**Appendix 1- Table 1**

Table 1. Participants, intervention, comparators, outcomes, and study design (PICOS) framework for study inclusion and exclusion criteria

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Category |  | Inclusion |  | Exclusion |
| Participants | Individuals aged ≥18 years with pronated feet | Individuals with adverse health events (e.g., injuries, recent surgery); individuals with neurological, systemic, or degenerative conditions; individuals aged <18 years; |
| Intervention | Short-term (one session) application of all kinds of anti-pronation FO | Other interventions besides FO, long-term interventions |
| Comparator | Barefoot, shoes only, and sham FO condition | Absence of a control condition |
| Outcome | Lower limb kinematics and kinetics during walking | Measures of lower limb kinematics and kinetics during activities other than walking (e.g., running, jumping) |
| Study design | Case control studies, case series, cohort study, cross sectional studies, randomized controlled trials | Case studies, systematic reviews |

**Appendix 1-** **Search strategy**

Search strategy for PEDro (inception to March 23, 2024)

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: Insole\* AND

• Therapy: Orthoses, taping, splinting AND

• Body part: Foot and Ankle AND

• Method: Clinical trial

The fifth search:

• Abstract & Title: Insole\* AND

• Therapy: Orthoses, taping, splinting AND

• Body part: Lower leg and knee AND

• Method: Clinical trial

The sixth search

• Abstract & Title: Insole\* AND

• Therapy: Orthoses, taping, splinting AND

• Body part: Thigh or hip AND

• Method: Clinical trial

Total 287

Search strategy for PubMed (inception to March 23, 2024)

Search strategy for PubMed

|  |  |
| --- | --- |
| 13 | #4 AND #8 AND #12 |
| 12 | #9 OR #10 OR #11 (Concept C) |
| 11 | "Lower limb\*" [tiab] OR "lower extremit\*" [tiab] OR foot [tiab] OR feet [tiab] OR ankle [tiab] OR ankles [tiab] OR leg [tiab] OR legs [tiab] OR knee [tiab] OR knee\* [tiab] OR hip [tiab] OR hips [tiab] OR pelvis [tiab] OR thigh [tiab] OR thighs [tiab] |
| 10 | "Lower limb\*" [ti] OR "lower extremit\*" [ti] OR foot [ti] OR feet [ti] OR ankle [ti] OR ankles [ti] OR leg [ti] OR legs [ti] OR knee [ti] OR knee\* [ti] OR hip [ti] OR hips [ti] OR pelvis [ti] OR thigh [ti] OR thighs [ti] |
| 9 | "Lower Extremity"[Mesh] OR "Lower Extremity Deformities, Congenital"[Mesh] OR "Foot"[Mesh] "Foot Joints"[Mesh] OR "Ankle Joint"[Mesh] OR "Ankle"[Mesh] OR "Knee Joint"[Mesh] OR "Knee"[Mesh] OR "Hip Joint"[Mesh] OR "Hip"[Mesh] OR "Pelvis"[Mesh] OR "Thigh"[Mesh] |
| 8 | #5 OR #6 OR #7 (Concept B) |
| 7 | biomechanic\* [ti] OR kinematic\* [ti] OR motion\* [ti] OR movement\* [ti] OR pressure\* [ti] OR dynamic [ti] OR load\* [ti] OR biomech\* [ti] OR mechanic\* [ti] OR shock\* [ti] OR absorb\* [ti] OR friction\* [ti] OR moment\* [ti] OR angle\* [ti] OR rotation\* [ti] OR force\* [ti] OR "angular impuls\*" [ti] OR velocit\* [ti] OR speed\* [ti] OR acceleration\* [ti] OR muscle\* [ti] OR activit\* [ti] OR torque\* [ti] OR power\* [ti] |
| 6 | friction\* [tiab] OR moment\* [tiab] OR angle\* [tiab] OR rotation\* [tiab] OR force\* [tiab] OR angular\* [tiab] Or impuls\* [tiab] OR velocit\* [tiab] OR speed\* [tiab] OR acceleration\* [tiab] OR activit\* [tiab] OR mechanic\* [tiab] OR power\* [tiab] OR biomechanic\* [tiab] OR kinematic\* [tiab] OR motion\* [tiab] OR movement\* [tiab] OR pressure\* [tiab] OR dynamic\* [tiab] OR load\* [tiab] OR biomech\* [tiab] OR mechanic\* [tiab] OR shock\* [tiab] OR absorb\* [tiab] |
| 5 | "Biomechanical Phenomena"[Mesh] OR "Mechanical Phenomena"[Mesh] |
| 4 | #1 OR #2 OR #3 (Concept A) |
| 3 | insert\* [ti] OR insole\* [ti] OR [ti] ortho\* OR "shoe insert\*" [ti] OR "foot ortho\*" [ti] OR "arch support\*" [ti] OR "foot appliance\*" [ti] |
| 2 | insert\* [tiab] OR insole\* [tiab] OR orthotic\* [tiab] OR orthos\* [tiab] OR orthot\* [tiab] OR insert\* [tiab] OR foot orthos\* [tiab] OR arch support\* [tiab] OR foot appliance [tiab] |
| 1 | foot orthoses [Mesh] OR orthotic devices [Mesh] OR orthopedic equipment [Mesh] |

Total 11655

Search strategy for Scopus (inception to March 23, 2024) via library of University of Mohaghegh Ardabili

Search strategy for Scopus

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Intervention | AND | Population | AND | Outcomes |
| insert\* | pronated feet\* | Biomech\* |
| OR insole\* | OR pronated foot\* | OR Kinetic\* |
| OR ortho\* | OR flat feet\* | OR kinematic\* |
| OR "Shoe insert\*" | OR flat foot\* | OR Speed |
| OR "Foot ortho\*" | OR flatfeet\* | OR force\* |
| OR "Arch support\*" | OR flatfoot\* | OR motion\* |
| OR "Foot appliance\*" | OR pes planus | OR rotation\* |
|  | OR planovalgus | OR impuls |
|  |  | OR acceleration |
|  |  | OR dynamic |
|  |  | OR power |
|  |  | OR Movement |
|  |  | OR load\* |
|  |  | OR Joint moment\* |
|  |  | OR Ground reaction force\* |
|  |  | OR mechanic\* |
|  |  | OR torque\* |
|  |  | OR angle\* |

Total: 1097

Search strategy for Cochrane central register of controlled trials (central) (inception to March 23, 2024)

Search strategy for Cochrane central register of controlled trials (central)

|  |  |
| --- | --- |
| ID | Search |
| #1 | MeSH descriptor: [Foot Orthoses] explode all trees |
| #2 | MeSH descriptor: [Biomechanical Phenomena] explode all trees |
| #3 | Biomech\* |
| #4 | Kinetic\* |
| #5 | kinematic\* |
| #6 | Speed |
| #7 | force\* |
| #8 | motion\* |
| #9 | rotation\* |
| #10 | Impuls |
| #11 | Acceleration |
| #12 | Dynamic |
| #13 | Power |
| #14 | Movement |
| #15 | load\* |
| #16 | Joint moment\* |
| #17 | Ground reaction force\* |
| #18 | mechanic\* |
| #19 | torque\* |
| #20 | angle\* |
| #21 | #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 OR #16 OR #17 OR #18 OR #19 OR #20 |
| #22 | MeSH descriptor: [Lower Extremity] explode all trees |
| #23 | MeSH descriptor: [Pronation] explode all trees |
| #24 | MeSH descriptor: [Flatfoot] explode all trees |
| #25 | pronated feet\* |
| #26 | pronated foot\* |
| #27 | flat feet\* |
| #28 | flat foot\* |
| #29 | flatfeet\* |
| #30 | flatfoot\* |
| #31 | pes planus |
| #32 | Planovalgus |
| #33 | #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 #32 |
| #34 | #1 AND #21 AND #22 AND #33 |

Total 22

Appendix 1-Table 2. Summary table of the included 24 studies for quantitative analyses.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Authors  (year) | Sample size  (M/F);  age (mean (SD));  Foot type | Foot posture  method | Type of foot orthoses  (design/material) | Control  (shoes/sandals) | Walking protocol | Outcomes | 2D/3D;  markers |
| Johanson (1994) (Johanson et al., 1994) | 22 (9/13); 30.5 (8) years; Forefoot varus | FF varus > 8° | Prefabricated, with water reacting with polyurethane and posting in EVA (durometer A 50–60). Medial FF posting: applied just behind the 1st MTPJ and extended to the 4th metatarsal (max 7 mm). Medial RF posting: applied to the medial aspect of the inferior surface of the calcaneus and extended half the width of the heel (max 6 mm). (A) shell with FF and RF post; (B) shell with RF post; (C) shell with forefoot post; (D) shell only. | Shoes only (Nike Air Craft, running shoes) | 3 to 6 cycles (treadmill) at 4 km/h | Kinematics (°): peak RF eversion | 2D; markers on skin |
| Brown et al. (1995) (Brown et al., 1995) | 14 (8/16); 30.9 (6.9) years; Forefoot varus | FF varus ≥ 8° | (A) Arch support: prefabricated (Spenco Arch supports arch filler) (B) Medial FF + RF posting: semi-rigid prefabricated (Langer Sporthotics All Sports) in PAS plastic; FF posted at 60% (max 8°) of FF deformity and RF posted at 50% (max 6°) of RF deformity; Posts in 50-55 durometer styrene butadiene rubber | Shoes only (Nike Air Craft, running shoes) | 2 trials of 3 to 6 cycles (treadmill) at self-selected speed (controlled) | Kinematics: peak RF eversion (°), RF eversion RoM (°) | 2D; markers on skin |
| Genova and Gross (2000) (Genova and Gross, 2000b) | 13 (8/5); 33.1 (12.7) years; abnormal pronation | Standing calcaneal eversion angle ≥ 10° | shoes with and without orthotic | Shoes only | 5 gait cycles (treadmill) at 1.9 m/s | Maximum calcaneal eversion angle; calcaneal eversion angle at heel off; | 2D; markers on shoe |
| Nawoczenski and Ludewig (2004) (Nawoczenski and Ludewig, 2004) | 18 (7/11); 28.2 (8.3) years; Pes planus and pronation | FF varus > 10°; Navicular drop ≥ 10 mm | Medial FF + RF posting: semi-rigid, shell in polypropylene/ polyethylene, covered with 3 mm of Poron or PPT. Posting in high density material (≥5 mm) under the medial aspect of the RF and FF.  (A) FF POST and (B) ARCH orthose | Sandals only (TEVA sport sandals, Deckers Outdoor Corporation) | 5 trials (walkway) at self-selected speed (controlled) | Kinematics (°): peak 1st MTP joint dorsiflexion (at midstance) | 3D; |
| Stacoff et al. (2007) (Stacoff et al., 2007) | 8; 47.4 (18.6) years; Pes valgus | Clinical observation | Medial RF posting: made with a harder lower (durometer C 70–80) and a softer upper layer (durometer C 40–45). Posted at the sustentaculum tali. A, B, C type | Sham orthoses in sandals (Finn comfort sandal, Hassfurt Germany) | 8–10 trials (walkway) for each condition (not controlled) | Kinematics (°): peak RF eversion (after touchdown), RF eversion ROM. Kinetics (Nm): peak RF eversion moment | 3D; markers on skin |
| Kulcu et al. (2007) (Kulcu et al., 2007) | 34 (9/25); 43.7 (9.7) years; flexible flatfoot | Radiographs | Over-the-counter, full length, Bauerfeind ViscoPed® S Shock Reducing Insoles (Bauerfeind USA, Inc., Kennesaw, GA) | Trekking sandals | The best data of three trials self-selected speed over a 10-m walkway | joint rotation angles of pelvis, hip, knee and ankle in sagittal plane) and kinetic (moments of knee and ankle in sagittal plane | 3D; markers on skin |
| Zifchock and Davis (2008) (Zifchock and Davis, 2008) | 19; 23.6 (6.4) years; Low arch | Arch Height Index < 0.295 | Medial RF posting: (A) semi-custom and (B) customized, semi-flexible, made in graphite and a vinyl cover. The amount of RF posting determined by the resting calcaneal stance position (max 7°) | Shoes only (Nike Air Pegasus, neutral running shoes) | 5 trials (75 ft. walkway) at 2 m/s (controlled) | Kinematics (°): peak RF eversion, RF eversion ROM | 3D; markers on skin |
| Hurd et al. (2010) (Hurd et al., 2010) | 15 (4/11); 34 (10) years; Flexible flat foot | FF varus > 5° | Arch support: prefabricated, (A) new off-the-shelf insert and (B) existing off-the-shelf semi-rigid, in graphite polyurethane, with a longitudinal arch support. | Shoes only (New balance 1122 motion-control running shoe) | 3 trials (walkway) at self-selected speed (controlled) | Kinematics (°): peak RF and FF eversion (during loading). Kinetics (N∙cm/kg): peak RF eversion moment | 3D; markers on skin |
| Chen et al (2010) (Chen et al., 2010) | 11 (6/5); 45.9 (15.66); planus or pronated position | Arch index = 0.11 | Custom made for each participant by Jun-Da Biotechonology Co., Ltd, Taiwan; vinyl-acetate and 12 ± 3% far-infrared nanopowders | Shoe made of rubber and PU | 3 trials (walkway), self-selected velocity | Peak knee flexion, ankle dorsiflexion and plantarflexion angle; Peak knee varus, ankle dorsiflexion and plantarflexion moment Nm/kg | 3D; markers on shoe |
| Cobb et al. (2011) (Cobb et al., 2011) | 16 (7/9); 25.4 (6.5); Low mobile arch | Arch ratio ≤ 0.287 | Arch support: (A) customized full contact orthosis with medial longitudinal arch support; shell from calcaneus to MH; full length top covered with vinyl. Medial FF + RF posting: (B) customized balanced traditional orthosis with RF and FF posting; shell from calcaneus to MH; full length top covered with vinyl. | Sandals only (Merrell Waterfall) | 5 trials (10 m walkway) at 1.3–1.4 m/s | Kinematics (°): RF eversion and 1st MTP joint abduction excursion | 3D; markers on skin |
| Dedieu et al (2013) (Dedieu et al., 2013) | 12 (5/7); 23.7 (3.4); everted static rearfoot posture | RF eversion > 5° and the height of navicular | Medial RF posting: customized, rigid, with medial RF post of high-density EVA. | Barefoot | 5 trials (walkway) at Self-selected speed (not controlled) | Kinematics (°): peak RF eversion | 3D; Markers on skin |
| Telfer et al (2013) (Telfer et al., 2013) | 12 (6/6);  28 (7.3);  Pronated foot | FPI-6 > 6; Calcaneal eversion > 4° | Customized, semi-rigid, ¾ length, 3D printed in polylactide, including different levels of medial RF posting: (A) 2°, (B) 6°, (C) 10° | Shoes only (Neutrally posted  training shoes) | 7 trials (walkway) at  self-selected speed  (controlled) | Kinematics (°): peak RF eversion, peak forefoot adduction. Kinetics (% BW ∗ Height): peak RF eversion moment, knee abduction moment | 3D; markers on skin |
| Tang et al (2015) (Tang et al., 2015) | 10 (7/3); 24.8 (8.8); flatfoot | Footprint Arch Index > 0.26 | Medial FF posting: customized, total contact, made with a lower layer in semi-rigid plastozote, an upper layer in PPT, and includes forefoot medial posting. | Barefoot and Shoes only (Sport shoes) | 3 trials (walkway) at self-selected speed (not controlled) | Kinematics (°): peak RF eversion | 3D; 1 segment; markers on shoes |
| Bishop et al. (2016) (Bishop et al., 2016) | 18 (11/7); 25.1 (2.8) years; Flat-arched feet | NNHT < 0.21 | Neutral RF posting: customized, 4 mm thick polypropylene, RF posting in EVA of 350 kg.m2 density, 1.5 mm top cover | Shoes only (Asics Gel-Pulse 3, neutral running shoes) | 5 trials (10 m walkway) at self-selected speed (controlled) | Kinematics: peak RF eversion (°), RF eversion ROM (°), peak 1st MTP joint dorsiflexion (°). Kinetics: peak RF eversion moment (% BW). | 3D; markers on skin |
| Prachgosin et al (2017) (Prachgosin et al., 2017) | 7; 31.86 (3.4); flatfoot | Footprint arch index and foot radiographs | Customized Total-contact orthosis (TCO), EVA, and microcellular rubber | Flat shoes with toe-only rocker less than 10 degrees (Nanyang©, Nanyang Industry Co. Ltd, Bangkok, Thailand) | 3 trials (walkway) at  self-selected speed  (controlled) | Lower limb biomechanics (knee and ankle). Kinetics in Nm/kg | 3D; markers on skin |
| Kosonen et al (2017) (Kosonen et al., 2017) | 11; (1.76 ± 0.08 m); overpronation | Navicular drop value over 10 mm | Medially posted insoles based on heated orthotic blanks (Footbalance Systems Ltd., Vantaa, Finland) | Running shoes (Nike Pegasus 30, neutral shoe) with normal insoles | 5 trials along a 30 m long track at self-selected speed | Forefoot angles in respect to hindfoot and tibia and hindfoot angles in respect to tibia in all three planes; sagittal and frontal plane moments across ankle, knee and hip joints in Nm/kg. | 3D, marker on skin |
| Han et al (2019) (Han et al., 2019) | 28; 20.29 (0.46); flexible flat foot | Arch height index < 0.31; navicular drop > 10 mm | Two type insoles, the type A insole with only arch support function, and the type B insole with both arch support and cushion pads for shock absorbing functions | Own shoes (with normal insole) | 5 trials; controlled speed | Ankle joint moment (Nm/kg) and rearfoot motion variables | 3D, marker on skin |
| Peng et al (2020) (Peng et al., 2020) | 15 (9/6); 21.7 (1.2); flat foot | Arch index of ≥ 0.28 | Prefabricated; Arch support and 6º inclined medial forefoot posting insoles, Universal Flat Foot, Dr Kong, HK, China | Running shoes (Reebok Run Supreme 4.0, Reebok, Boston, United States) | 6 trials; Self-selected comfortable speed, 10-m walkway | The 3D peak of Hip, knee, and ankle joint angles and moments (BW.BH) | 3D |
| Costa et al (2021) (Costa et al., 2021) | 16 (7/9); 26.63 (7.94); pronated foot | FPI-6 ≥ 6 | 4 arch-supported insoles (EVA) with varying degrees of medial heel wedge (EVA) (0◦, 3◦ (A), 6◦ (B), and 9◦ (C)). the medial wedges were fixed within the shoe using double-sided tape underneath the insoles from the calcaneus to the end of the medial longitudinal arch support. | Shoe with 0◦ wedge | 5 trials; self-selected speed on a 12 m walkway | Ankle, knee, and hip angles and moments (Nm/kg) | 3D; markers on footwear |
| Desmyttere (2021) (Desmyttere et al., 2021a) | 19 (6/13); 37.6 (14); | FPI-6= 7.8 | Customized, ¾ length, 3D printed in Nylon 12, Two pairs of different stiffnesses (flexible and rigid), height of honeycomb cells at the medial arch region was 2.0 mm for flexible FO and 3.2 mm for rigid FO. posting consisted of a 2 mm carbon fiber plate. Flexible FO (A), flexible FO with posting (B), rigid FO (C). | Standardized running shoe model (860 v8, New Balance, USA) | last 30-s of each 3-min trial treadmill | Ankle and foot kinematics and joint moments. (Nm/kg) | 3D: marker on skin |
| Permsombat and Pensri (2021) (Permsombat and Pensri, 2021) | 13 (8/5); 23.3 (3.0);  highly pronated foot | FPI-6 = 10.7 | Arch-supported Medial RF posting: Customized, ¾ length, rigid, leather and thermoplastic | BF condition | 5 trials; (10-meter walkway) at 1.2 m/s | Averaged joint excursion of RF, ankle, knee, and hip in all three planes | 3D: marker on skin |
| Lourenço et al (2022) (Lourenço et al., 2022) | 19 (9/10); 27.0 (8.07); pronated feet | FPI-6 = 9.84 | (A) Prefabricated (EVA) manufactured by Dilep´e Orthopedic Products, Brazil, with medial longitudinal arch support and no posting under the RF. (B) Customized were the prefabricated insole with the addition of a 6º medial wedge under the RF. Wedge was custom made on a CNC (Computer Numerical Control) milling machine also using EVA. | Standardized footwear (New Fit, Bout’s, Brazil) with the control insole | 5 trials; 12-meter walkway; self-selected speed | Ankle coronal plane, knee coronal plane, and hip transverse planes angles and moments (Nm/kg) | 3D; markers on shoes |
| Hsu et al (2022) (Hsu et al., 2022) | 10 (5/5); 30.7 (12.86); Flat foot | FPI-6= 7.13 (1.46) (Left side) and 7.38 (2.07)  (Right side) | 3D printed insoles, thermoplastic polyurethane, EVA, (A) auto-scan insole: 3/4 foot length; (B) total contact insole: 3/4 foot length; (C) medial wedge insole: full foot length | Standard shoes | 5 trials; self-selected speed | Ankle Joint Peak Eversion, Ankle Joint Peak Dorsiflexion, Ankle Joint Frontal Plane Moment, Knee Joint Frontal Plane Moment (Nm/kg) | 3D; markers on skin |
| Alsaafin et al (2023) (Alsaafin et al., 2023) | 31 (0/31); 21.74 (2.49); Flatfoot | valgus of resting calcaneal stance position angle ≥4° | Rigid orthoses; based on Blake inverted orthotic technique, (A) 15° inverted angle and (B) 25° inverted angle | Standard shoe | 5 trials; 10 m walkway at self-selected comfortable speed | Ankle, knee, and hip angles | 3D; markers on the shoes |

M: Male; F: Female; SD: Standard deviation; NNHT: Navicular height normalized to foot length RF: Rearfoot; FF: Forefoot; MF: Midfoot; FPI-6: Foot posture index, 6 item version; BW: Body weight; 2D: 2-dimensionnal; 3D: 3-dimensional; EVA: Ethylene vinyl acetate; PPT: cellular urethane

Appendix 1- Table 3. Downs and Black methodological quality assessment scores of the 24 included studies.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Author (year) | Reporting | | | | | | | |  | External validity | |  | Internal validity (bias) | | | | |  | Internal validity  (confounding) | | |  | Power | Score  (%) | Quality |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 10 | 11 | 12 | 14 | 15 | 16 | 18 | 20 | 21 | 22 | 25 | 27 |
| Johanson (1994) (Johanson et al., 1994) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 74 | MQ |
| Brown et al. (1995) (Brown et al., 1995) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 79 | HQ |
| Genova (2000) (Genova and Gross, 2000b) | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |  | 0 | 0 |  | 0 | 0 | 1 | 1 | 1 |  | 1 | 0 | 1 |  | 0 | 58 | MQ |
| Nawoczenski and Ludewig (2004) (Nawoczenski and Ludewig, 2004) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |  | 1 | 0 |  | 0 | 0 | 1 | 1 | 1 |  | 1 | 0 | 1 |  | 1 | 84 | HQ |
| Stacoff et al. (2007) (Stacoff et al., 2007) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 63 | MQ |
| Kulcu rt al. (2007) (Kulcu et al., 2007) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |  | 0 | 0 |  | 0 | 0 | 1 | 1 | 1 |  | 1 | 0 | 1 |  | 0 | 74 | MQ |
| Zifchock and Davis (2008) (Zifchock and Davis, 2008) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |  | 0 | 0 |  | 0 | 0 | 1 | 1 | 1 |  | 1 | 0 | 1 |  | 1 | 79 | HQ |
| Hurd et al. (2010) (Hurd et al., 2010) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 79 | HQ |
| Chen et al (2010) (Chen et al., 2010) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 79 | HQ |
| Cobb et al. (2011) (Cobb et al., 2011) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 74 | MQ |
| Dedieu et al (2013) (Dedieu et al., 2013) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 74 | MQ |
| Telfer et al (2013) (Telfer et al., 2013) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 90 | HQ |
| Tang et al (2015) (Tang et al., 2015) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 69 | MQ |
| Bishop et al. (2016) (Bishop et al., 2016) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 84 | HQ |
| Prachgosin et al (Prachgosin et al., 2017) (2017) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 79 | HQ |
| Kosonen et al (2017) (Kosonen et al., 2017) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 79 | HQ |
| Han et al (2019) (Han et al., 2019) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 79 | HQ |
| Peng et al (2020) (Peng et al., 2020) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 84 | HQ |
| Costa et al (2021) (Costa et al., 2021) | 1 | 1 | 1 | 1 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 79 | HQ |
| Desmyttere (2021) (Desmyttere et al., 2021a) | 1 | 1 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 74 | MQ |
| Permsombat and Pensri (2021) (Permsombat and Pensri, 2021) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 74 | MQ |
| Lourenço et al (2022) (Lourenço et al., 2022) | 1 | 1 | 1 | 1 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 79 | HQ |
| Hsu et al (2022) (Hsu et al., 2022) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 79 | HQ |
| Alsaafin et al (2023) (Alsaafin et al., 2023) | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 79 | HQ |
| Average score (mean (SD)) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 74 | MQ |

1=Yes; 0=No; SD: Standard Deviation; HQ: High Quality (Score≥75%); MQ: Moderate Quality (60%≤Score < 75%); LQ: Low Quality (Score < 60%).

Appendix 1- Table 4. Summary results of the research findings according to the applied foot orthoses fabrication methods.

|  |  |  |
| --- | --- | --- |
| Outcome | Applied fabrication methods | SMDs |
| Rearfoot eversion angle | Customized (Bishop et al., 2016; Dedieu et al., 2013; Tang et al., 2015; Telfer et al., 2013) | SMDs 1.55, 95% CI 0.46 to 2.64, **p=0.005** |
| Prefabricated (Brown et al., 1995; Genova and Gross, 2000b; Han et al., 2019; Hurd et al., 2010; Johanson et al., 1994; Stacoff et al., 2007) | SMDs 0.43, 95% CI 0.24 to 0.61, **p<0.00001** |
| Ankle dorsiflexion angle | Customized (Chen et al., 2010; Desmyttere et al., 2021a; Hsu et al., 2022) | SMDs -0.49, 95% CI -0.89 to -0.08, **p=0.02** |
| Prefabricated (Alsaafin et al., 2023; Peng et al., 2020) | SMDs -0.86, 95% CI -2.90 to 1.18, p=0.41 |
| Ankle eversion angle | Customized (Desmyttere et al., 2021a; Hsu et al., 2022) | SMDs 1.00, 95% CI -0.03 to 2.03, p=0.06 |
| Prefabricated (Brown et al., 1995; Costa et al., 2021; Johanson et al., 1994; Lourenço et al., 2022; Peng et al., 2020) | SMDs 0.44, 95% CI 0.24 to 0.63, **p<0.00001** |
| Ankle eversion moment | Customized (Hsu et al., 2022; Lafortune et al., 1994; Prachgosin et al., 2017) | SMDs 0.17, 95% CI -0.20 to 0.54, p=0.37 |
| Prefabricated (Costa et al., 2021; Han et al., 2019; Lafortune et al., 1994) | SMDs 0.48, 95% CI 0.23 to 0.74, **p=0.0002** |
| Knee adduction moment | Customized (Cohen, 1988; Desmyttere et al., 2021a; Hsu et al., 2022; Kosonen et al., 2017; Lourenço et al., 2022) | SMDs -0.21, 95% CI -0.46 to 0.04, p=0.1 |
| Prefabricated (Costa et al., 2021; Lourenço et al., 2022) | SMDs -0.47, 95% CI -0.81 to -0.12, **p=0.008** |

CI: Confidence Interval. As effect size, standardized mean differences (SMDs) were used. A negative value is indicative of an “improvement”, and a positive value of an “impairment” with regards to the respective outcome parameter during the application of foot orthosis compared to no orthosis.

Bold numbers indicate significance at p value < 0.05.

Appendix 1- Table 5. Summary results of the research findings according to the applied testing methods for the assessment of foot pronation.

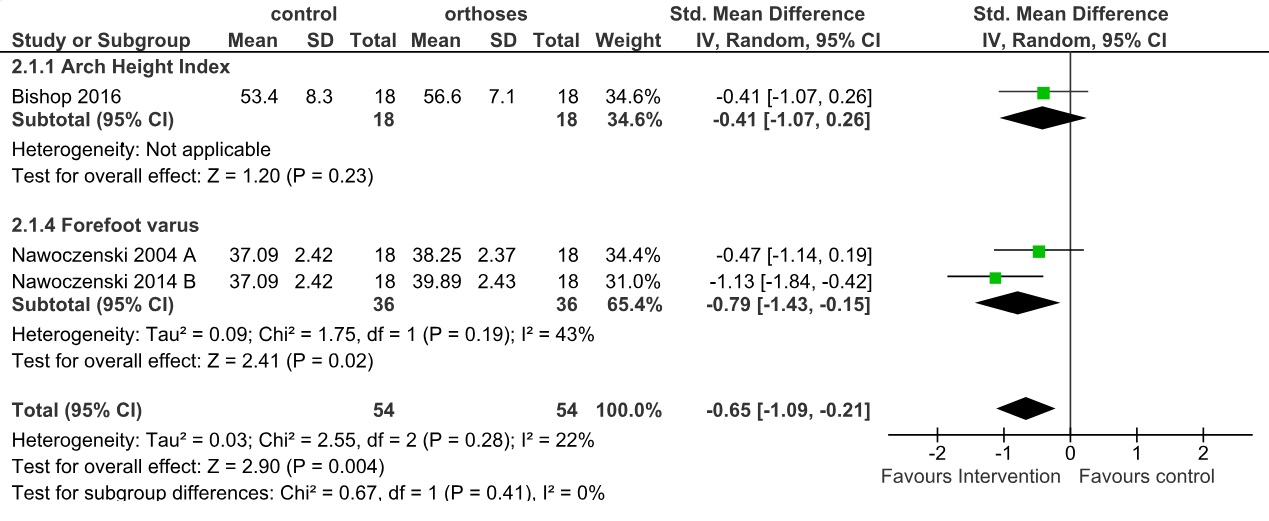
|  |  |  |
| --- | --- | --- |
| Outcome | Applied methods for the assessment of foot pronation | SMDs |
| Rearfoot eversion angle | Foot posture index or clinical observation (Stacoff et al., 2007; Telfer et al., 2013) | SMDs=1.42, 95% CI 0.20 to 2.63, **p=0.02** |
| Foot print arch index (Tang et al., 2015) | SMDs=0.64, 95% CI -0.26 to 1.55, p=0.16 |
| Arch height index (Bishop et al., 2016; Han et al., 2019) | SMDs=0.42, 95% CI -0.20 to 1.05, p=0.18 |
| Forefoot varus (Brown et al., 1995; Hurd et al., 2010; Johanson et al., 1994) | SMDs=0.36, 95% CI 0.13 to 0.6, **p=0.002** |
| Rearfoot eversion or rest calcaneal stance position (Dedieu et al., 2013) | SMDs=1.28, 95% CI 0.39 to 2.17, **p=0.005** |
| Ankle dorsiflexion angle | Foot posture index or clinical observation (Desmyttere et al., 2021a; Hsu et al., 2022) | SMDs=-0.42, 95% CI -0.72 to -0.12, **p=0.007** |
| Foot print arch index (Peng et al., 2020) | SMDs=0.42, 95% CI -0.30 to 1.15, p=0.26 |
| Arch height index (Chen et al., 2010) | SMDs=-0.19, 95% CI -1.03 to 0.65, p=0.18 |
| Rearfoot eversion or rest calcaneal stance position (Alsaafin et al., 2023) | SMDs=-0.42, 95% CI -0.78 to -0.06, **p=0.02** |
| Ankle eversion angle | Foot posture index or clinical observation (Costa et al., 2021; Desmyttere et al., 2021a; Hsu et al., 2022; Lourenço et al., 2022) | SMDs=0.68, 95% CI 0.13 to 1.23, **p=0.01** |
| Foot print arch index (Peng et al., 2020) | (SMDs=0.55, 95% CI -0.18 to 1.28, p=0.14 |
| Forefoot varus (Brown et al., 1995; Johanson et al., 1994) | SMDs=0.5, 95% CI 0.24 to 0.77, **p=0.0002** |
| Ankle eversion moment | Foot posture index or clinical observation (Costa et al., 2021; Hsu et al., 2022; Lourenço et al., 2022) | SMDs=0.21, 95% CI -0.04 to 0.47, p=0.10 |
| Foot print arch index (Prachgosin et al., 2017) | SMDs=0.08, 95% CI -0.97 to 1.13, p=0.88 |
| Arch height index (Han et al., 2019) | SMDs=0.79, 95% CI 0.41 to 1.18, **p<0.0001** |
| Knee adduction moment | Foot posture index or clinical observation | SMDs=-0.50, 95% CI -0.72 to -0.28, **p<0.00001** |
| Arch height index | SMDs=0.18, 95% CI -0.42 to 0.77, p=0.56 |

CI: Confidence Interval. As effect size measure, standardized mean differences (SMDs) were computed. A negative value is indicative of an “improvement”, and a positive value of an “impairment” with regards to the respective outcome parameter during the application of foot orthosis compared to no orthosis.

Bold numbers indicate significance at p value < 0.05.

**Appendix 2**

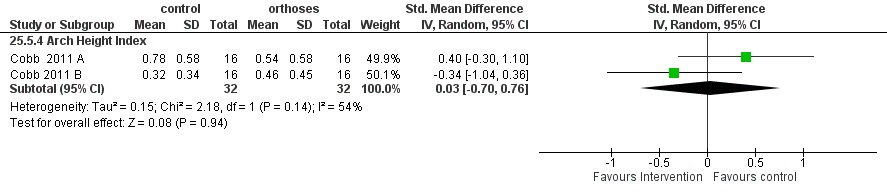
Researchers from two studies with customized FO fabrication reported the effects of FO application on peak first metatarsophalangeal joint (MTPJ) dorsiflexion 1,2. The subgroup analysis revealed no significant effect of FO application in the study that assessed foot posture using the arch height index 1. However, the meta-analysis revealed a significant and moderate effect of FO application in another study 2 using two different FO types. In this study, the forefoot varus assessment method was applied to determine flat-feet (Fig 1). Overall, the results from the meta-analysis indicated a significant and moderate effect on peak MTPJ when using FO compared to control (moderate SMDs=-0.65, 95% CI -1.09 to -0.21, p=0.004) (Fig 1). On average, the peak MTPJ was found to be 2.04° (95% CI −3.26 to −0.83) greater in FO compared with control. There was trivial study heterogeneity (I2=22%).



Appendix. Fig 1. Forest plot illustrating effects of foot orthoses application on peak first metatarsophalangeal joint dorsiflexion during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 3**

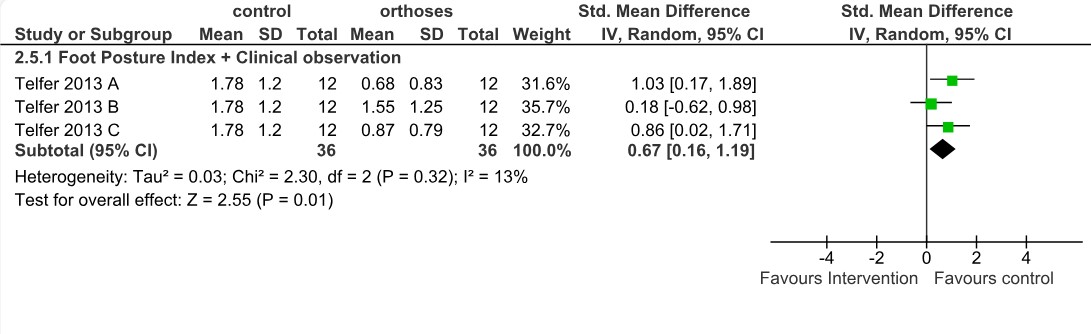
Authors from one study 3 with two types of customized FO reported the first metatarsophalangeal joint abduction excursion and showed no significant difference between the FO and control condition (Fig 2).



Appendix. Fig 2. Forest plot illustrating the effects of foot orthoses application on peak first metatarsophalangeal joint abduction excursion during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 4**

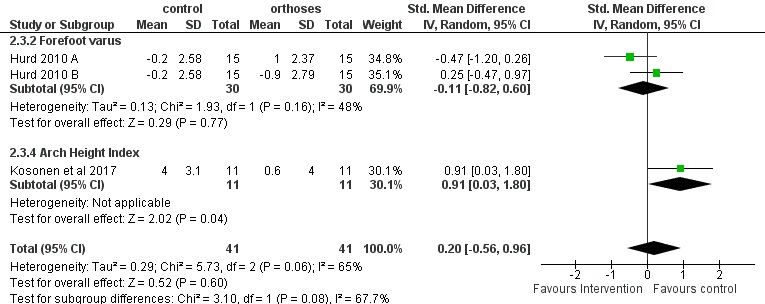
The authors from one study with three degree of customized FO posting reported the effects of FO on peak forefoot abduction 4. The meta-analysis revealed a significant and moderate effect on peak FF abduction when using FO compared to control (moderate SMDs=0.67, 95% CI 0.16 to 1.19, p=0.01) (Fig 3). On average, the peak forefoot abduction in control condition was found to be 0.8° (95% CI 0.1 to 1.72) greater compared to FO condition.



Appendix. Fig 3. Forest plot illustrating the effect of foot orthoses application on peak forefoot abduction during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 5**

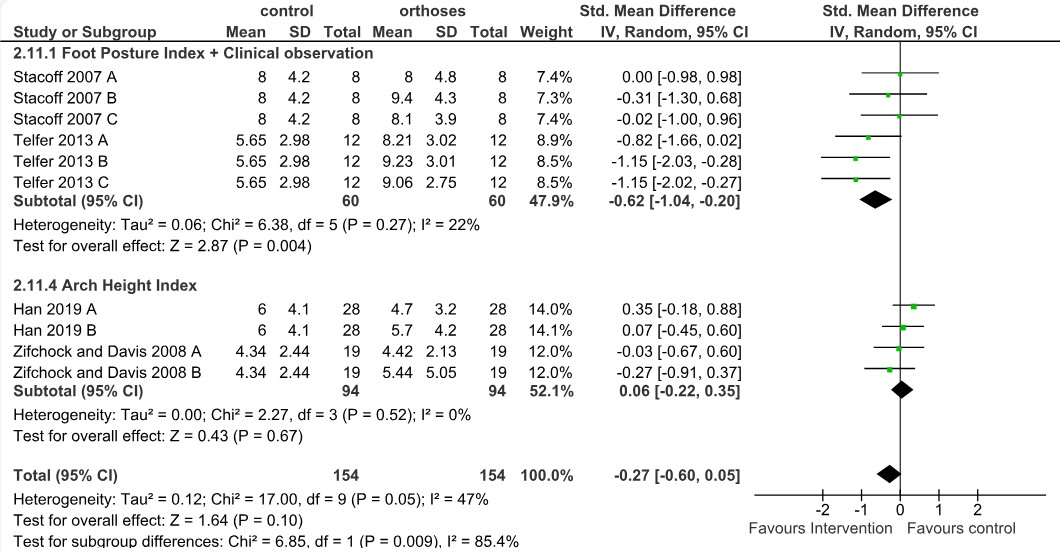
Researchers from two studies examined the effects of prefabricated 5 and customized 6 FOs on peak forefoot eversion 5,6. Overall, the meta-analysis indicated moderate study heterogeneity and no significant effect of FO application (small SMDs=0.20, 95% CI -0.56 to 0.96, p=0.60, I2=65%). The subgroup meta-analysis showed a significant effect of customized FO in the study that used the arch height index for foot posture assessment 6 (large SMDs=0.91, 95% CI 0.03 to 1.80, p=0.04). More specifically, the peak forefoot eversion was 3.40° (95% CI 0.41 to 6.39) lower in the FO condition compared to control (Fig 4).



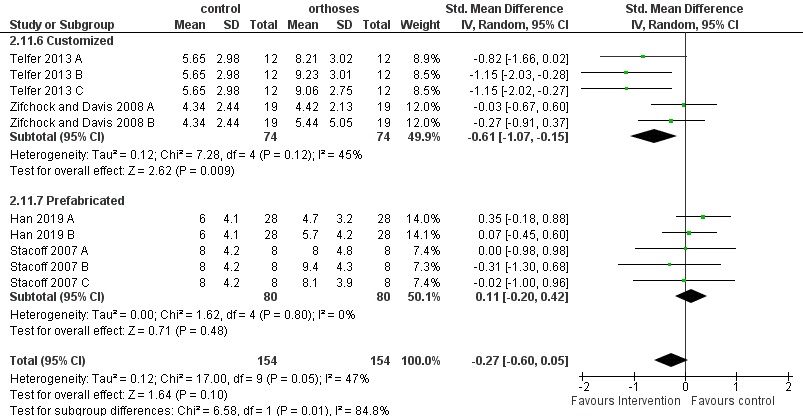
Appendix. Fig 4. Forest plot illustrating the effects of foot orthoses application on peak forefoot eversion during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 6**

Authors from four studies reported the effects of FO application on peak rearfoot inversion 4,7-9. Overall, the meta-analysis indicated no significant effect of FO application (SMDs=-0.27, 95% CI -0.60 to 0.05, p=0.1, I2=47%). (Fig 5). However, the subgroup meta-analysis showed a significant effect of FO application in the studies that used FPI-6 or clinical observation for foot posture assessment 4,8 (moderate SMDs=-0.62, 95% CI -1.04 to -0.20, p=0.004, I2=22%). Of note, peak rearfoot inversion was 2.54° lower in the FO condition compared to control (95% CI -3.73 to -1.35). Furthermore, the subgroup analysis showed no significant effect of FO application in the studies 7,9 that assessed foot posture using the arch height index (Fig 5) (SMDs=0.06, 95% CI -0.22 to 0.35, p=0.67, I2=22%). The subgroup analyses of the FO fabrication method revealed significantly greater peak rearfoot inversion in customized FOs (three studies: SMDs -0.61, 95% CI -1.07 to -0.15, p=0.009, I2=45%). There was no significant effect of prefabricated FOs (two studies: SMDs 0.11, 95% CI -0.20 to 0.42, p=0.48, I2=0%; Fig 6).



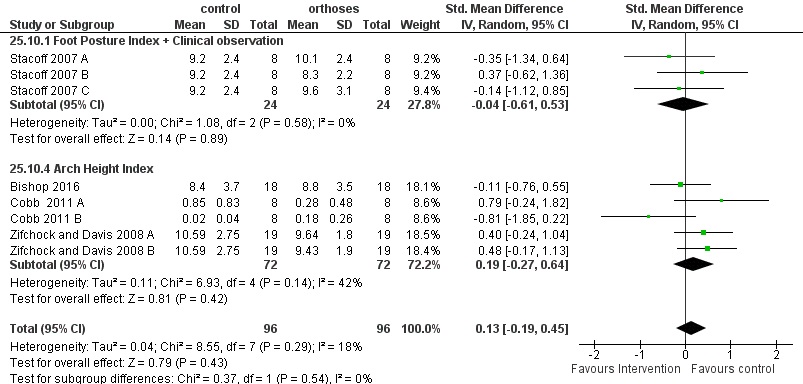
Appendix. Fig 5. Forest plot illustrating the effects of foot orthoses application on peak rearfoot inversion during walking in individuals with flat-feet. The subtotal effect with regards to the methodological approach for the assessment of flat-feet was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



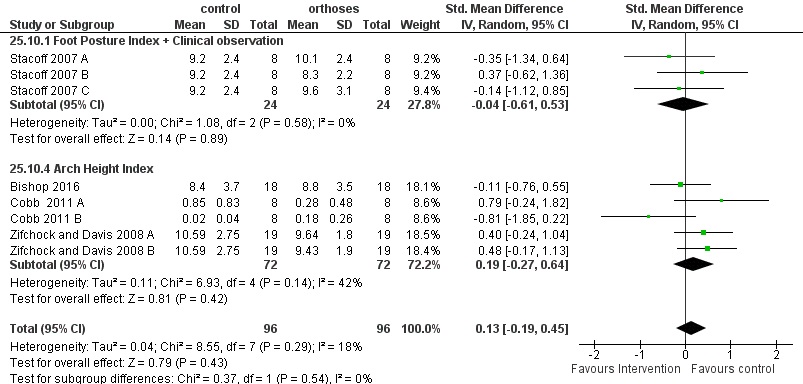
Appendix. Fig. 6. Forest plot illustrating the effects of foot orthoses application (intervention) versus control on peak rearfoot inversion during walking in individuals with flat-feet. The subtotal effect with regards to the FO fabrication method was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix** 7

Authors from four studies reported the effects of FO application on rearfoot eversion excursion 1,3,8,9. Findings from the meta-analysis indicated no significant effect of FO application (Fig 7 and Fig 8). One study used customized FOs in the arch height index group 6 and examined the FO effects on peak rearfoot dorsiflexion. No significant difference was found between the FO and the control condition (SMDs=-0.67, 95% CI -1.53, 0.20).



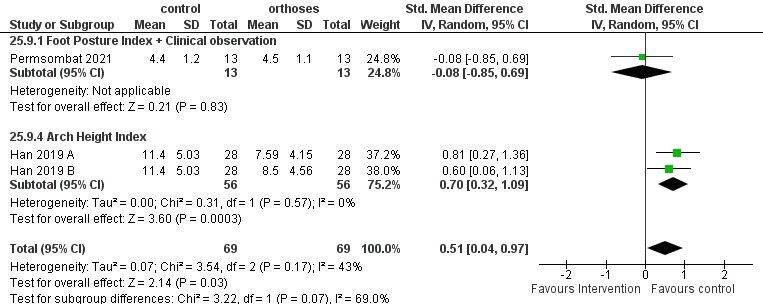
Appendix. Fig 7. Forest plot illustrating the effects of foot orthoses application on rearfoot eversion joint excursion during walking in individuals with flat-feet. The subtotal effect with regards to the methodological approach for the assessment of flat-feet was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



Appendix. Fig. 8. Forest plot illustrating the effects of foot orthoses application (intervention) versus control on rearfoot eversion joint excursion during walking in individuals with flat-feet. The subtotal effect with regards to the FO fabrication method was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 8**

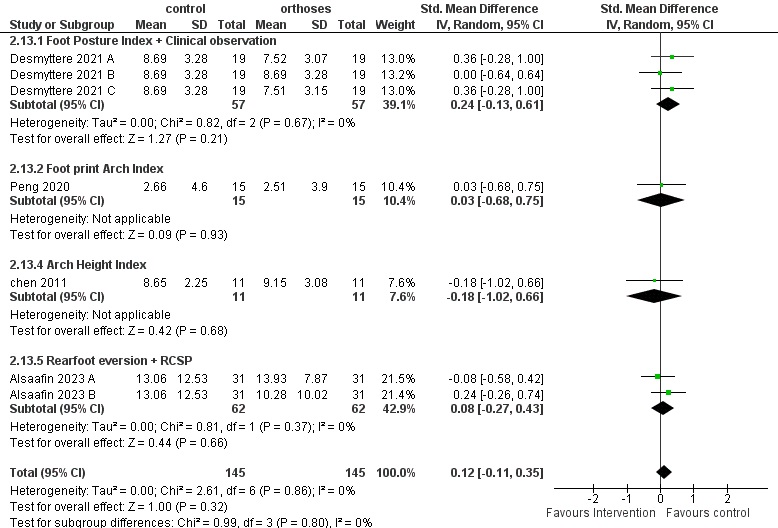
Researchers from two studies with prefabricated 10 and customized 7 FOs reported the effects of FO application on rearfoot frontal plane joint excursion 7,10. Overall, the meta-analysis indicated a moderate FO effect with small study heterogeneity (moderate SMDs=0.51, 95% CI 0.04 to 0.97, p=0.03, I2=43%). More specifically, the rearfoot frontal plane excursion was 2.01° (95% CI -0.73 to 4.76) lower in the FO condition compared to control (Fig 9). The subgroup meta-analysis showed a significant FO effect only in one study 7 with two different types of prefabricated FOs that used the arch height index for foot posture assessment (Fig 9) (moderate SMDs=0.70, 95% CI 0.32 to 1.09, p=0.0003).



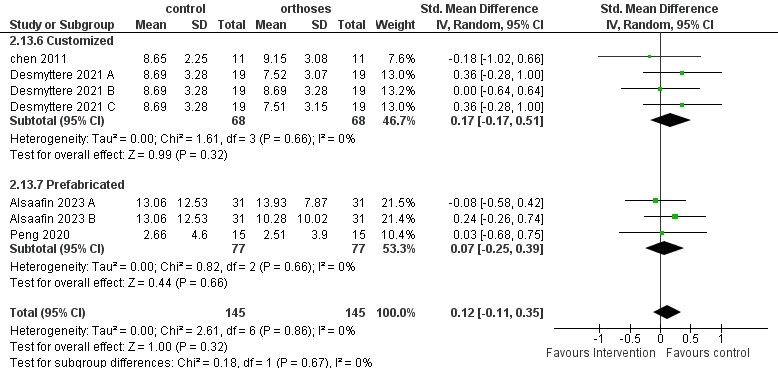
Appendix. Fig 9. Forest plot illustrating the effects of foot orthoses application on rearfoot frontal plane joint excursion during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 9**

Researchers from four studies examined the effects of FO application on peak ankle plantarflexion 11-14. The overall and subgroup meta-analytical findings showed no significant difference between control and FO conditions (Fig 10 and Fig 11). There was no study heterogeneity (I2=0%).



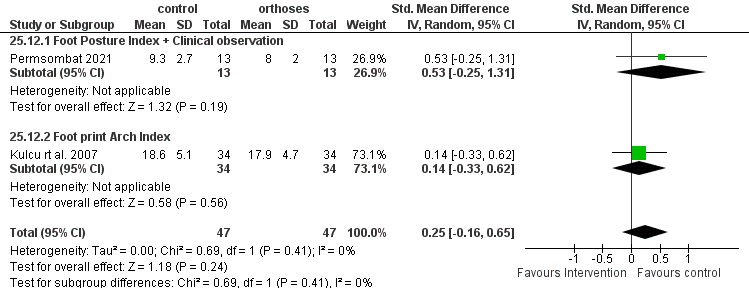
Appendix. Fig 10. Forest plot illustrating the effects of foot orthoses application on peak ankle plantarflexion during walking in individuals with flat-feet. The subtotal effect with regards to the methodological approach for the assessment of flat-feet was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



Appendix. Fig. 11. Forest plot illustrating the effects of foot orthoses application (intervention) versus control on peak ankle plantarflexion during walking in individuals with flat-feet. The subtotal effect of FO fabrication methods was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 10**

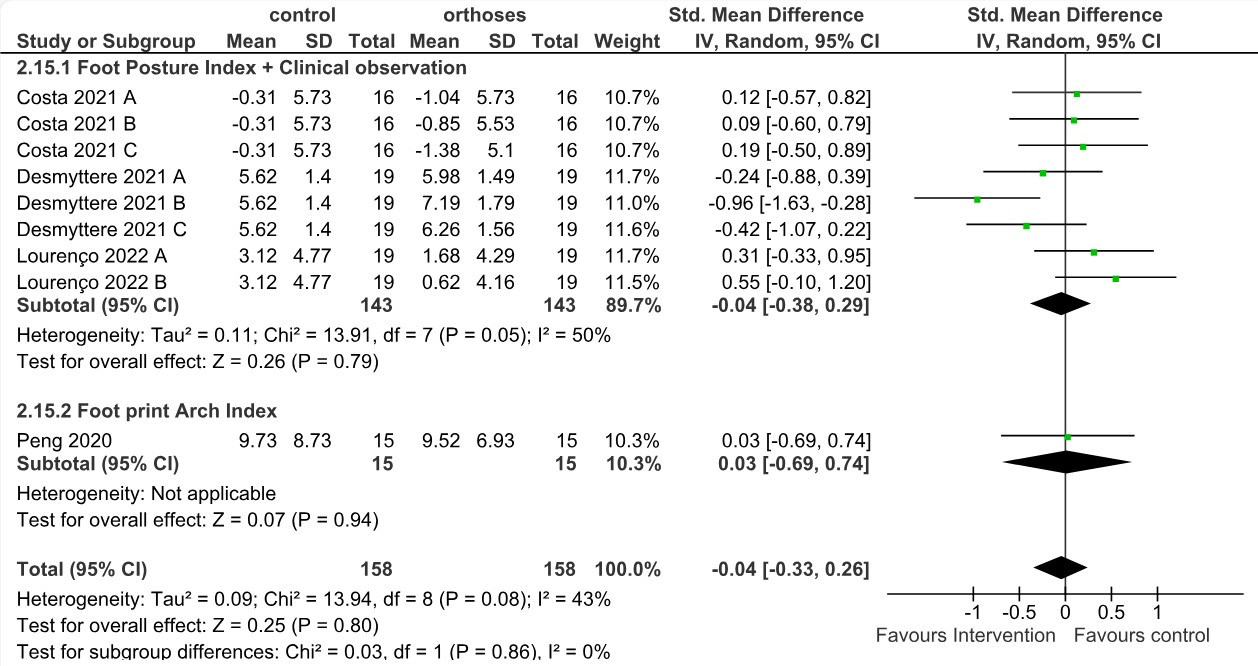
Authors from two studies reported the effects of FO application using prefabricated 10 and customized 15 FOs on ankle sagittal plane excursion 10,15. The overall and subgroup findings from our meta-analysis showed no significant difference between control and FO conditions (Fig 11). There was no study heterogeneity (I2=0%).



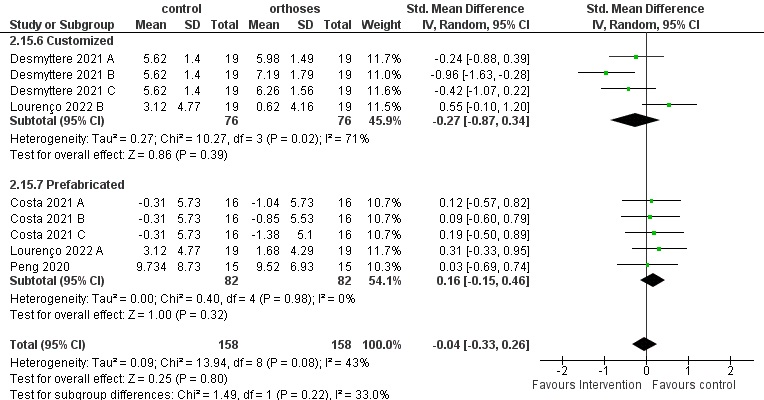
Appendix. Fig 11. Forest plot illustrating the effects of foot orthoses application on ankle sagittal plane excursion during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 11**

Authors from four studies reported the effects of FO application on peak ankle inversion 13,14,16,17. Findings from our meta-analysis including overall and subgroup effects showed no significant difference between control and FO conditions (Fig 12, Fig 13). There was a small level of study heterogeneity (I2=43%).



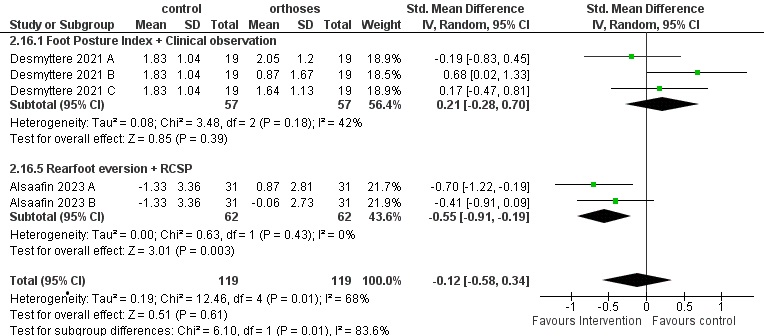
Appendix. Fig 12. Forest plot illustrating the effects of foot orthoses application on peak ankle inversion during walking in individuals with flat-feet. The subtotal effect with regards to the methodological approach for the assessment of flat-feet was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



Appendix. Fig. 13. Forest plot showing the effects of foot orthoses application (intervention) versus control on peak ankle inversion during walking in individuals with flat-feet. The subtotal effect with regards to the applied FO fabrication method was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 12**

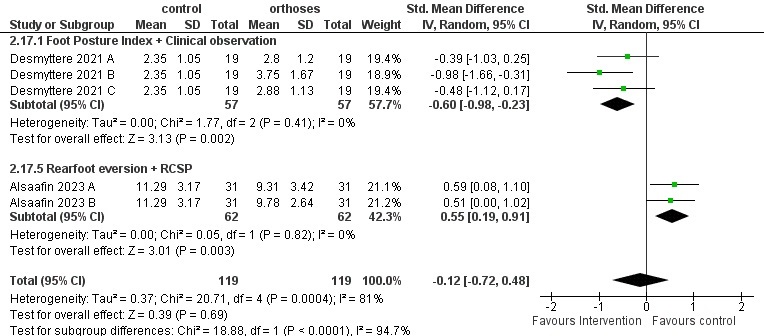
Two studies indicated the effects of FO application on peak ankle adduction with prefabricated 11 and customized 13 FOs. The subgroup analyses showed no significant effects of customized FOs in the study that assessed foot posture with FPI-6 or clinical observation 13 (SMDs=0.21, 95% CI -0.28 to 0.70, p=0.39). However, the subgroup meta-analysis indicated a significant effect of prefabricated FOs in another study 11 that used rearfoot eversion or RCSP (moderate SMDs=-0.55, 95% CI -0.91 to -0.19, p=0.003) to determine flat foot posture. More specifically, the peak ankle adduction was 1.73° (95% CI 0.58 to 1.62) greater in the FO condition compared to control. Overall, the meta-analysis indicated no significant FO effect (Fig 14) (trivial SMDs=-0.12, 95% CI -0.58 to 0.34, p=0.61). Moderate study heterogeneity was observed (I2=68%).



Appendix. Fig 14. Forest plot showing the effects of foot orthoses application on peak ankle adduction during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 13**

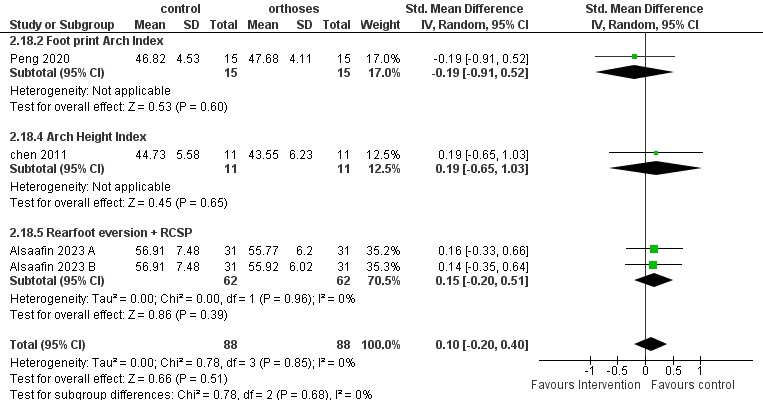
Two studies reported the effects of FO application on peak ankle abduction 11,13 with prefabricated 11 and customized 13 FOs. The subgroup meta-analyses showed conflicting results. In the study that used FPI-6 or clinical observation ankle abduction was 0.74° (95% CI -1.28 to -0.19) greater in the customized 13 FO condition. However, the results were opposite with rearfoot eversion or RCSP (moderate SMDs=0.55, 95% CI 0.19 to 0.91, p=0.003). More specifically, peak rearfoot abduction was 1.72° (95% CI 0.63 to 2.80, p=0.002) lower in the prefabricated 11 FO condition compared to the control condition (95% CI -3.73 to -1.35). Overall, there was no significant effect of FO application (SMDs=-0.12, 95% CI -0.72 to -0.48, p=0.97, I2=81%) (Fig 15).



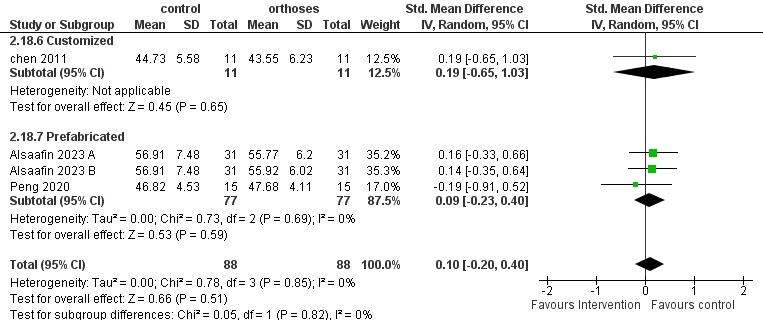
Appendix. Fig 15. Forest plot showing the effects of foot orthoses application on peak ankle abduction during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 14**

The effect of FO application on peak knee flexion was assessed in three studies 11,12,14. Study heterogeneity was zero percent. The total and subgroup meta-analyses indicated no significant difference between FO and control conditions (Fig 16 and Fig 17).



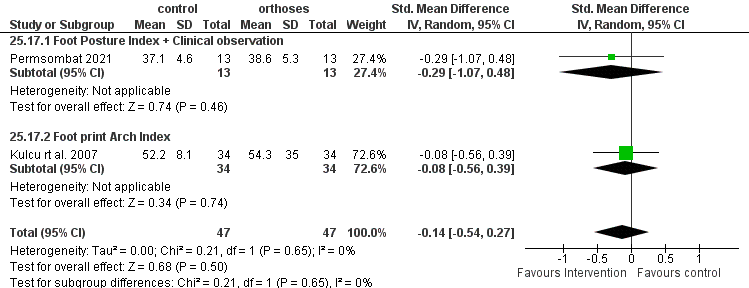
Appendix. Fig 16. Forest plot illustrating the effects of foot orthoses application on peak knee flexion angle during walking in individuals with flat-feet. The subtotal effect with regards to the methodological approach for the assessment of flat-feet was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



Appendix. Fig. 17. Forest plot showing the effects of foot orthoses application (intervention) versus control on peak knee flexion angle during walking in individuals with flat-feet. The subtotal effect of fabrication methods of FO for each parameter and the total effect was calculated as a standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 15**

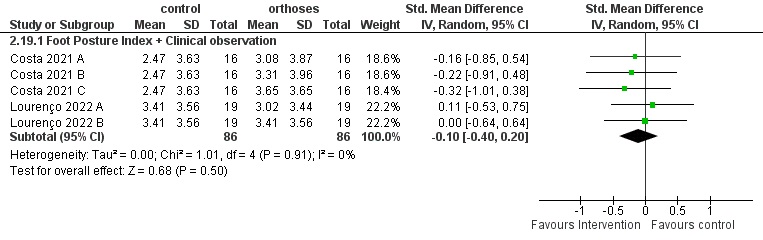
The effect of FO application on knee sagittal plane excursion was assessed in three studies 10,15 using prefabricated 10 and customized 15 FO. Study heterogeneity was zero percent. The total and subgroup meta-analyses indicated no significant difference between FO and control conditions (Fig 18).



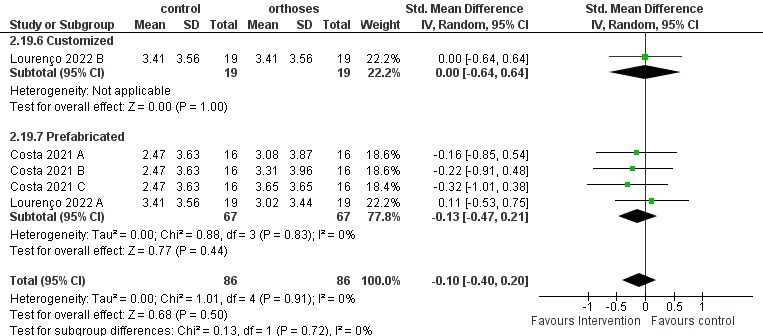
Appendix. Fig 18. Forest plot showing the effects of foot orthoses application on knee sagittal plane excursion during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 16**

Author from two studies reported the effects of FO application on peak knee adduction 16,17 using prefabricated 16,17 and customized 17 FOs. The total and subgroup meta-analyses indicated no significant difference between FO and control conditions (Fig 19 and Fig 20).



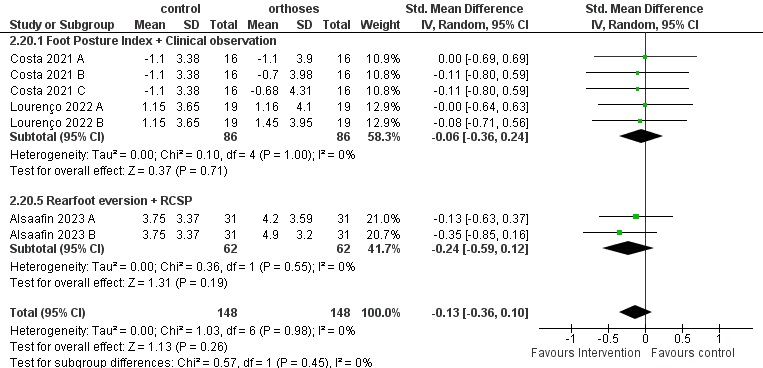
Appendix. Fig 19. Forest plot illustrating the effects of FO application on peak knee adduction angle during walking in individuals with flat-feet. The subtotal effect with regards to the methodological approach for the assessment of flat-feet was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



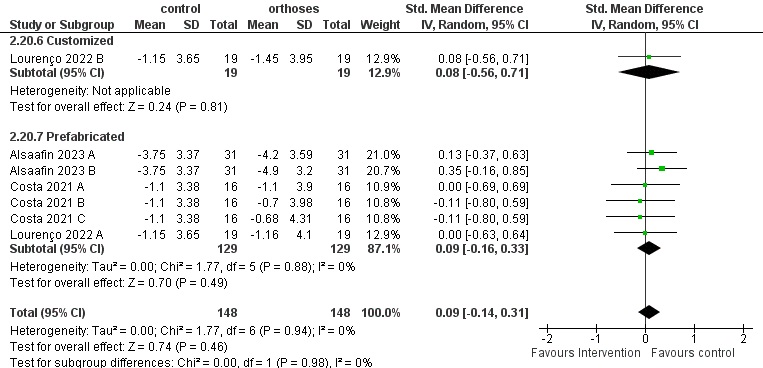
Appendix. Fig. 20. Forest plot showing the effects of FO application (intervention) versus control on peak knee adduction angle during walking in individuals with flat-feet. The subtotal effect with regards to the FO fabrication method was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 17**

Three studies reported the effects of FO application on peak knee abduction 11,16,17 using prefabricated 11,16,17 and customized 17 FOs. Meta-analytical findings for overall and subgroups indicated no significant FO effects (Fig 21 and Fig 22).



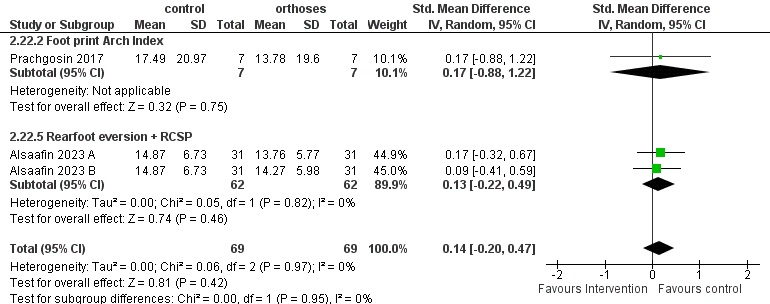
Appendix. Fig 21. Forest plot illustrating the effects of FO application on peak knee abduction angle during walking in individuals with flat-feet. The subtotal effect with regards to the methodological approach for the assessment of flat-feet was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



Appendix. Fig. 22. Forest plot showing the effects of FO application (intervention) versus control on peak knee abduction angle during walking in individuals with flat-feet. The subtotal effect with regards to the FO fabrication method was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 18**

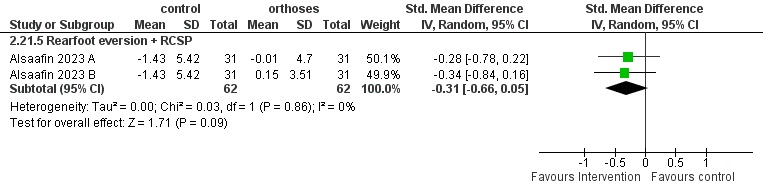
Two studies reported the effects of FO application on peak knee external rotation 11,18 using prefabricated 11 and customized 18 FOs. Findings for total and subgroup meta-analysis indicated no significant effects of FO application (Fig 22).



Appendix. Fig 22. Forest plot illustrating the effects of FO application on peak knee external rotation angle during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 19**

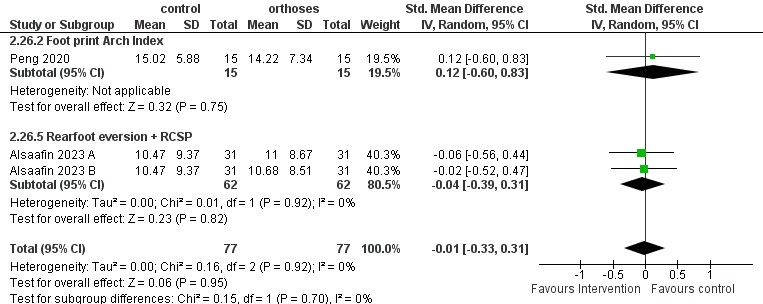
One study 11 with two different types of prefabricated FOs reported peak knee internal rotation. There was no significant difference between FO and control conditions (Fig 23).



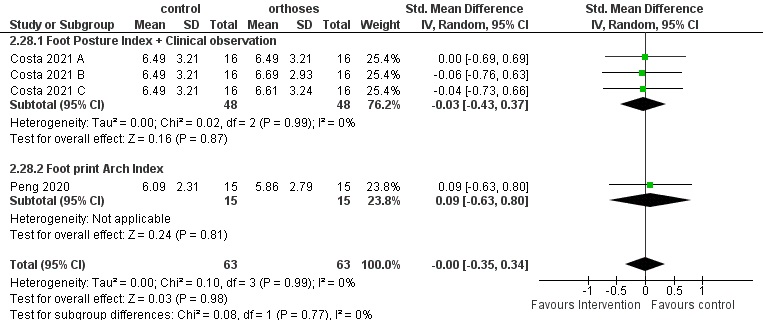
Appendix. Fig 23. Forest plot illustrating the effects of FO application on peak knee internal rotation angle during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 20**

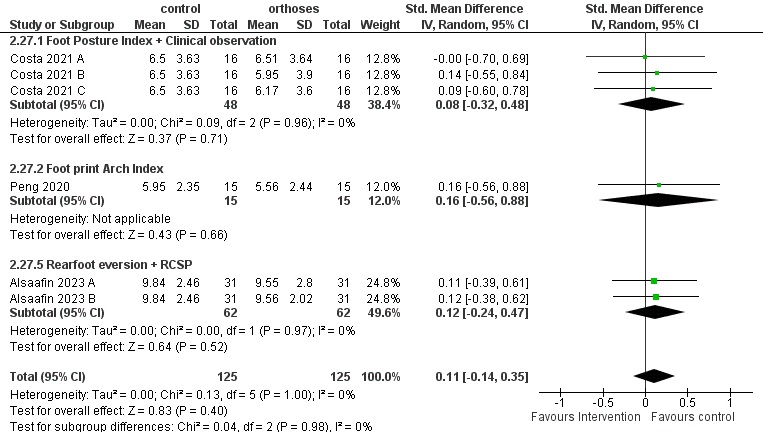
Two studies with prefabricated FOs evaluated the effects of FO application on peak hip extension 11,14 (Fig 24), abduction 14,16 (Fig 25). Three studies with prefabricated FOs reported peak hip adduction 11,14,16 (Fig 26). These studies did not yield any significant differences for the above-mentioned parameters. In terms of study heterogeneity, there was no indication of variation (I2=0%).



Appendix. Fig 24. Forest plot illustrating the effects of FO application on peak hip extension during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



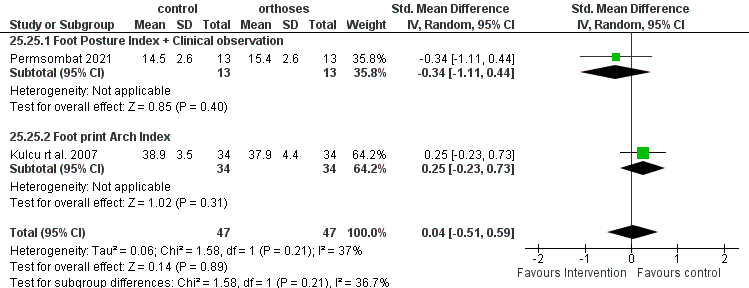
Appendix. Fig 25. Forest plot illustrating the effects of FO application on peak hip abduction during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



Appendix. Fig 26. Forest plot illustrating the effects of FO application on peak hip adduction during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 21**

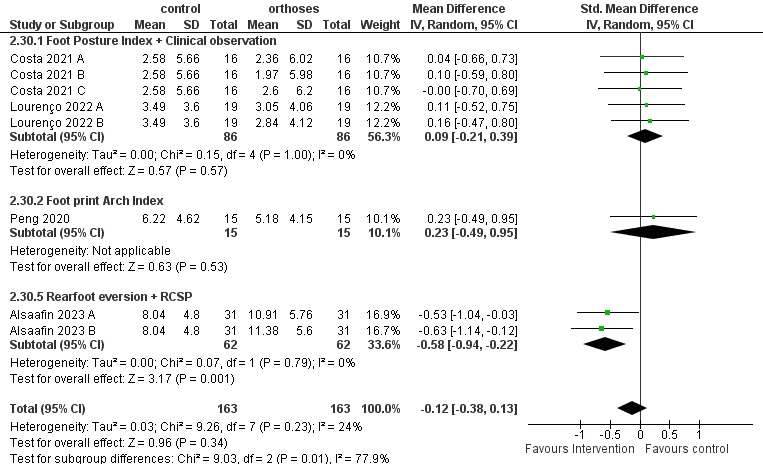
Hip sagittal plane excursion was reported in two studies 10,15 that applied prefabricated 10 and customized 15 FOs. Total and subgroup meta-analyses showed no significant difference between control and FO conditions (Fig 27). Low study heterogeneity was found (I2=36.7%).



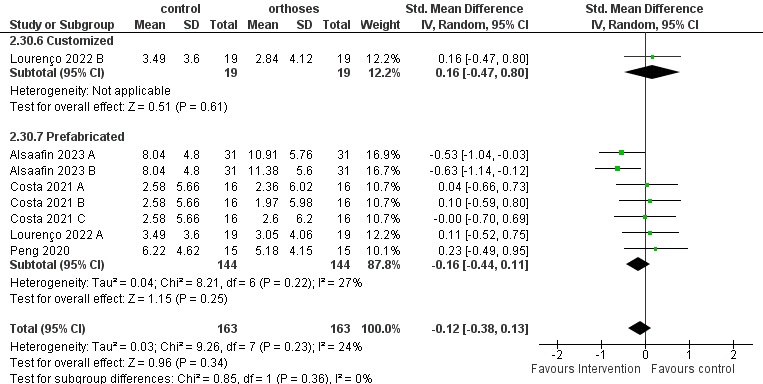
Appendix. Fig 27. Forest plot showing the effects of FO application on hip sagittal plane excursion during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 22**

The effects of FO application on peak hip external rotation were reported in four studies. Overall, the meta-analysis indicated no significant effects of FO application (SMDs=-0.12, 95% CI -0.38 to 0.13, p=0.034, I2=24%). Nonetheless, the subgroup meta-analysis of the assessment methodology of flat-feet showed significant effects of FO application in the studies that used rearfoot eversion or RCSP 11 for flat foot assessment (moderate SMDs=-0.58, 95% CI -0.94 to -0.22, p=0.001, I2=0%) (Fig 28). More specifically, peak hip external rotation was 3.11° (95% CI -4.96 to -1.26) lower in the FO condition compared to the control condition (Fig 28). The subgroup analyses of FO fabrication revealed no significant effect of customized and prefabricated FO application (Fig 29).



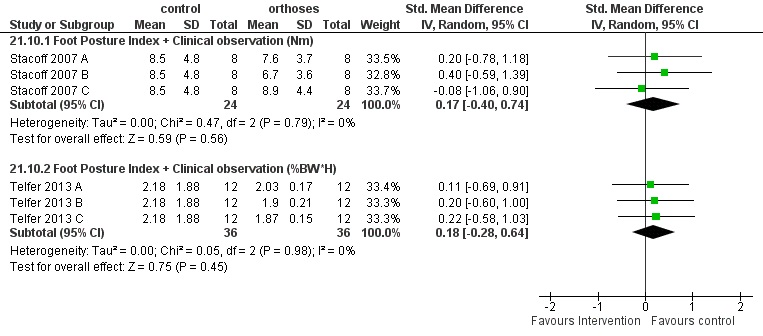
Appendix. Fig 28. Forest plot illustrating the effects of FO application on peak hip external rotation during walking in individuals with flat-feet. The subtotal effect with regards to the methodological approach for the assessment of flat-feet was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



Appendix. Fig. 29. Forest plot showing the effects of FOoses application (intervention) versus control on peak knee abduction angle during walking in individuals with flat-feet. The subtotal effect with regards to the applied FO fabrication method was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 23**

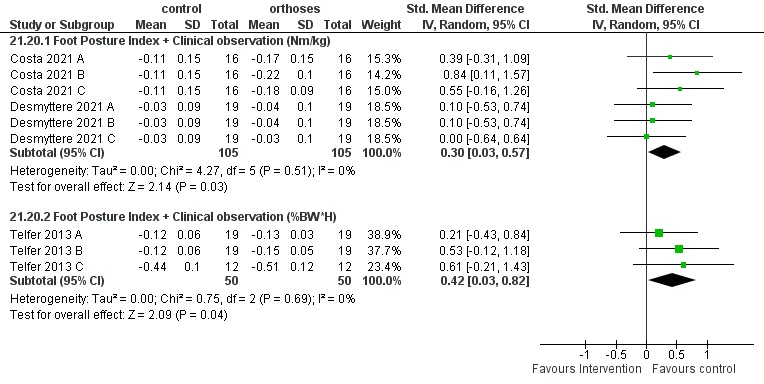
Using customized FO application, one study reported peak eversion moments in %BW\*H 4. Another study reported peak eversion moments in Nm 8 with prefabricated FO application. The results indicated no significant difference between FO and control (Fig 30).



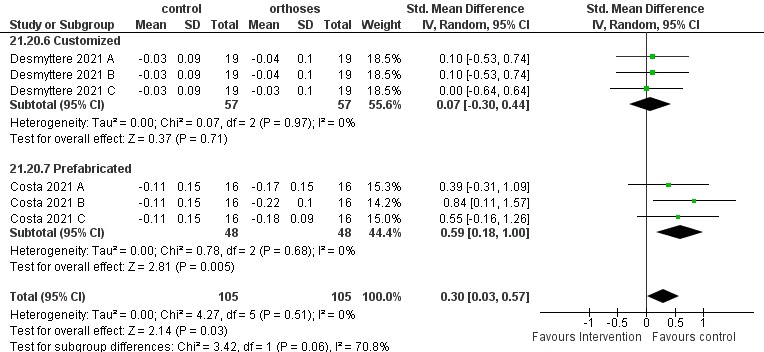
Appendix. Fig 30. Forest plot illustrating the effects of FO application on peak rearfoot eversion moment during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 24**

Authors from two studies reported the effects of FO application on knee abduction moments 13,16. The meta-analytical results showed significant differences in peak knee abduction moments between FO and control conditions (SMDs=-0.30, 95% CI -0.50 to -0.10, p=0.004, I2=0%) (Fig 31). More specifically, the peak knee abduction moment was 0.03 Nm/kg (95% CI 0.00 to 0.06) greater in the FO condition. The subgroup analyses with regards to the applied FO fabrication method revealed significantly greater peak ankle dorsiflexion in prefabricated FOs (Fig 32). Moreover, Telfer et al. 4 reported a significant effect of customized FO application on the knee abduction moment in the %BW\*H. Results of the meta-analysis showed no significant effects of FO application (Fig 31)



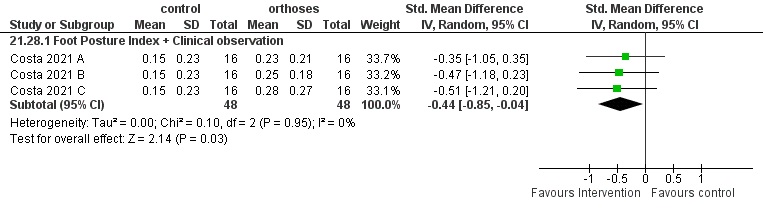
Appendix. Fig 31. Forest plot illustrating the effects of FO application on peak knee abduction moment during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



Appendix. Fig. 32. Forest plot showing the effects of FO application (intervention) versus control on peak knee abduction moment during walking in individuals with flat-feet. The subtotal effect of FO fabrication methods was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 25**

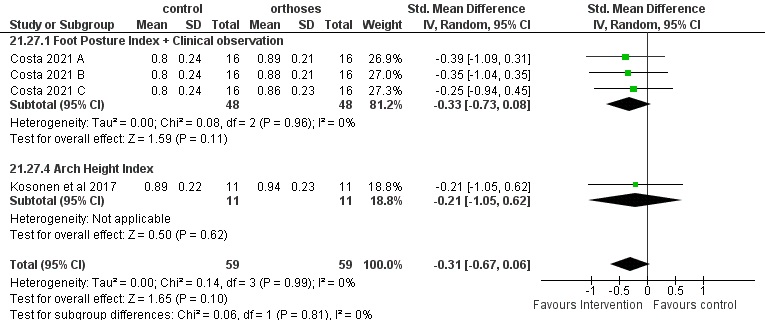
One study 16 with three different types of prefabricated FOs reported findings for the outcome measure peak hip abduction moment (Nm/kg). There was a significant difference between FO and control conditions (Fig 33). Of note, the peak hip abduction moment was 0.1 Nm/kg (95% CI -0.19 to -0.01) greater in the FO condition.



Appendix. Fig 33. Forest plot illustrating the effects of FO application on peak hip abduction moment during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 26**

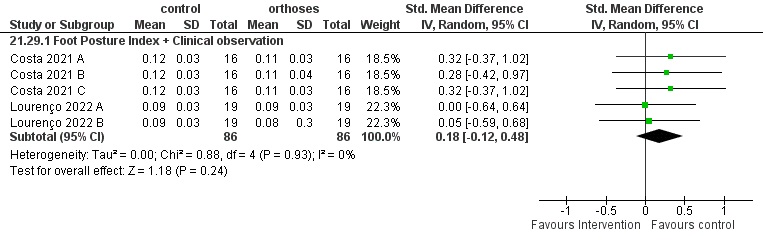
Authors from two studies with different foot posture assessment methods reported the effects of prefabricated 16 and customized 6 FO application on peak hip adduction moments 6,16 . Total and subgroup meta-analysis indicated no significant effect of FO application (Fig 34).



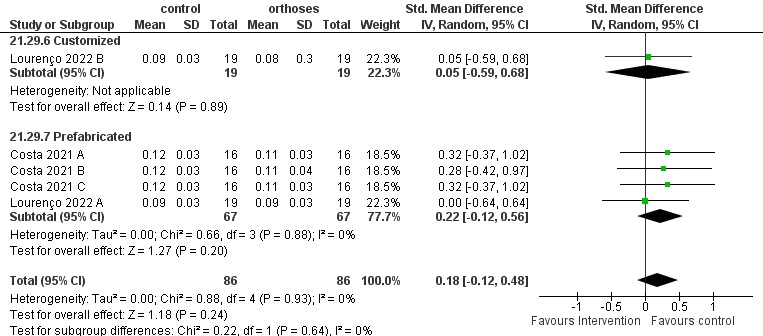
Appendix. Fig 34. Forest plot illustrating the effects of FO application on peak hip adduction moment during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 27**

Researchers from two studies reported the effects of FO application on peak hip internal rotation moments 6,16. The meta-analytical results for the total and subgroup effect indicated no significant impact of FO application (Fig 35 and Fig 36).



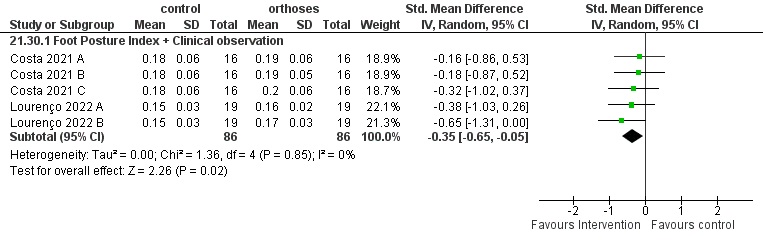
Appendix. Fig 35. Forest plot illustrating the effects of FO application on peak hip internal rotation moments during walking in individuals with flat-feet. The subtotal effect with regards to the methodological approach for flat-feet assessment were calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



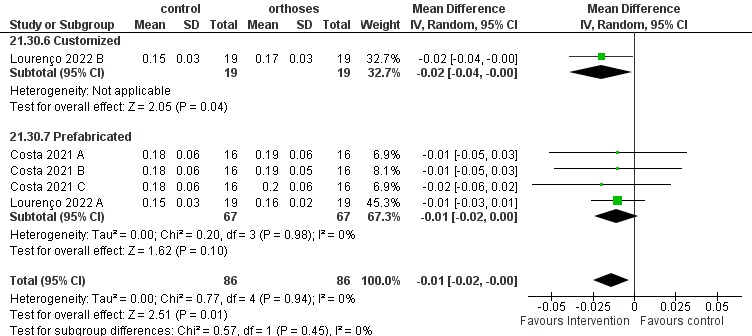
Appendix. Fig 36. Forest plot showing the effects of FO application (intervention) versus control on peak hip internal rotation moment during walking in individuals with flat-feet. The subtotal effect of the applied FO fabrication method was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 28**

Authors from two studies reported the effects of FO application on peak hip external rotation moments 6,16. Based on the meta-analytical results, there was a significant and small effect of FO application (small SMDs=-0.35, 95% CI -0.65 to -0.05, p=0.02, I2=0%) (Fig 37 and Fig 38). Peak hip external rotation moment was 0.01 Nm/kg (95% CI -0.02 to -0.00) greater in the FO condition. The subgroup analysis of the applied FO fabrication method revealed significantly greater peak ankle dorsiflexion for customized FOs (Fig 37 and 38).



Appendix. Fig 37. Forest plot illustrating the effects of FO application on peak hip external rotation moment during walking in individuals with flat-feet. The subtotal effect for each parameter and the total effect were calculated as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.



Appendix. Fig. 38. Forest plot showing the effects of FO application (intervention) versus control on peak hip external rotation moment during walking in individuals with flat-feet. The subtotal effect of the applied FO fabrication methods was calculated for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 29**

Authors from one study 19 reported the effect of FO application on mean rearfoot eversion and showed significant differences between the customized FOs and control conditions (large SMDs=-3.01, 95% CI -4.24, -1.78). The findings indicated that the mean rearfoot eversion was 1.62° (95% CI -2.04, -1.20) smaller in FO 19. The rearfoot joint excursion in sagittal and horizontal planes was assessed in one study of moderate methodological quality 10. No significant differences were found between customized FOs and control for rearfoot plantarflexion/dorsiflexion and internal/external rotation 10 (Table 1).

Only one study reported the effects of FO application on mean ankle angle in the sagittal plane 19 and joint excursion in frontal and horizontal planes 10 and found no significant difference (p>0.05) between the customized FO and control conditions for these parameters (Table 4).

Another study examined the effects of FO application on knee joint excursion 10 in frontal and horizontal planes and found no significant difference (p>0.05) between the customized FO and control conditions for these parameters (Table 4).

Effects of FO application on hip joint excursion 10 in frontal and horizontal planes were reported in one study. No significant differences were found between customized FOs and controls for these variables (Table 4).

**Appendix 30**

Appendix. Table 4. Summary of the statistical analyses on the effects of FO application on kinematics explored in single studies

|  |  |  |  |
| --- | --- | --- | --- |
| Outcome measures | Included study, quality (methodological), and sample size (n) | p value | Effect size (95% CI) |
| Rearfoot | | | |
| Mean eversion angle | Dedieu et al (2013) 19, MQ, n=12 | **< 0.0001** | SMDs **-3.01 [-4.24, -1.78]** |
| Joint excursion dorsi/plantarflexion | Permsombat and Pensri (2021) 10, MQ, n=13 | 0.32 | SMDs 1.00 [-0.97, 2.97] |
| Joint excursion internal/external | Permsombat and Pensri (2021) 10, MQ, n=13 | 0.58 | SMDs -0.50 [-2.27, 1.27] |
| Peak rearfoot dorsiflexion | Kosonen et al (2017) 6, HQ, n=11 | 0.13 | SMDs -0.66 [-1.53, 0.20] |
| Peak external rotation |  |  |  |
| Ankle | | | |
| Mean dorsi/plantarflexion | Dedieu et al (2013) 19, MQ, n=12 | 0.78 | SMDs 0.11 [-0.69, 0.91] |
| Joint excursion eversion/inversion | Permsombat and Pensri (2021) 10, MQ, n=13 | 0.72 | SMD**s** 0.50 [-2.19, 3.19] |
| Joint excursion internal/external | Permsombat and Pensri (2021) 10, MQ, n=13 | 0.45 | SMDs -0.80 [-2.89, 1.29] |
| Knee |  |  |  |
| Joint excursion abduction/adduction | Permsombat and Pensri (2021) 10, MQ, n=13 | 0.07 | SMDs 1.00 [-0.08, 2.08] |
| Joint excursion inter/external rotation | Permsombat and Pensri (2021) 10, MQ, n=13 | 0.73 | SMDs -0.30 [-1.99, 1.39] |
| Hip | | | |
| Joint excursion abduction/adduction | Permsombat and Pensri (2021) 10, MQ, n=13 | 0.69 | SMDs 0.40 [-1.54, 2.34] |
| Joint excursion internal/external rotation | Permsombat and Pensri (2021) 10, MQ, n=13 | 0.92 | SMDs -0.10 [-2.12, 1.92] |

FO: foot orthosis; HQ: High quality; MQ: Moderate quality; CI: Confidence interval. As an effect size measure, the standardized mean difference (SMDs) was used. A negative value shows an “increase”, and a positive value shows a “decrease” for that parameter during wearing orthosis compared to no orthosis.

Bold numbers indicate significance at P value < 0.05.

**Appendix 31**

Authors from one study 14 reported the effects of FO application on peak ankle plantarflexion, dorsiflexion, inversion, eversion, and internal and external moments in body weight times the body height (BW\*BH) and indicated a significant difference between prefabricated FOs and controls for peak inversion and external rotation (Table 5). Another study used customized FOs 12 and reported peak ankle dorsiflexion moment in Nm/kg. The results showed no significant difference between conditions (Table 5).

Peng and colleagues 14 assessed the effects of FO application on peak knee flexion, extension, abduction, and internal and external rotation moment and indicated no significant difference between prefabricated FOs and controls (Table 5). Prachgosin et al 18 studied the effects of FO application on peak knee extension moments during walking using customized and prefabricated FOs. The analyses did not reveal any significant differences between study conditions (Table 5).

Authors from another study assessed the effects of FO application on peak hip flexion, extension, abduction, and internal and external rotation moment 14, and found no significant difference and limited evidence for prefabricated FOs versus control (Table 5).

Appendix. Table 5.

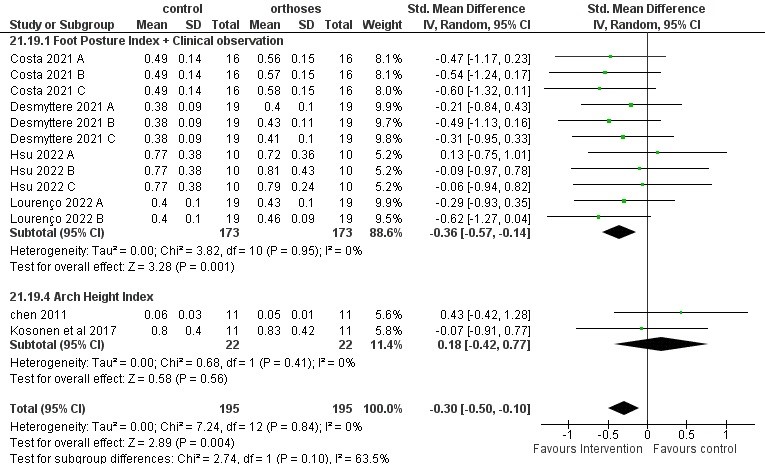
Summary of the statistical analyses on the effects of FO application on kinetics explored in single studies

|  |  |  |  |
| --- | --- | --- | --- |
| Outcome measure | Included study, quality [methodological], and sample size (n) | p value | Effect size (95% CI) |
| Rearfoot |  |  |  |
|  |  |  |  |
| Ankle |  |  |  |
| Peak dorsiflexion moment | Peng et al 2020 14, HQ, n=15 | 0.56 | SMDs 0.21 [-0.50, 0.93] |
| Peak plantar moment | Peng et al 2020 14, HQ, n=15 | 0.56 | SMDs -0.21 [-0.93, 0.50] |
| Peak eversion moment | Peng et al 2020 14, HQ, n=15 | 0.05 | SMDs 0.73 [-0.01, 1.47] |
| Peak inversion moment | Peng et al 2020 14, HQ, n=15 | **0.01** | SMDs **-0.97 [-1.74, -0.21]** |
| Peak internal moment | Peng et al 2020 14, HQ, n=15 | 0.45 | SMDs -0.28 [-0.99, 0.44] |
| Peak external moment | Peng et al 2020 14, HQ, n=15 | **0.01** | SMDs **-0.97 [-1.74, -0.21]** |
| Peak dorsiflexion moment | Chen et al 2010 12, HQ, n=11 | **0.57** | SMDs -0.24 [-1.08, 0.60] |
| Knee |  |  |  |
| peak extension moment | Prachgosin et al 2017, HQ, n=7 | 0.83 | SMDs -0.11 [-1.16, 0.93] |
| Peak flexion moment | Peng et al 2020 14, HQ, n=15 | 1.00 | SMDs 0.00 [-0.72, 0.72] |
| Peak extension moment | Peng et al 2020 14, HQ, n=15 | 1.00 | SMDs 0.00 [-0.72, 0.72] |
| Peak adduction moment | Peng et al 2020 14, HQ, n=15 | 0.19 | SMDs -0.49 [-1.21, 0.24] |
| Peak internal moment | Peng et al 2020 14, HQ, n=15 | 1.00 | SMDs 0.00 [-0.72, 0.72] |
| Peak external moment | Peng et al 2020 14, HQ, n=15 | 1.00 | SMDs 0.00 [-0.72, 0.72] |
| Hip |  |  |  |
| Peak flexion moment | Peng et al 2020 14, HQ, n=15 | 0.63 | SMDs -0.18 [-0.89, 0.54] |
| Peak extension moment | Peng et al 2020 14, HQ, n=15 | 0.54 | SMDs -0.23 [-0.94, 0.49] |
| Peak adduction moment | Peng et al 2020 14, HQ, n=15 | 0.58 | SMDs 0.20 [-0.51, 0.92] |
| Peak internal moment | Peng et al 2020 14, HQ, n=15 | 1.00 | SMDs 0.00 [-0.72, 0.72] |
| Peak external moment | Peng et al 2020 14, HQ, n=15 | 0.30 | SMDs -0.38 [-1.10, 0.34] |

FO: foot orthosis; HQ: High quality; MQ: Moderate quality; CI: Confidence interval. Effect size is standardized mean difference (SMDs). A negative value shows an “increase”, and a positive value shows a “decrease” for that parameter during the application of foot orthoses compared to no orthosis.

Bold numbers indicate significance p values (p < 0.05).

**Appendix 32**



**Appendix 32.** Forest plot illustrating the effects of foot orthoses application (intervention) versus control on the peak knee adduction moment during walking in individuals with flat-feet. The subgroup effect with regards to the methodological approach for flat-feet assessment was computed for each parameter and the total effect as standardized mean difference (95% CI). SD: Standard deviation; Std: Standardized; CI: Confidence interval.

**Appendix 33**

Clinical implications

This meta-analysis revealed a lower peak rearfoot eversion angle (~ 1.74°) when using FOs compared to control. The association of kinematic changes with clinical benefits, especially from midfoot and forefoot control, is mentioned in only one study 20. Since the lower limb act as a closed kinematic chain, significant angular changes in the ankle joint are translated to more proximal joints 21,22. Although FOs are prescribed to alter foot abnormality in individuals with flat-feet, they may affect the mechanics of the more proximal joints 4,21,22. Indeed, there is evidence that the application of FOs improves knee and pelvic angles in the sagittal plane during the stance phase of walking 21,22. Park et al. 21,22 suggested that the joint modifications were due to the rearfoot inversion enabled by a lower plantar and fascia muscle tension. However, there is preliminary evidence that medially posted FOs may have adverse effects in the form of greater knee adduction moments 4. Indeed, Telfer et al found that a lower rearfoot eversion, induced by medially posted FO, was not only associated with a lower rearfoot eversion moment but also a greater knee adduction moment 4. Since greater moments have been associated with the development and progression of medial compartment knee osteoarthritis 23, medially posted FOs should be prescribed with caution. Moreover, a dose-response effect exists between the level of posting and the ankle and knee joint biomechanics, as a higher medially posted device results in a lower rearfoot eversion and a greater knee adduction moment 4. In contrast, Cheung et al. 24 reported that custom-made FOs are more effective (produce lower peak rearfoot eversion angles) than prefabricated FOs. The authors argued that the personalized device enables adaptations through biomechanical changes which are more effective in the correction of the foot posture. Indeed, a FO with a contoured medial arch has been shown to prevent the deformation of the medial longitudinal arch and it may lead to lower foot pronation during walking 4. Accordingly, new technologies, such as additive manufacturing (i.e., 3D printing), must be considered as they allow the production of custom shapes and geometries which is impossible through traditional fabrication techniques. Therefore, 3D printing appears to allow new options for individualized FO fabrication 4.

Based on the findings of our meta-analysis, the application of both, customized and prefabricated FOs resulted in reduced rearfoot eversion angles compared to control. Furthermore, the subgroup comparisons suggested that customized FOs were more effective than prefabricated orthoses in reducing rearfoot eversion. A likely reason for this outcome is that the engineering of customized FOs involves more professional and sophisticated input with regards to the foot posture of the individual 24.

**Appendix 34**

Limitations and methodological considerations

Due to a limited number of studies, we were unable to examine and aggregate the effects of FO application on muscular activity and plantar pressure. These neuromuscular or pressure-sensitive outcome measures would additionally provide information on the underlying mechanisms responsible for FO-related changes in foot posture. Another limitation of this systematic review is that we only examined the effects of FO application on walking mechanics but not running and standing mechanics. Again, the number of available studies did not allow to meta-analyze these experimental conditions. Of note, greater foot pronation and ground reaction forces have been reported during running compared with walking which is why a transfer from one physical activity mode (walking) to the other (running) appears possible 25,26.

Another limitation is that the materials used for the FOs were not quantitatively considered in our meta-analysis. Instead, we reported qualitative information in regards of FO material for each study in Table 2.

We further noted that the authors from the included studies applied different types of foot posture assessment methods. We tried to deal with this potential cause of bias by reporting our findings in the context of the respective foot posture method. Notably, we observed greater effects of FO application on walking mechanics in the studies that used the FPI-6 to measure foot posture. A previous study reported that the FPI-6 method is a highly reliable (intraclass correlation coefficient [ICC] = 0.93) approach to be used for the assessment of foot posture. In contrast, navicular drop method appears to be less reliable with an ICC=0.40 27.

Our meta-analysis included studies that assessed the effects of FO application on walking kinematics and kinetics while walking barefoot, with sandals, or in standardized shoes. This could have affected the outcomes of our meta-analysis as well.

Finally, several included studies (n=11) did not compute a priori sample size calculations. Therefore, it is attainable that some were underpowered to detect actual FO effects.

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