggi et al. (2016) investigated the effects of full-length prefabricated FOs made of polyurethane and thermoplastic and custom EVA FOs on plantar pressure during stair ambulation. The authors reported an increase in peak forefoot pressure in prefabricated FOs compared to custom FOs (MD: 41.0 and 39.5 kPa) and footwear only (MD: 26.3 and 22.3 kPa). Additionally, increased maximum midfoot force in custom (MD: 5.6 and 8.3 %BW) and prefabricated (MD: 5.1 and 5.7 kPa) FOs was observed in comparison to the control condition during stair ascent and descent, respectively. They also reported greater forefoot pressure-time integral in prefabricated FOs compared to custom FOs during stair ascent (MD: 18.8 kPa) and greater midfoot pressure-time integral wearing custom (MD: 9.4 kPa) and prefabricated (MD: 8.5 kPa) FOs compared to a control condition during stair descent. Nouman et al. (2017) reported that full-length custom FOs fabricated from multifoam, plastazote and rubber reduced toes (ES: 0.85 and 1.00), forefoot (ES: 0.82 and 0.88) and increased midfoot (ES: 0.78 and 1.26) peak plantar pressure during stair ascent and descent in individuals with diabetes and neuropathy. No effects were found for the force-time integral across foot regions.

Alshawabka et al. (2014) reported that full-length medium density prefabricated FOs with a 5° lateral wedge reduced external knee adduction moments (ES : 0.75 and 0.94), knee adduction angular impulse (ES: 0.88 and 0.90), knee flexor moments (ES: 0.92 and

0.49) and increased ankle eversion moments (ES: 0.89 and 0.92) and ankle eversion angles (ES: 0.52 and 0.66) compared to a control condition during stair ascent and descent in individuals with medial knee osteoarthritis. Moyer et al. (2017) reported that full-length custom EVA FOs with a 3, 6 or 9 mm lateral wedge increased peak knee flexion moment (MD: 0.31 %BW*height) and reduced toe out (MD: 4.3º) and trunk lean (MD: 0.9º) angles compared to a control condition in individuals with medial knee osteoarthritis. The authors also reported negligeable effects on knee frontal moments and angles, knee flexion angles and vertical ground reaction forces.

3.3.3. Unilateral jump landing tasks

Five studies reported a unilateral drop jump landing task which included 26 participants with chronic ankle instability (Moisan et al., 2019) and 91 healthy participants (Carcia et al., 2007; Jenkins et al., 2011; Lam et al., 2021; Wang et al., 2020). Moisan et al. (2019) reported that custom polypropylene FOs with a neutral rearfoot post and a lateral bar decreased tibialis anterior muscle activity of individuals with chronic ankle instability during landing on a stable surface from a 46 cm high platform. FOs had no effects on ankle and knee angles and moments, and gluteus medius, vastus medialis, vastus lateralis, biceps femoris, gastrocnemius medialis, gastrocnemius lateralis and peroneus longus muscle activity remained unchanged when landing on a stable, unstable or 25º laterally inclined surface, nor from a maximal single-leg single jump landing compared to a control condition. Jenkins et al. (2011) reported that full-length prefabricated FOs including a 4º rearfoot medial wedge reduced peak hip adduction (MD: 2.3º) and hip adduction excursion (MD: 1.5º) angles in females, although not in male participants, when compared to a control condition during landing from a vertical jump. Carcia et al. (2006) reported that ¾ length

Functional task	Authors	Equipment	Protocol	Outcomes	Main findings
1) Maximal single-leg side jump landing 2) Unilateral drop jump landing on even surface 3) Unilateral drop jump landing on a 25 deg laterally inclined surface 4) Unilateral drop jump landing on unstable surface	Moisan et al. (2019)	1 force plate (Bertec)	Sampling rate: 2000 Hz Low-pass filtered by a dual pass, fourth-order Butterworth filter with a cut-off frequency of 50 Hz Inverse dynamics was used to calculate joint moments (normalized to body mass) Normalized to 100% of the landing phase for each task Initial contact was determined when the vertical GRF>10 N	Knee and ankle moments Landing and pre-activation phases of jump landing	ø significant difference for ankle and knee moments
1) Simulated Lay-up (Basketball) with Single-leg landing 2) Shuttle run to maximum effort with 180° change of direction	Yu et al. (2007)	2 force plates (4060A, Bertec) Pedar insoles (Novel Inc.)	Sampling rate: 1200 Hz (force), 200 Hz (pressure) Pressure insoles placed over FOs in dominant leg only Force on sensor = area of force was calculated by each respective area divided by the total of sensors in this region under the foot sole Normalized to body mass	Peak vertical GRF Plantar force and pressures on the head and base of the fifth metatarsal	ø significant effect on peak vertical GRF during both tasks ↑ maximum plantar force and pressure under the head of the fifth metatarsal during the stance of shuttle run with FOs ø significant effect on maximum plantar force and pressure on the head of the fifth metatarsal during landing after a lay-up with FOs ↑ maximum plantar force and pressure on the head of the fifth metatarsal during landing after a lay-up than during the stance of the shuttle run with FOs
1) Drop landing	Lam et al. (2021)	1 force plate (Advanced Medical Technology Inc.)	Sampling rate : 1000 Hz Initial contact was determined when the vertical GRF>10 N Landing phase was determined as initial contact to maximum knee flexion Normalized to body mass	Peak vertical GRF Ankle and knee moments in sagittal and frontal planes	ø significant interactions between collar height and FOs for any GRF and joint moments variables Significant FOs effects for forefoot peak GRF and peak ankle inversion moment FOs ↑ forefoot peak GRF and ↓ ankle inversion moment for FOs vs control
1) Drop landing	Wang et al. (2020)	1 force plate (Advanced Medical Technology Inc.)	Sampling rate: 1000 Hz Inverse dynamics was used to calculate ankle and knee moments Initial contact was determined when the vertical GRF >10 N Normalized to body mass	GRF: forefoot peak vGRF, rearfoot peak vGRF, rearfoot max loading rate Joint moments: peak ankle plantarflexion, peak ankle eversion, peak knee extension	ø significant interaction for GRF variables between FOs and landing height or main effect of insole Simple main effect for ↓ PF moment with red FOs vs White-flat FOs, but ø differences between FOs when landing from higher landing height Red and White-Control FOs ↑ peak ankle eversion moment at higher compared to lower landing height ø significant differences between landing heights were observed with white FOs Red FOs ↓ PF moment VS White-Flat insoles
1) Drop jump 2) Maximal vertical jump 3) Single-leg squat	Rathleff et al. (2016)	Pedar insoles (Novel Inc.)	Sample data : 100 Hz Outcomes reported via peak force per region divided by total peak force and expressed as percentage	Peak foot medial to lateral force Foot mean and peak force Nine regions : hallux, 2-5 metatarsal bones, medial forefoot, midfoot and rearfoot, central forefoot, lateral midfoot and forefoot, lateral rearfoot	**Drop jump** ↓ peak force by 2.9% -point and ↓ mean force by 4.9%-point with FOs vs control **Single-leg squat** ↓ peak force by 4.1% -point and ↓ mean force by 7.4%-point with FOs vs control 12 participants who improved in the patellofemoral pain syndrome severity scale had a larger reduction in peak medial-to-lateral foot loading during drop jump with FOs vs participants who did not report an improvement
1) Two-legged vertical jump	Arastoo et al. (2014)	1 force plate (Bertec)	Sampling rate: 500 Hz GRF normalized to body mass	GRF in anterior-posterior, mediolateral and vertical directions from initial to terminal stance	↑ peak F2 in participants with flatfeet without FOs vs with FOs ↑ stance time duration during two-legged vertical jumping for participants with flatfeet with FOs vs without FOs
1) Vertical countermovement jump 2) Standing broad jump	Ho et al. (2019)	1 force plate (90x 60 cm, (Advanced Medical Technology Inc.)	Sampling rate : 1000 Hz Fourth order low-pass Butterworth filter with a cut-off frequency of 13.33 Hz Instant take off was determined when the vertical GRF<3N Normalized to body mass	Hip, knee and ankle peak angular velocities, peak sagittal moments and powers	**Vertical countermovement jump** ø significant effects of FOs **Standing broad jump** FOs ↓ peak horizontal GRF and ↓ peak ankle frontal moment at take off
1) Single and double leg standing 2) Mass lifting 3) Stair ascent and descent	Caravaggi et al. (2016)	Pedar insoles (Novel gmbh)	Sampling rate : 50 Hz	Maximum force (%BW), peak pressure and time-normalized pressure-time integral at the forefoot, midfoot and rearfoot and for the total foot	ø significant difference for cadence between FOs during stair ascent and descent Plantar pressure with custom FOs were significantly different from corresponding measures with control and prefabricated FOs conditions in almost all plantar regions, across all motor tasks ↓ maximum force with custom vs prefabricated FOs during single-leg standing Midfoot: ↑ maximum force for custom FOs vs control ø significant differences under the forefoot for maximum force were observed between FOs Custom FOs were more effective at ↓ peak pressure across motor tasks under rearfoot and forefoot Midfoot: ↑ peak pressure for custom FOs vs control condition in most motor tasks ↑ time-normalized pressure-time integral for custom FOs at midfoot and ↓ under rearfoot and forefoot across most motor tasks ↑ order of peak pressure with custom FOs for each motor task at rearfoot, midfoot and forefoot and in the total foot
1) Gait initiation	Esfandiari et al. (2020)	1 force plate, (60 x 50 cm, 9260AA, Kistler Instrument AG)	Sampling rate: 1000 Hz Recorded for 6 s Low-pass filtered with a cut-off frequency of 20 Hz	Anteroposterior and mediolateral center of pressure position, 3 components of GRF, associated moments and free vertical moment	ø significant effect of FOs compared to a shoe only condition
1) Stair ascent 2) Stair descent	Alshawabka et al. (2014)	2 force plates (Advanced Medical Technology Inc., BP400600) *force plate embedded into custom stairs	Sampling rate: 200 Hz **External** joint moments calculated using inverse dynamics Normalized to body mass Based on the maximum and minimum peak values for each conditions and each participant	External knee adduction moment and center of pressure during early stance, mid stance and late stance Knee adduction angular impulse Knee flexion moment	**Early stance phase** ↓ peak external knee adduction moment with FOs for stair ascent (-6.8%) and descent (-8.4%) vs control **Mid stance phase** ↓ mean values of external knee adduction momen with FOs for stair ascent (-13%) and stair descent (-10.7%) vs control **Late stance phase** ↓ second peak of external knee adduction momen with FOs during stair ascent (-15%) and descent (- 8.34%) vs control ↓ Knee adduction angular impulse with FOs vs control during stair ascent and descent ↑ lateral center of pressure trajectory with FOs vs control during stair ascent and descent
1) Stair ascent 2) Stair descent	Hart et al. (2020)	3 force plates (Advanced Medical Technology Inc.)	Sampling rate : 1080 Hz Filtered with a fourth-order, zero lag Butterworth low-pass filter with a cut-off frequency of 6 Hz - 30 Hz Normalized to body mass	Hip and knee flexion angular impulse Hip and knee adduction angular impulse Hip external rotation angular impulse Ankle dorsiflexion and eversion angular impulse Knee and ankle internal rotation angular impulse	**Stair ascent** **With FOs** ↓ hip external rotation angular impulse, ↓ ankle dorsiflexion, ↓ ankle eversion, ↓ internal rotation angular impulse ø significant differences between conditions for the knee **Stair descent** **With FOs** ↓ hip adduction angular impulse ↓ ankle dorsiflexion and ↓ eversion angular impulse
1) Stair ascent 2) Stair descent	Moyer et al. (2017)	Force plates (Advanced Medical Technology Inc.) *Stair-embedded force plate	Samping rate: 600 Hz Knee moments reported in the orthogonal coordinate system of the tibia Visually inspected to ensure data was synchronized at heel-strike and toe-off Filtered using a dual-pass, fourth order Butterworth low-pass filter with a cut-off frequency of 6 Hz Normalized to body mass and height, plotted to 100% of stance Moments in stance phase of the second ascent (or second last descent) step were analyzed	1st peak knee adduction moment, 2nd peak knee adduction moment, peak knee flexion moment, peak knee extension moment, vGRF Maximum and minimum knee flexion and adduction angles	Custom FOs with a lateral wedge ↑ peak knee flexion moment and reduced toe out and trunk lean angles compared to a control condition ø significant effect on knee frontal moments and angles, knee flexion angles and vertical ground reaction forces.
1) Walking on an inclined surface 2) Stair walking (ascent and descent)	Nouman et al. (2017)	Pedar insoles (Novel Inc.)	Sampling rate: 100 Hz Inbuilt threshold of 15 kPa that resulted in a cutoff value in pressure recording to reduce noise	Peak plantar pressure and force-time integral for 4 foot regions (Toes, forefoot, midfoot and hindfoot)	**Stair ascent and descent** ↑ peak plantar pressure under the midfoot with FOs vs control ↓ peak plantar pressure under the toes and forefoot with FOs vs control ø significant differences in force-time integral with and without FOs Pressure mapping indicated there was a redistribution of peak plantar pressure and ↑ contact area with FOs
1) Stair ascent 2) Stair descent	Tan et al. (2020)	Two embedded force plates (Kistler, type 9865B) One force plate for stair ascent/descent (Advanced Medical Technology Inc., Accugait)	Sampling rate : 100 Hz Calculated during the stance phase of gait, with stance phase reported from 0 to 100% Averaged across a minimum of 2 trials for stair ambulation Normalized to body mass	Peak hip, knee and ankle flexion and extension moments during early stance Peak ankle plantarflexion and dorsiflexion moments during the stance phase Peak knee adduction moments during early and late stance	ø significant main effect during stair ascent During stair descent, significant main effect of FOs on peak external dorsiflexion moment, with a trend towards ↓ peak dorsiflexion moment for FOs vs flat inserts and shoes alone
1) Step-descent task	Bonifácio et al. (2018)	2 force plates (Advanced Medical Technology Inc.)	Sampling rate: 2000 Hz Filtered with fourth-order Butterworth low-pass filters with cut off frequencies of 25 Hz Calculated using three-dimensional inverse dynamics. Normalized to body mass	Peak ankle, knee and hip moments in sagittal, frontal and transverse planes	↑ peak knee adduction moment for FOs with a rearfoot post and FOs with rearfoot and forefoot posts vs control during step descent ↓ peak knee internal rotation moment for FOs with a rearfoot post and rearfoot and forefoot posts vs control
1) Step-descent task	Burston et al. (2018)	4 force plates (Advanced Medical Technology Inc.)	Sampling rate: 200 Hz Filtered with fourth-order Butterworth low-pass filters with cut off frequencies of 25 Hz z Quantified from toe off to initial contact of the contralateral side	Maximum knee flexion, adduction and abduction during the forward continuum and lowering phases Knee ROM in the frontal and transverse planes	FOs ↓ reduced knee frontal moments during the forward continuum phase compared to a control condition ø other significant effect
1) Basketball free-throw with a fatigue protocol (Yo-yo intermitted recovery protocol, consecutive maximal vertical jump)	Lam et al. (2019)	1 force plate (Advanced Medical Technology Inc.)	Sampling rate: 1000 Hz The analyzed period was defined to the lowest point of elbow joint to the point of basketball release of the shooting arm Filtered with fourth order Butterworth bidirectional low-pass filters with cut-off frequency determined with a residual analysis	Maximum range of resultant, medial-lateral and anterior-posterior center of pressure excursion, total resultant, ML and anterior-posterior center of pressure excursion, mean resultant, medial-lateral and anterior-posterior sway velocity along the center of pressure path and 95% ellipse sway area included within the center of pressure path	FOs produced significantly ↓ total resultant and anterior-posterior sway excursions, resultant and anterior-posterior center of pressure velocities and base of support area vs flat insoles ø other significant effect

Table 2. Summary of articles related to kinetics

Functional task	Authors	Marker set	Equipment	Protocol	Outcomes	Main findings
1) Maximal single-leg side jump landing 2) Unilateral drop jump landing on even surface 3) Unilateral drop jump landing on a 25 deg laterally inclined surface 4) Unilateral drop jump landing on unstable surface	Moisan et al. (2019)	Four three-marker clusters : sacrum, distal one third of the thigh, distal one third of the leg and posterior part of the calcaneus. 15 virtual markers : Bilateral : Anterior-superior iliac spine + Posterior-superior iliac spine On the affected lower-extremity : greater trochanter, lateral and medial femoral condyles, fibular head, tibial tuberosity, lateral and medial malleoli, proximal posterior surface of the calcaneus, distal attachment of the Achilles tendon, sustantaculum tali and fibular tubercle	9-camera motion analysis system (Optotrak Certus)	Sampling rate: 100 Hz Low-pass filtered at 6 Hz by a dual-pass, fourth-order Butterworth filter. Knee and ankle angle calculated with a Cardan sequence of X (extension/flexion), Y (adduction/abduction), Z (internal/external rotation). Normalized to 100% of the landing phase of each task	Ankle and knee angles in sagittal, frontal and transverse planes	↔ significant difference were observed for ankle and knee angles
1) Simulated Lay-up (Basketball) with a single-leg landing 2) Shuttle run to maximum effort with a 180° change of direction	Yu et al. (2007)	Bilateral: medial and lateral tibial condyles, anterior and proximal aspects of the tibia, and the shoes over the heel, on the head of the first and fifth metatarsals and over the medial and lateral malleoli	3D videographic and analog data acquisition system with 6 infrared video camera (Peak Performance Technologies)	Sampling rate : 120 Hz Filtered with fourth-order Butterworth low-pass digital filter at estimated optimal cutoff frequency Ankle joint angles calculated with a Cardan-Euler sequence of Z : plantarflexion/dorsiflexion, Y: inversion/eversion, X: internal/external rotation	Maximum ankle inversion angle	↑ maximum ankle inversion angle (2.5°) during landing of the lay-up and during the stance of the shuttle run with FOs vs control
1) Single-leg foward hop 2) Drop landing	Cardia et al. (2006)	L5-S1 Mid-lateral thigh Distal to the fibular head Proximal/distal aspects of segments were digitized	3 electromagnetic sensor Ascension technology	Sampling rate: 100 Hz	Tibial and femoral transverse angles: Initial contact angle, peak angle, excursion, time-to-peak angle	Hop task : ↑ tibia lateral excursion in transverse plane with FOs vs control during initial contact Landing task: ↑ peak tibia transverse angle with FOs vs control
1) Drop landing	Lam et al. (2021)	Four pelvis markers (Anterior-superior iliac spine, Posterior-superior iliac spine), medial and lateral femoral condyles and malleolus, calcaneus (posterior proximal, posterior distal and lateral aspects), 1st metatarsal head (medial side), 2nd metatarsal head (dorsal side), 5th metatarsal head (lateral side) *Markers of medial and lateral epicondyles were used during calibration trials but then removed during landing trials	8-camera motion analysis system (Oxford Metrics)	Sampling rate : 200 Hz Filtered with fourth-order Butterworth low-pass filter with a cut-off frequency of 12 Hz	Angle at touchdown : Ankle plantarflexion and inversion, knee flexion and varus Peak angle during contact: Ankle dorsiflexion, inversion and eversion, knee flexion, varus and valgus Total range of motion during contact: Ankle and knee in sagittal and frontal planes Maximum velocity during contact for ankle inversion	↑ initial knee flexion angle with FOs vs control ↔ other significant effects
1) Drop landing	Wang et al. (2020)	Reflective markers: Anterior-superior iliac spine, posterior-superior iliac spine, medial and lateral femoral epicondyles, medial and lateral malleoli, three calcaneus markers (upper, lower and lateral aspect of calcaneus), medial side of first metatarsal head, upper side of second metatarsal head and lateral side of the fifth metatarsal head (markers on malleolus and femoral epicondyles were used during a calibration trial) 2 four-marker rigid clusters : thigh and leg segments	8-camera motion analysis system (Oxford Metrics)	Sampling rate: 200 Hz Filtered with fourth-order Butterworth low-pass digital filter with cut-off frequencies determined using residual analysis Contact period: initial contact of one foot to 50 ms after knee flexion Joint angles: defined as the orientation of one distal segment relative to proximal segment (positive value: flexion, extension, internal rotation for respective orthogonal planes, zero degree defined at a neutral standing position for inversion-eversion and internal-external rotation)	Ankle: Plantarflexion and eversion at touchdown, peak dorsiflexion, peak eversion, range of motion sagittal, range of motion frontal Knee: Flexion at touchdown, peak flexion, range of motion sagittal	↔ significant effects of FOs on ankle and knee kinematics
1) Maximum vertical jump with a single-leg landing	Jenkins et al. (2011)	Bilateral: Anterior-superior iliac spine, L5-S1 junction, greater trochanter, medial and lateral knee, medial and lateral malleoli, medial and lateral metatarsal heads Tracking markers: Bilateral on the upper leg, lower leg and rearfoot	8-camera motion analysis system (Qualisys motion Analysis system)	Sampling rate: 240 Hz Segment coordinate systems X-Y-Z were established for lower extremity Three-dimensionnal coordinates were filtered with second-order recursive Butterworth filter with a cut-off frequency of 12 Hz	Excursion and peak hip adduction and abduction angles	↔ significant differences between genders **Males** ↔ differences between FOs vs control for hip adduction angle **Females** ↓ peak hip adduction and ↓ hip adduction excursion with FOs vs control 11/18 women had ↓ hip adduction excursion while 7/18 women had ↑ than or equal to the mean of 1.3° less hip adduction excursion with FOs 13/18 women had a ↓ peak hip adduction while 6/18 had ↑ than or equal to the mean of 2.3° less peak hip adduction with FOs
1) Vertical countermovement jump 2) Standing broad jump	Ho et al. (2019)	Left and right anterior-superior iliac spines, posterior-superior iliac spines, lateral and medial femoral epicondyles, medial and lateral malleoli, medial side of the first metatarsal head, lateral side of the first metatarsal head, posterior upper, posterior lower and lateral aspect of the calcaneus Four-marker rigid clusters : thigh, shank	10-camera motion analysis system (Vicon, Metrics Ltd, Oxford, UK)	Sampling rate: 200 Hz Fourth order Butterworth low-pass filter with a cut-off frequency of 13.33 Hz Braking and propulsion phases were determined with the knee flexion	Hip, knee and ankle angles in sagittal and frontal planes during take-off	**Vertical countermovement jump** ↓ ankle eversion at take off for FOs vs control ↔ other significant effects **Standing broad jump** ↓ ankle eversion at take off for FOs vs control ↔ other significant effects
1) Stair ascent 2) Stair descent	Alshawabka et al. (2014)	Anterior-superior iliac spines, posterior-superior iliac spines, greater trochanter, medial and lateral femoral epicondyle, head of fibula, tibial tuberosity and medial and lateral malleoli. Markers were glued to heel and forefoot of the shoes. Cluster markers: shank, thigh, pelvis	16-camera motion analysis system (Qualisys OQUS)	Sampling rate: 100 Hz CAST protocol was used for segmental kinematics Lower extremity segments were modelled as rigid body Medial and lateral borders defined ankle and knee joints X-Y-Z Cardan-Euler rotation sequence Based on the maximum and minimum peak values for each conditions and each participant	Peak ankle eversion angle	↑ of peak ankle/subtalar eversion with FOs vs control during stair ascent and descent
1) Stair ascent 2) Stair descent	Hart et al. (2020)	Bilateral : Anterior-superior iliac spine, anterior and lateral aspects of the proximal and distal thigh, midpoint between Posterior-superior iliac spine, medial and lateral femoral epicondyles, proximal and distal ends of anterior tibia, lateral and medial malleoli, proximal and distal aspects of the posterior calcaneum, medial midfoot over the distal and dorsimedial aspect of the navicular lateral midfoot over the dorsal and distal aspect of the cuboid and dorsal surface of the distal forefoot at the midpoint between the second and third metatarsophalangeal joint	9-camera motion analysis system (Vicon, Oxford, UK)	Sampling rate : 120 Hz Data were filtered with a fourth-order, zero lag Butterworth filter with cut-off frequencies:of 6 Hz - 60 Hz	Peak angles: hip flexion, knee flexion, ankle dorsiflexion Angular excursions: hip internal rotation, knee adduction, knee internal rotation Maximum and minimum angles: ankle inversion, ankle internal rotation	↓ peak hip flexion, maximum ankle inversion, maximum ankle external rotation with FOs vs control ↑ peak knee flexion angle in the first half of the stance phase, ↓ knee adduction angle excursion and ↓ maximal ankle inversion angle with FOs vs control ↔ significant differences between conditions for the knee
1) Stair ascent 2) Stair descent	Moyer et al. (2017)	Modified Helen Hayes market set Bilateral markers on the medial aspect of the knee joint and medial malleolus for the calibration trial These four markers were removed prior the stair testing	10-camera motion analysis system (Motion Analysis Corporation)	Sampling rate: 60 Hz Foot, shank and thigh segments were modelled as a rigid body with a local coordinate system Translations and rotations of each segment reported to neutral positions defined during a calibration trial Normalized to body mass and height, plotted to 100% of stance Moments in stance phase of the second ascending (or second last descent) step were analyzed Peak magnitudes of external knee moments in the 1st and 2nd halves of stance were calculated	Maximum and minimum knee adduction and flexion angles Toe out and trunk lean angles	**Stair ascent** ↓ toe out angle for FOs with a lateral wedge vs control ↓ trunk lean angle for FOs with a lateral wedge vs control **Stair descent** ↓ toe out angle for FOs with a lateral wedge vs control ↔ significant differences between conditions for the knee
1) Stair ascent 2) Stair descent	Tan et al. (2020)	Bilateral: base of the second metatarsal, posterior heel, medial and lateral malleoli, lateral aspect of the tibia, lateral aspect of the femur, Anterior-superior iliac spine, Posterior-superior iliac spine, 10th thoracic vertebrae, 2nd thoracic vertebrae, sternum	10 camera motion analysis system (Vicon motion system)	Sampling rate: 100 Hz Filtered using Woltring filter routine with 10 mm predicted mean squared error Averaged across a minimum of 2 trials for stair ambulation	Peak hip, knee and ankle flexion and extension angles during early stance Peak hip and ankle flexion and extension angles during the stance phase	↔ significant effects of FOs for ankle, knee and hip kinematics during stair ascent and descent
1) Step-descent	Bonifàcio et al. (2018)	On dominant lower extremity: Anterior-superior iliac spines, posterior-superior iliac spines, greater trochanter, medial and lateral femoral epicondyle, medial and lateral malleoli and over medial and lateral aspects of 1st and 5th metatarsal, rearfoot, midfoot and forefoot aspects of the shoes Non-collinear markers were attached to the	10-camera motion analysis system (Oqus 7, Qualisys Medical)	Sampling rate: 100 Hz Filtered with fourth-order Butterworth filters with cut-off frequencies of 6 Hz and 25 Hz	Peak angles: metatarsal to calcaneal internal rotation, ankle abduction, ankle eversion, hip range of motion in the frontal plane, hip external and internal rotation and hip adduction	↓ peak metatarsocalcaneal internal rotation and peak ankle eversion angles with FOs with a rearfoot post and FOs with rearfoot and forefoot posts vs control ↑ hip external rotation angle with FOs with a rearfoot post and FOs with rearfoot and forefoot posts vs control ↓ hip adduction and ↓ hip frontal plane range of motion with FOs with a rearfoot post vs FOs with rearfoot and forefoot posts and control
1) Step-descent	Burston et al. (2018)	Bilateral: Anterior-superior iliac spine, Posterior-superior iliac spine, greater trochanter, medial and lateral femoral epicondyles, medial and lateral malleoli and over medial and lateral aspects of 1st and 5th metatarsal, rearfoot, midfoot and forefoot aspects of the shoes Non-collinear markers were attached to the shank and thigh	10 camera motion analysis system (Oqus, Qualisys medical)	Sampling rate: 100 Hz Filtered with a fourth order Butterworth low-pass filter with cut off frequencies of 6 and 25 Hz Hip joint center determined with a regresssion equation Cardan-Euler sequence of X-Y-Z Quantified from toe off and initial contact of the contralateral side.	Knee: maximal flexion, maximal adduction and abduction, frontal range of motion, transverse range forward continuum, transverse range lowering phase	↔ significant effect for FOs on knee kinematics during step descent
1) Step-up	Lack et al. (2014a)	Modified Helen-Hayes marker set: Bilateral Anterior-superior iliac spine, posterior-superior iliac spine, lateral femoral condyle, lateral malleolus outside of the shoes to represent the lateral calcaneus and fifth metatarsal head Marker mounting wands : lateral femur and at the level of the tibial tuberosity	Four Codamotion Cx1 sensor unit (Charnwood Dynamics)	Sampling rate: 200 Hz Data were averaged across five trials for each subject. Data were extracted at four times (-100 ms, 0ms, +100 ms, +200 ms) after initial contact	Hip and knee sagittal, frontal and transverse angles	↓ hip adduction angle (1.56°) with FOs vs control at 100 ms post initial contact ↓ hip adduction angle (1.19°) at initial contact and at 200 ms post-initial contact (1.87°) ↓ knee internal rotation (1.3°) at initial contact ↔ significant difference for hip transverse and knee frontal angles
1) Step-up	Lack et al. (2014b)	Modified Helen-Hayes marker set: Bilateral anterior-superior iliac spine, posterior-superior iliac spine, lateral femoral condyle, lateral malleolus outside of the shoes to represent the lateral calcaneus and fifth metatarsal head Marker mounting wands : lateral femur and at the level of the tibial tuberosity	Four Codamotion Cx1 sensor unit (Charnwood Dynamics)	Sampling rate: 200 Hz Data were averaged across five trials for each subject. Data were extracted at four times (-100 ms, 0ms, +100 ms, +200 ms) after initial contact	Hip and knee sagittal, frontal and transverse angles	↓ hip adduction (0.82°) at 200 ms after initial contact with FOs vs control ↓ hip internal rotation at initial contact (-1.4°) with FOs ↓ knee internal rotation (0.46°) at 100 ms after initial contact. ↔ significant changes for hip and knee in the sagittal plane

Table 3. Summary of articles related to kinematics

prefabricated rigid FOs with a 6º medial rearfoot wedge reduced peak internal tibial rotation angle during landing from a 20 cm high platform (MD: 0.9º). Lam et al. (2021) reported that full-length polyurethane prefabricated FOs increased initial knee flexion angle (1.3º) and induced higher forefoot peak ground reaction forces (partial eta squared ($\eta 2$): 0.63) as well as smaller ankle inversion moments ($\eta 2$: 0.56) compared to a control condition during jump landings from an unknown height in healthy individuals. Wang et al. (2020) reported that full-length prefabricated red polyurethane FOs reduced ankle plantarflexion moments and increased peak ankle eversion moments during landing from a 45 and 61 cm platform compared to a flat white insole condition. No difference in ground reaction forces as well as ankle and knee kinematics were reported.

3.3.4. Jump tasks

Six of the studies included a jump task involving 106 healthy participants (Arastoo et al., 2014; Carcia et al., 2006; Hertel et al., 2005; Ho et al., 2019), 23 with patellofemoral pain and 26 with chronic ankle instability (Moisan et al., 2019). Ho et al. (2019) reported that firm, full-length prefabricated FOs reduced ankle eversion angle at take off ($\eta 2$: 0.22) during a countermovement jump and ankle eversion angle at take off ($\eta 2$: 0.19), peak horizontal ground reaction forces ($\eta 2$: 0.36) and peak ankle frontal moment ($\eta 2$: 0.17). No effects of FOs on hip, knee angles, angular velocity, moments and power as well as ankle angular velocity and power were observed during both tasks. Hertel et al. (2005) reported that full-length prefabricated FOs (with a neutral, 7º medially inclined and 4º laterally inclined rearfoot post) reduced vastus lateralis muscle activity and did not change vastus medialis and gluteus medius muscle activity during a vertical jump task. Arastoo et al. (2014) reported that full-length prefabricated polyurethane FOs reduced the second vertical

Functional task	Authors	Equipment	Protocol	Muscles recorded	Outcomes	Main findings
1) Maximal single-leg side jump landing 2) Unilateral drop jump landing on even surface 3) Unilateral drop jump landing on a 25 deg laterally inclined surface 4) Unilateral drop jump landing on unstable surface	Moisan et al. (2019)	Trigno Wireless EMG system	Sampling rate: 2000Hz Gain: 1000 Filtered with a zero lag, bi-directionnal, 20-450 Hz bandpass fourth-order Butterworth filter Root Mean Square (RMS) data were normalised with the mean peak RMS amplitude of all trials of the shod conditions, for each task Preactivation and landing phase were normalized to 100% for each task	Gluteus medius Vastus lateralis Vastus medialis Biceps femoris Lateral gastrocnemius Medial gastrocnemius Peroneus longus Tibialis anterior	RMS amplitude of each muscle during preactivation (0-100%) and landing phases (0-100%)	**With FOs vs control** **Unilateral drop jump landing on a stable surface** ↓ tibialis anterior activation from 19 to 38% and 39 to 99% of the landing phase ↑ medial gastrocnemius activation from 11 to 18% of the preactivation phase **Unilateral drop jump landing on an unstable surface** ↑ Lateral gastrocnemius activation from 16 to 17% and 18 to 26% of the preactivation phase ≠ significant differences were observed during other tasks
1) Single-leg squat 2) Lateral stepdown 3) Maximum vertical jump	Hertel et al. (2005)	Biopac MP100 (Biopac Systems Inc.)	Sampling rate : 1000 Hz Gain: 1000 Band width of 10 to 500 Hz, input impedance 2 MOmhs, common mode rejection ratio: 11 dB, maximum voltage ± 10V RMS was calculated over a 0.5s moving window Normalization to the mean of maximum RMS values for each task, which were averaged, and then divided by the MVIC maximums	Vastus medialis Vastus lateralis Gluteus medius	% of maximum eletromyographic activity	≠ significant interactions for muscle activity between foot type and orthotic condition during any of the three tasks Significant main effects for orthotic condition were found for all three tasks **Single-leg squat:** ↑ muscle activity for vastus medialis and gluteus medius for orthotics vs control conditions ≠ single orthotic posting was more advantageous vs others in increasing vastus medialis or gluteus medius activity ≠ significant main effect or interactions for vastus medialis activity **Lateral step-down:** ↑ vastus medialis activity in all orthotic conditions vs control condition ≠ single orthotic posting was more advantageous vs others in increasing vastus medialis activity (same trend was seen for gluteus medius but the difference were not significant) ≠ significant differences for vastus lateralis **Vertical jump:** ↓ vastus lateralis in all orthotic conditions vs control condition ≠ single orthotic posting was more deleterious vs others for vastus lateralis ≠ significant effects on vastus medialis or gluteus medius activity
1) Transition from double-legged to single-legged stance eyes open/eyes closed	Dingenen et al. (2015a)	Noraxon Myosystem 1400 with MyoReasearch (Noraxon, USA)	Sampling rate: 2000 Hz Rectified and filtered with a 6th order Butterworth low-pass filter Cut-off Frequency: 45 Hz Fixed window of 100 ms before stance transition (double-leg stance phase) was compated with a moving window of the same length along the measurement Increase of more than 2 SD over the baseline activity was considered the onset of muscle activity in the reaction to transition Onset of muscle activity was identified with GRFs	Gluteus medius Tibialis anterior Peroneus longus Vastus medialis obliqus Vastus lateralis Adductor longus Tensor fascia latae Medial gastrocnemius Gluteus maximus	Onset of muscle activity	≠ significant effects for FOs vs control
1) Transition from double-legged to single-legged stance eyes open/eyes closed	Dingenen et al. (2015b)	Noraxon Myosystem 1400 with MyoReasearch (Noraxon, USA)	Sampling rate: 2000 Hz Rectified and filtered with a 6th order Butterworth low-pass filter Cut-off Frequency: 45 Hz Fixed window of 100 ms before stance transition (double-leg stance phase) was compated with a moving window of the same length along the measurement Increase of more than 2 SD over the baseline activity was considered the onset of muscle activity in the reaction to transition Onset of muscle activity was identified with GRFs	Gluteus medius Tibialis anterior Peroneus longus Vastus medialis obliqus Vastus lateralis Adductor longus Tensor fascia latae Medial gastrocnemius Gluteus maximus	Onset of muscle activity	≠ significant effects for FOs vs control
1) Step-descent	Bonifàcio et al. (2018)	Trigno Wireless EM	Sampling rate: 2000 Hz Data were zeroed, band-pass filtered with corner frequencies of 20 Hz and 500 Hz Full-wave rectified and enveloped using fourth-order low-pass Butterworth filter with a cut-off frequency: 25 Hz Normalized to the maximal signal during the dynamic contractions during the movement task Peak and integrated EMG were normalized to the maximal signal during single extremity descent phase for each muscle	Tibialis anterior Peroneus longus Medial gastrocnemius Abductor hallucis	Peak and integrated EMG Onset of muscle activity	↓ peak EMG activity and IEMG for abductor hallucis muscle for FOs with a rearfoot post and FOs with rearfoot and forefoot posts vs control ↓ Tibialis anterior iEMG or FOs with a rearfoot post vs FOs with rearfoot and forefoot posts and control
1) Step-up	Lack et al. (2014a)	Telemyo 2400TG2 Surface EMG wireless (Noraxon, USA)	Sampling rate: 1500 Hz Preamplified, bandpass filtered with cut-off frequencies of 10-500 Hz Rectified and smoothed using a 0.02 s running median method 0.5 s before and after initial contact were analysed. Peak EMG amplitude for the five trials for each participant and conditions tests Predetermined threshold and maintained for > 30 s was defined to be the muscle onset. The threshold was calculated from the minimumand means of all trials plus 10% of the range	Vastus medialis obliqus Vastus lateralis Gluteus medius	Peak EMG amplitudes Onset of muscle activity	≠ significant differences for onset of muscle activity and peak EMG amplitudes ≠ significant correlations between muscle onset and Foot Posture Index score
1) Step-up	Lack et al. (2014b)	Telemyo 2400TG2 Surface EMG wireless (Noraxon, USA)	Sampling rate: 1500 Hz Preamplified, bandpass filtered with cut-off frequencies of 10-500 Hz Rectified and smoothed using a 0.02 s running median method 0.5 s before and after initial contact were analysed. Peak EMG amplitude for the five trials for each participant and conditions tests Predetermined threshold and maintained for > 30 s was defined to be the muscle onset. The threshold was calculated from the minimumand means of all trials plus	Vastus medialis obliqus Vastus lateralis Gluteus medius	Peak EMG amplitudes Onset of muscle activity	≠ significant change for vastus medialis obliqus, vastus lateralis and gluteus medius ↓ gluteus medius peak amplitude for FOs vs control ≠ significant differences for vastus medialis obliqus and vastus lateralis peak amplitudes

Table 4. Summary of articles related to EMG

peak ground reaction force (MD: 42.3%BW) and increased stance time (MD: 0.08 s). Rathleff et al. (2016) reported that full-length custom FOs reduced peak (MD: 2.9%) and mean (MD: 4.9%) medial-to-lateral forces under the forefoot in individuals with patellofemoral pain during a two-legged drop jump from a 20 cm platform followed by a vertical jump. Carcia et al. (2006) reported that ¾ length prefabricated rigid FOs with a 6° medial rearfoot wedge reduced internal tibial rotation angle during the initial contact immediately following a forward hop jump (MD: 0.9°).

3.3.5. Single leg squat

Hertel et al. (2005) reported that full-length prefabricated FOs (with a neutral, 7° medially inclined and 4° laterally inclined rearfoot post) increased vastus medialis and gluteus medius muscle activity and did not change vastus lateralis muscle activity in 30 healthy participants with cavus, rectus and planus feet during a single-leg squat. Rathleff et al. (2016) reported that full-length custom FOs reduced peak (MD: 4.1%) and mean (MD: 7.4%) medial-to-lateral forces under the forefoot in 23 individuals with patellofemoral pain.

3.3.6. Other functional tasks

Caravaggi et al. (2016) investigated the effects of full-length prefabricated FOs fabricated from polyurethane and thermoplastic and custom EVA FOs on plantar pressure (with an in-shoe system) during a weight (4 kg) lifting task in 17 participants with an unknown musculoskeletal status. They reported greater midfoot maximum force for the custom FOs compared to prefabricated FOs (MD: 6.1 %BW) and control (MD: 2.6 %BW) condition. Prefabricated FOs increased rearfoot peak pressure compared to a control condition (MD: 13 kPa) and custom FOs (MD: 13 kPa). Custom FOs also increased midfoot pressure-time integral compared to a control condition (MD: 9.1 kPa) as well as custom (MD: 7.1 kPa) and prefabricated (MD: 13.6 kPa) FOs increased rearfoot pressure-time integral compared to a control condition.

Lam et al. (2019) reported that full-length prefabricated FOs reduced total resultant (η2: 0.29) and anterior-posterior sway (η2: 0.29) excursions as well as resultant (η2: 0.29) and anterior-posterior (η2: 0.29) center of pressure velocities and base of support area (η2: 0.30) in 13 healthy participants. Yu et al. (2007) reported that full-length semi-rigid prefabricated FOs increased ankle inversion angle (MD: 2.8°), maximum plantar force under the fifth metatarsal base (MD: 0.03 BW) and maximum plantar pressure under the fifth metatarsal base (MD: 9.2 kPa) during landing from a basketball lay-up in 14 healthy participants. Prefabricated FOs also increased maximum ankle inversion angle (MD: 2.1°), maximum plantar force under the fifth metatarsal head (0.06 BW) and base (MD: 0.03 BW), maximum plantar pressure under the fifth metatarsal head (MD: 21.5 kPa) and base (MD: 12.7 kPa) during the stance phase of a shuttle run.

Dingenen et al. (Dingenen et al., 2015a; Dingenen et al., 2015b) reported that prefabricated and custom FOs did not change the onset time of the gastrocnemius, peroneus longus, tibialis anterior, vastus medialis, vastus lateralis, adductor longus, gluteus medius and gluteus maximus muscles compared to a control condition during a transition from double to single leg stance in 15 participants with chronic ankle instability and 15 healthy participants.

Esfandiari et al. (2020) reported that full-length EVA prefabricated FOs with a 5° lateral wedge did not change center of pressure trajectories during gait initiation in 40 participants with early knee osteoarthritis.

3.4. Risk of bias assessment

The overall mean score of the modified Quality Index of the included studies was 77% (ranging from 63 to 95%). From these, 16 studies were considered of high quality and 8 of moderate quality (see Table 1). External validity, the blinding of researchers, recruitment duration and power were the principal methodological limitations. Only one study blinded assessors to the experimental conditions (Wang et al., 2020), only four studies specified that participants who were prepared to participate were representative of the entire population from which they were recruited (Arastoo et al., 2014; Caravaggi et al., 2016; Hart et al., 2020; Moisan et al., 2019) and only eight studies reported a sample size justification (Carcia et al., 2006; Esfandiari et al., 2020; Lam et al., 2021; Lam et al., 2019; Moisan et al., 2019; Rathleff et al., 2016; Tan et al., 2020; Wang et al., 2020). See Appendix B in Supplementary materials for the risk of bias score for each individual study.

4. Discussion

4.1. Summary of findings

The purpose of this systematic review was to determine the effects of FOs on the biomechanics of the lower extremities in adults with and without musculoskeletal disorders during functional tasks. Our main findings were that during low impact tasks (e.g., step and stair ambulation), FOs decrease ankle inversion and increase midfoot plantar forces and pressure. During tasks with greater impact loads (e.g., landing from a jump), FOs had little effects on EMG and kinematics of the lower extremities but decreased ankle inversion moments. Despite the effects of FOs on lower extremity biomechanics appearing task-dependent, FOs did affect the biomechanics of distal segments (i.e., distal to the knee) during most functional tasks. The results of the studies included in this review do not appear to be affected by risk of bias scores (e.g., studies with lower scores reporting conflicting results).

4.2. Effects of FOs on the biomechanics of the lower extremities

During step and stair ambulation (ascent and descent), studies reported that FOs provide a significant pronatory control at the foot and ankle as highlighted by decreased metatarsocalcaneal internal rotation angle (Bonifácio et al., 2018), ankle eversion (Bonifácio et al., 2018) and external rotation (Bonifácio et al., 2018; Hart et al., 2020) angles, external ankle dorsiflexion moment (Tan et al., 2020), external ankle eversion and dorsiflexion impulse (Hart et al., 2020) as well as decreased abductor hallucis longus and tibialis anterior muscle activity (Bonifácio et al., 2018). However, as kinematics markers were affixed on participants' shoes rather than directly on the skin in the study of Bonifácio et al. (2018), it could have induced systematic errors, greater than the actual reported FOs effects (Alcantara et al., 2018). Hart et al. (2020) reported a contradictory and counterintuitive result regarding ankle frontal angle movements (i.e., increase ankle eversion angle) during stair ambulation with FOs. Considering the small magnitude of differences (1.1^{o} and 0.9^{o}) and effect sizes (0.28 and 0.26) as well as the moderate to large decreases in ankle external eversion impulses (ES: 0.89 and 0.69) when wearing FOs, the authors questioned the clinical relevance of the increased ankle eversion angle. FOs seem to decrease hip adduction angles (Bonifácio et al., 2018; Lack et al., 2014a; Lack et al., 2014b) and external angular impulse (Hart et al., 2020) as well as knee internal rotation angles (Lack et al., 2014a; Lack et al., 2014b) and moments (Bonifácio et al., 2018) during step and stair ambulation tasks. As lower limb joints are interdependent during these functional tasks, mechanical changes to the foot and ankle likely induce proximal effects to the knee and hip. Although these changes are small, they could perhaps provide cumulative effects when worn all day, explaining their therapeutic benefits for individuals injured to lower extremity soft tissue structures. However, FOs effects seem to be less pronounced for proximal compared to distal joints as highlighted by the medium to large effect sizes at the ankle and weak effect sizes at the knee and hip (Bonifácio et al., 2018; Hart et al., 2020; Lack et al., 2014a; Lack et al., 2014b). Also, considering the very small kinematic changes at the knee and hip, they could simply be systematic measurement errors (McGinley et al., 2009) rather than actual FOs effects. FOs with a lateral wedge, aiming to increase the supinatory control (rather than the pronatory control for standard FOs), seem to have opposite effects on the biomechanics of the lower extremities (Alshawabka et al., 2014). The effects of FOs on the biomechanics of the lower extremities during step and stair ambulation are consistent with what was observed during jumping (e.g., reduced ankle eversion angle).

During landing from a jump, the effects of FOs on lower extremity kinematics are small with mean reported reductions of internal tibia rotation of 0.9º (Carcia et al., 2006), hip adduction of 2.3º (Jenkins et al., 2011) and mean increase in knee flexion during initial contact of 1.3º (Lam et al., 2021). Furthermore, a lack of significant kinematic effects have been reported at the ankle (Lam et al., 2021; Moisan et al., 2019; Wang et al., 2020) and knee during landing tasks (Moisan et al., 2019; Wang et al., 2020). Despite the minimal ankle and knee moments changes when acutely wearing FOs during jump landings, FOs appear to significantly change kinetic outcome measures. FOs have been observed to decrease ankle inversion moments (Lam et al., 2021; Wang et al., 2020) and medial-to-lateral forces under the forefoot as well as increase plantar forces and pressure under the fifth metatarsal (Yu et al., 2007) during landing. As landing from a jump is a task requiring high load attenuation demands on the lower extremities (Bates et al., 2013; Moisan et al., 2020; Moisan et al., 2022), this may explain the smaller kinematic effects of FOs compared to other tasks such as walking (Desmyttere et al., 2018; Hajizadeh et al., 2020) and step and stair ambulation (Bonifácio et al., 2018; Hart et al., 2020). FOs should perhaps be manufactured to provide more pronatory control (e.g., stiffer shells and medial wedges) to achieve the same level of changes to the lower extremity biomechanics as observed in less challenging tasks. Additionally, it should be noted that few studies have compared the effects of FOs on lower extremity biomechanics between tasks with high and low load attenuation demands. Hertel et al. (2005) reported that FOs increased vastus medialis and gluteus medius muscle activity during single-leg squat and lateral step-down tasks and decreased vastus lateralis muscle activity during maximal vertical jump. Moisan et al. (2019) reported decreased tibialis anterior muscle activity during unilateral drop jump landing which was not observed during walking. As consequence to the lack of literature comparing high versus low load attenuation tasks, it remains challenging to draw further conclusions related to the biomechanical effects of FOs across these tasks.

4.3.FOs specificities, population characteristics and lower extremity biomechanics

The secondary objective of this systematic review was to determine if FOs specificities and population characteristics induce different effects on the biomechanics of the lower extremities. Custom FOs seem to better redistribute plantar pressure compared to prefabricated FOs during functional tasks. Indeed, Caravaggi et al. (2016) reported that wearing custom full-length EVA FOs during stair ascent, stair descent and weight lifting tasks resulted in decreased peak pressure at the rearfoot and forefoot compared to prefabricated FOs made of polyurethane and thermoplastic. More force was sustained by the midfoot, which appeared consistent with the larger foot-insole contact area with custom FOs over the medial longitudinal arch compared to prefabricated FOs. The moulding of the custom FOs explains the better plantar pressure redistribution. During a step descent task, custom FOs with an arch support and a 5^0 rearfoot wedge decreased hip adduction, hip frontal plane range of motion and tibialis anterior muscle activity compared to custom FOs with an arch support and a 5^0 rearfoot and forefoot wedge (Bonifácio et al., 2018). The highly similar features between both types of FOs most likely explain the lack of differences in foot and ankle kinematics and kinetics.

Previous systematic reviews have reported that FOs with different features and geometry induce different kinematic and kinetic effects on the lower extremities during walking (Desmyttere et al., 2018; Hajizadeh et al., 2020). However, based on the available evidence, there is still little understanding on how different FOs features and geometry change their effects on the biomechanics of the lower extremities during functional tasks. There were no population-specific effects of FOs reported in our included studies. For example, identical FOs produced highly similar effects in individuals with patellofemoral pain and no musculoskeletal disorders during a step-up task (Lack et al., 2014a; Lack et al., 2014b). Very few studies quantified the effects of FOs on the biomechanics of the lower extremities in different cohorts. The importance of participants' foot type in FOs prescription could not be assessed due to the lack of systematic reporting and/or the inclusion of participants with heterogeneous foot types. It is still unclear to what extent these population-specific details modulate the effectiveness of wearing FOs.

4.4. Clinical implications and recommendations for further research

This systematic review informs clinicians and researchers of the current state of knowledge pertaining to the effects of FOs on the biomechanics of the lower extremities during functional tasks and thus help better understanding their mechanism of action. This review was needed as mechanisms of effect informs which individuals may benefit most from wearing orthoses (e.g., specific morphotypes, musculoskeletal disorders or biomechanics of the lower limbs) and most effective modes of delivery (i.e., FOs designs, geometry, extrinsic additions). In clinical contexts, FOs' geometry and material properties are thoroughly selected to meet the specific biomechanical needs of each patient (Chapman et al., 2018; Landorf et al., 2001). The number of articles quantifying the biomechanical effects of FOs has risen rapidly, but unfortunately, there is still little understanding about how FOs' geometry and material properties change the mechanics of these devices and how they affect the biomechanics of the lower extremities during functional tasks. Future research studying the effects of FOs on functional tasks are needed to validate the development of future clinical trials which aim to use specific FO designs to address the biomechanical deficits associated with musculoskeletal disorders and potentially better reduce chief complaints of wearers (e.g., pain and altered function).

Future work should aim to identify the variables that best predict the effects of FOs on the biomechanics of the lower extremities during functional tasks. This will allow for a more appropriate selection of FOs designs to use for specific populations in future research and ultimately inform the development of more clinically meaningful trials. FOs seem to mainly affect distal joints of the lower extremities although few studies have investigated the effects of FOs on the biomechanics of the foot, mainly due to technical limitations that are now resolved with newest technique and kinematic models (Caravaggi et al., 2019; Leardini et al., 2019). To date, studies have evaluated the immediate effects of FOs, however, as FOs are worn over a longer period of time in real-world contexts, future protocols are encouraged to determine FOs effect after periods of adaptation.

4.5.Limitations and methodological considerations

There are some limitations to this review worth highlighting. Potential articles were not searched using Embase database because it is not accessible at our institution, which could have led us to miss relevant studies. Consistent generalizations of FOs effects on the biomechanics of the lower extremities were limited. There is a lack of validated theories governing the prescription of FOs in clinical and research contexts explaining the diversity of FOs features in previous studies. Despite reporting that FOs effectiveness is inconclusive in a few tasks or for a few joints, these conclusions may be inaccurate considering the FOs diversity across studies. Thus, a meta-analysis was not performed and the publication bias was not assessed. It should also be noted that the biomechanical assessment of the human body and/or establishing connections between different types of data (EMG, kinematics and kinetics) is highly complex. The outcomes included in this systematic review do not directly inform about internal joint contact, ligaments/tendon strain and/or muscular forces during functional tasks, although these may be important to understand FOs mechanism of action in the treatment of musculoskeletal disorders. Further work is needed to determine the relationship between these outcomes.

Moreover, the use of the modified Quality Index checklist to evaluate the risk of bias is a limitation per se. This checklist has only been validated to assess methodological quality of randomized and non-randomized studies of health care interventions. However, this appraisal tool was used in a similar systematic review (Desmyttere et al., 2018) and was the most suitable for our purpose. Finally, most included studies investigated FOs effects on lower extremities of healthy individuals, thereby decreasing the external validity of the results. Despite these results providing a proof-of-concept to allow a better understanding of the mechanism of action of FOs, they could not be generalized to clinically relevant populations.

5. Conclusion

FOs seem to have task-specific effects on the biomechanics of the lower extremities, but the current state of evidence is weak. During functional tasks with less impact loads, FOs decrease ankle inversion angles and increase midfoot plantar forces and pressure. During tasks with greater impact loads, FOs have little effects on EMG and kinematics of the lower extremities but decrease ankle inversion moments. During most functional tasks, FOs mainly affect the biomechanics of the distal segments. Despite these results, it remains unclear the extent to which FOs features induce different biomechanical effects, and furthermore, if these FO effects change for different populations. Considering the diversity across studies regarding recruited participants, types of analyses and FOs, we suggest that future studies aim to determine the biomechanical effects of FOs with different features for the same population and how important are the individuals wearing FOs to predict their effects on the biomechanics of the lower extremities.

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Appendix A – Search strategies

Search strategy for MEDLINE (1971 to June 11, 2021)

1. MH foot orthoses OR MH orthotic devices+ OR MH orthopedic equipment
2. AB insert* OR AB insole* OR AB orthotic* OR AB orthos* OR AB orthot* OR AB shoe* insert*OR AB foot orthos* OR AB arch support* OR AB foot appliance
3. TI insert* OR TI insole* OR TI orthotic* OR TI orthos* OR TI orthot* OR TI "shoe insert*" OR TI "foot orthos*" OR TI "arch support*" OR TI "foot appliance*"
4. 1 OR 2 OR 3 (Concept A)
5. MH locomotion OR MH stair climbing OR MH sports medicine OR MH exercise
6. TI exercise* OR TI jump* OR TI land* OR TI stair* OR TI step* OR TI sport* OR TI locomotion OR TI lift* OR TI squat* OR TI basketball OR TI volleyball OR TI football OR TI climbing OR TI handball OR soccer OR TI drop* OR TI "functional task*"
7. AB exercise* OR AB jump* OR AB land* OR AB stair* OR AB step* OR AB sport* OR AB locomotion OR AB lift* OR AB squat* OR AB basketball OR AB volleyball OR AB football OR AB handball OR AB climb* OR AB soccer OR AB drop* OR AB "functional task*"
8. 5 OR 6 OR 7 (Concept B)
9. MH biomechanical phenomena OR MH mechanical phenomena OR MH electromyography
10. TI biomechanic* OR TI kinematic* OR TI (electromyograph* or EMG) OR TI motion* OR TI movement* OR TI pressure* OR TI dynamic OR TI load OR TI biomech* OR TI mechanic* OR TI shock* OR TI absorb* OR TI friction* OR TI moment* OR TI angle* OR TI rotation* OR TI force* OR TI "angular impuls*" OR TI velocit* OR TI speed* OR TI acceleration* OR TI muscle* activit* OR TI torque* OR TI power*
11. AB friction* OR AB moment* OR AB angle* OR AB rotation* OR AB force* OR AB angular* impuls* OR AB velocit* OR AB speed* OR AB acceleration* OR AB muscle* activit* OR AB mechanic* OR AB power* OR AB biomechanic* OR AB kinematic* OR AB (electromyograph* or EMG) OR AB motion* OR AB movement* OR AB pressure* OR AB dynamic OR AB load OR AB biomech* OR AB mechanic* OR AB shock* OR AB absorb*
12. 9 OR 10 OR 11 (Concept C)
13. MH "lower extremity" OR MH foot OR MH (ankle or ankle joint) OR MH hip of hip joint OR MH (knee or knee joint) OR MH thigh OR MH pelvis
14. TI lower limb* OR TI "lower extremit*" OR TI (foot or feet) OR TI ankle OR TI ankles OR TI leg OR TI legs OR TI knee OR knees OR TI hip OR TI hips OR TI pelvis OR TI thigh or TI thighs

15. AB “lower limb*” OR AB “lower extremit*” OR AB (foot or feet) OR AB ankle OR AB ankles OR AB leg OR AB legs OR AB knee OR AB knees OR AB hip OR AB hips OR AB pelvis OR AB thigh OR AB thighs
16. 19 OR 20 OR 21 (Concept D)
17. 4 AND 12 AND 18 AND 22

Total : 2767

CINAHL (1981 to June 11, 2021) via EBSCOhost

Idem to MEDLINE

Total : 3072

SPORTDiscus (1930 to June 11, 2021) via EBSCOhost

Idem to MEDLINE

Total : 734

Search strategy for Cochrane (1993 to June 11, 2021)

1. MeSH descriptor [Foot Orthoses] explode all trees
2. MeSH descriptor [Biomechanical phenomena] explode all trees
3. Biomechanic*
4. Kinematic*
5. Kinetic*
6. Electromyograph*
7. Speed
8. Movement
9. Joint moment
10. Impulse
11. Plantar pressure
12. Ground reaction force*
13. Load
14. Shock
15. Absorb*
16. #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15
17. MeSH descriptor [Lower extremity] explode all trees
18. Exercise*
19. Jump*
20. Land*
21. Stair*

22. Step*
23. Sport*
24. Locomotion
25. Lift*
26. Squat*
27. Basketball
28. Volleyball
29. Football
30. Handball
31. Climb*
32. #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30 or #31
33. #1 and #16 and #17 and #32

Total : 18

Search strategy for PEDro (1929 to June 11, 2021)

First search:

- Abstract & Title: Foot ortho* AND
- Therapy: Orthoses, taping, splinting AND
- Body part: Foot and Ankle AND
- Method: Clinical trial

Second search:

- Abstract & Title: Foot ortho* AND
- Therapy: Orthoses, taping, splinting AND
- Body part: Lower leg and knee AND
- Method: Clinical trial

Third search

- Abstract & Title: Foot ortho* AND
- Therapy: Orthoses, taping, splinting AND
- Body part: Thigh or hip AND
- Method: Clinical trial

Fourth search

- Abstract & Title: Foot ortho* AND
- Therapy: Orthoses, taping, splinting AND
- Body part: Lumbar spine, sacro-illiac joint or pelvis AND
- Method: Clinical trial

Total: 151

Appendix B - Results of the modified Quality Index checklist

		Reporting								External validity		Internal validity (bias)				Internal validity (confounding)			Power		
		1	2	3	4	5	6	7	10	11	12	15	16	18	20	21	22	25	27		
Authors	**Year**	**Hypotheses/ objectives (1)**	**Outcomes (1)**	**Participants (1)**	**Intervention description (1)**	**Confounders (2)**	**Findings description (1)**	**Random variability (1)**	**p value (1)**	**Subjects asked to participate (1)**	**Subjects prepared to participate (1)**	**Researchers blinding (1)**	**Data dredging (1)**	**Statistics (1)**	**Outcome measures (1)**	**Recruitement population (1)**	**Recruitement duration (1)**	**Adjustment for confounding (1)**	**Power calculation (1)**	**Total (19)**	**Percentage (%)**
Alshawabka et al.	2014	0	1	1	1	2	1	1	1	0	0	0	1	1	1	0	0	1	0	12	**63**
Arastoo et al.	2014	1	1	1	1	2	1	1	1	1	1	0	1	1	1	1	0	1	0	16	**84**
Bonifácio et al.	2018	0	1	1	1	2	1	1	1	0	0	0	1	1	1	0	0	1	0	12	**63**
Burston et al.	2018	1	1	1	1	2	1	1	1	1	0	0	1	1	1	1	0	1	0	15	**79**
Caravaggi et al.	2016	0	1	1	1	2	1	1	1	1	1	0	1	1	1	1	0	1	0	15	**79**
Carcia et al.	2006	1	1	1	1	2	1	1	1	0	0	0	1	1	1	1	0	1	1	15	**79**
Dingenen et al.	2015a	1	1	1	1	2	1	1	1	1	0	0	1	1	1	1	0	1	0	15	**79**
Dingenen et al.	2015b	1	1	1	1	2	1	1	1	1	0	0	1	1	1	1	0	1	0	15	**79**
Esfandiari et al.	2020	0	1	1	1	2	1	1	1	0	0	0	1	1	1	0	0	1	1	13	**68**
Hart et al.	2020	0	1	1	1	2	1	1	1	1	1	0	1	1	1	1	0	1	0	15	**79**
Hertel et al.	2005	1	1	0	1	2	1	1	1	0	0	0	1	1	1	0	0	1	0	12	**63**
Ho et al.	2019	1	1	1	1	2	1	1	1	1	0	0	1	1	1	1	0	1	0	15	**79**
Jenkins et al.	2011	1	1	1	1	2	1	1	1	1	0	0	1	1	1	0	0	1	0	14	**74**
Lack et al.	2014a	1	1	1	1	2	1	1	1	1	0	0	1	1	1	1	0	1	0	15	**79**
Lack et al.	2014b	0	1	1	1	2	1	1	1	1	0	0	1	1	1	1	0	1	0	14	**74**
Lam et al.	2019	1	1	1	1	2	1	1	1	1	0	0	1	1	1	0	0	1	1	15	**79**
Lam et al.	2021	1	1	1	1	2	1	1	1	0	0	0	1	1	1	1	0	1	1	15	**79**
Moisan et al.	2019	1	1	1	1	2	1	1	1	1	1	0	1	1	1	1	1	1	1	18	**95**
Moyer et al.	2017	1	1	1	1	2	1	1	1	1	0	0	1	1	1	1	0	1	0	15	**79**
Nouman et al.	2017	0	1	1	1	2	1	1	1	1	0	0	1	1	1	1	0	1	0	14	**74**
Rathleff et al.	2015	1	1	1	1	2	1	1	1	1	0	0	1	1	1	1	0	1	1	16	**84**
Tan et al.	2020	1	1	1	1	2	1	1	1	1	0	0	1	1	1	1	1	1	1	17	**90**

Wang et al.	2020	1	1	1	1	2	1	1	1	1	0	1	1	1	1	1	0	1	1	17	**90**
Yu et al.	2007	1	1	0	1	2	1	1	1	0	0	0	1	1	1	0	0	1	0	12	**63**

Justification of the modifications:

Only 18 out of 27 items of the Downs and Black checklist were included of which eight pertained to reporting (1, 2, 3, 4, 5, 6, 7, 10), two to external validity (11 and 12), four to internal validity (bias) (15, 16, 18 and 20), three to internal validity (confounding) (21, 22 and 25), and one to power (27). Each item was scored as 0 ("no" or UD (unable to determine))
or 1 ("yes"), except for item 5 for the principal confounders, scored as 0 ("no"), 1 ("partially"), 2 ("yes"). Item 27, which was related to power, was reported as 0 (no sample size justification reported) or 1 (sample size justification reported) rather than the original 0 to 5 scale (Desmyttere et al., 2018). The maximum possible score for each individual study was 19.

Appendix C

Study (author, year)	Exclusion criteria	Details
Arastoo, 2010	Protocol	Results duplication
Becerro de Bengoa Vallejo et al., 2016	Task	Participants were evaluated during walking
Chapman et al., 2016	Task	Participants were evaluated during walking
Gibson et al., 2014	Task	Participants were evaluated during walking
Grewal et al., 2016	Condition	No shoes only condition was included
Joseph et al., 2008	Condition	Participants wore flat insoles without an arch support
Joseph et al., 2010	Condition	Participants wore flat insoles without an arch support
Joseph et al., 2014	Condition	Participants wore flat insoles without an arch support
Khodaei et al., 2017	Task	Participants were evaluated during walking
Lam et al., 2019a	Condition	Participants did not wear FOs
Lo et al., 2016	Condition	No shoes only condition was included
Olmsted et al., 2004	Task	Participants were evaluated during a postural stability task
Protopapas and Perry, 2020	Condition	FOs condition was not compared to a shoe only condition
Raspovic et al., 2000	Task	Participants were evaluated during walking
Robb and Perry, 2020	Variables	Lower extremities' biomechanics was not measured
Stern and Gottschall, 2012	Task	Participants were evaluated during walking
Tillman et al., 2003	Condition	Participants wore flat insoles without an arch support
Vanicek et al., 2004	Task	Participants were evaluated during a static task
Zhai et al., 2016	Protocol	Data of FOs and shoes only conditions were not collected during the same session
Zhai et al., 2019	Protocol	Data of FOs and shoes only conditions were not collected during the same session

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