FLATFOOT AND CONSERVATIVE TREATMENTS IN PHYSICALLY ACTIVE ADULTS. A SYSTEMATIC REVIEW

PIE PLANO Y TRATAMIENTOS CONSERVADORES EN ADULTOS FISICAMENTE ACTIVOS. UNA REVISIÓN SISTEMÁTICA

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ABSTRACT

The flatfoot term is used to describe any abnormality that causes the collapse of the medial longitudinal arch of the foot, when it is symptomatic it conditions the degree, type and quality of physical activity practiced in an adult. We propose to review the existing conservative treatments for flatfoot in young and middle-aged adults. A systematic review of the published scientific literature on flatfoot and conservative treatments was carried out. For its preparation, the guidelines of the PRISMA declaration have been followed. The conservative treatments used for flatfoot are applied uniquely or in combination, these include strengthening exercises, stretching, wear orthotics devices, taping application, footwear modification and electrical stimulation. Conservative treatment studies in young and middle-aged adults with symptomatic flatfoot are required to evaluate the short- and long-term effect of current protocols in populations with different levels of physical fitness.

KEY WORDS: planovalgus, physical activity, sport, flatfoot exercise, short foot exercise

RESUMEN

El término pie plano es utilizado para describir cualquier anormalidad que causa el colapso del arco longitudinal medial del pie, cuando es sintomático condiciona el grado, tipo y calidad de actividad física que practique un adulto. Como objetivo nos planteamos revisar los tratamientos conservadores existentes para el pie plano en adultos jóvenes y de mediana edad. Siguiendo las directrices de la declaración PRISMA, se realizó una revisión sistemática de la literatura científica publicada sobre el pie plano y tratamientos conservadores. Los tratamientos conservadores para el pie plano son aplicados de manera aislada o en combinación, estos incluyen ejercicios de fortalecimiento, de estiramientos, uso de ortesis, aplicación de vendaje, modificación del calzado y estimulación eléctrica. Son requeridos estudios de tratamientos conservadores en adultos jóvenes y de mediana edad con pie plano sintomático que evalúen el efecto a corto y largo plazo de los actuales protocolos en poblaciones con diferente nivel de condición física.

PALABRAS CLAVE: plano valgo, actividad física, deporte, ejercicios pie plano, ejercicio de pie corto

INTRODUCTION

The term flatfoot is used to describe any abnormality that causes the collapse of the medial longitudinal arch of the foot (1-3). Some of the most used terms to describe flaffoot are pes planus, planovalgus, calcaneo-valgus, and fallen arches. Flatfeet can cause severe symptoms or be asymptomatic (4). Currently, flatfoot is a normal variant if its function and capacity is normal and without any symptoms (4, 5). Flatfoot is a complex condition involving changes in the forefoot, midfoot, and hindfoot. The term flatfoot is a description that encompasses any process that relaxes the stability of the bony arch of the foot, which can be developmental (expressed in childhood) or acquired (expressed during adulthood) (2), or in the adults as a residual deformity of the development flatfoot during childhood (4).

Developmental flatfoot may cause symptomatic or asymptomatic flexible flatfoot, rigid flatfoot associated with a tarsal coalition, or flatfoot associated with an accessory navicular bone, or residual of congenital vertical talus or clubfoot, and generalized soft tissue or ligamentous laxity (Ehlers-Danlos, Marfan's syndrome). Acquired flatfoot causes posterior tibial tendon (PTT) dysfunction, which may cause a rupture or a laceration, midfoot laxity, hindfoot external rotation, tight triceps suralis, or isolated gastrocnemius tightness, forefoot abduction, talus subluxation, traumatic deformities (talo-navicular joint or calcaneal injuries), osteoarthritis, ruptures of the plantar fascia, Charcot´s foot and neuromuscular imbalances (2, 4).

As previously described, in adults, flatfoot can be categorized as a residual flatfoot deformity during development or as an acquired flatfoot. However, it is difficult to define the exact cause of flatfoot in each situation because multiple factors are involved that may contribute to the deformity (4). One of the main factors that have been associated with flatfoot deformity is PTT dysfunction, however, PTT is considered as part of the problem rather than causing the PTT deformity (2). The sequence of events leading to a flatfoot deformity is still not fully understood, it is likely that many forces combine to exceed the physiological limiting values of the midfoot (2), this combination of force could explain the difficulty of the analysis, hindering the best treatment (5). To explain this event, it has been suggested that tight heel tendon increases the upward leverage on the calcaneus, increasing tension on the plantar fascia and plantar ligaments, with pre-existing midfoot laxity this may cause attenuation and possible rupture of the plantar and medial structures around the medial longitudinal arch (2). For several years now, attempts have been made to identify morphological predispositions that may lead to an increased risk of flatfoot, such as changes in the talar morphology, or a pre-existing flexible flatfoot (6).

Although flatfoot is an issue that affects up to 25% of the general population (3), and it is a syndrome of multiple combinations that make its analysis and therefore its treatment difficult (5), when it is symptomatic it determines the degree, type and quality of physical activity practiced by the adult, it even could lead to abandoning of the practice of physical activity, with negative repercussions on health, we have found few review articles on its conservative treatment (7, 8). Therefore, it is very important that the professional in charge of the maintenance and recovery of physical health knows the existing evidence on the conservative treatment of flatfoot.

Derived from the search for scientific papers in reference databases such as PudMed on the treatment of flatfoot in middle-aged adults (18-64 years) physically active or athletes, we found no scientific evidence of controlled clinical trials addressing this type of population with the flatfoot condition.

The few studies carried out with athletes with flatfoot are case study, in this sense, a young adult basketball player presented a bilateral tarsal coalition, who, after several conservative therapies, underwent another rehabilitation program focused on joint mobilization, soft tissue massage and muscle mobility, hydrotherapy and thermotherapy, after 14 weeks, pain decreased from 9 to 3 on the visual analogue scale allowing him to finish the season (9). These results are interesting; however, the problem remains with the patient, surgery is probably imminent sooner or later.

Conservative treatments in the short term are probably the best option, the benefit in reducing pain and function in the long term in competitive athletes being less clear. Another case study with an adolescent soccer player after a right medial foot trauma resulted in foot deformity, with hindfoot valgus, forefoot abduction, and inability to lift the heel with the right leg due to pain. After undergoing a 4-day conservative treatment for 4 weeks consisting of an Active Release Technique® which consists of applying digital tension along the tissue fibers in the sensitive areas of adhered fibers caused by trauma, being the patient instructed to actively move tissue fibers at the lesion site from a shortened to an elongated position. Additionally, during this time, twice a day for 6 days a week, the patient performed 3 types of rehabilitation exercises consisting of heel raises and standing on the toes, proprioception with bridges on a pilates ball with one leg support, single leg squats, abduction, adduction, front and rear hip exercises and lateral displacement with an elastic band on the ankles, these eccentric and concentric exercises designed to strengthen the posterior tibial muscle and balance of the lower limbs. After 4 weeks of treatment the subject was able to return to activity without any pain or weakness (10). In our knowledge, there is no article on conservative treatment in middle-aged adult competitive athletes with flatfoot.

In the general population, there are numerous treatments for pronated feet, the most widely used being custom foot orthoses, external shoe modifications, strength exercises for the musculature involved, or even surgery (11). However, bone fusions have been associated with poor results, therefore, there is currently a trend and recommendation for reconstruction in early stages before the onset of arthritis (1, 5), when it affects only one joint and, specially, saving the tibiotalar joint (5). In this sense, surgical interventions are justified when conservative treatments fail in both acquired flatfoot and flexible flatfoot with the aim of maintaining or restoring the shape of the medial arch, these interventions use arthrodesis and non-arthrodesis procedures, arthrodesis procedures should be the last resort when all other surgical treatments have failed (12).

Even so, non-operative management through conservative treatment is the first line of treatment, reporting a success of 67% to 90% (1, 7, 12, 13). Conservative treatments include immobilization for 6-8 weeks, use of nonsteroidal anti-inflammatory drugs, orthotics, insoles, physical therapy (1, 5, 7, 12), and stretching (e.g., Achilles tendon stretching) (12). One of the most widely prescribed and considered most effective conservative treatments for flatfoot is the use of an orthopedic boot for 6 weeks, but with poor long-term results, eventually requiring surgery (9). Therefore, according to Tang et al. (3), we consider that there are still few publications or guidelines on the primary care treatment of flatfoot in adults. Therefore, we have established as objective to review the existing conservative treatments for flatfoot in young and middle-aged adults.

MATERIAL AND METHODS

The systematic search was carried out in October 2021, in PubMed and ScienceDirect, without time restriction, only studies with comparison between groups were included, the filters *'clinical trials*' and '*adults*' *'young adults*' and *'middle-aged'* were added. The combination of terms that yielded the best results according to the study variables of this review in both search engines was: (flatfoot OR pes planus OR planovalgus OR calcaneo-valgus) AND (conservative treatment OR therapy OR rehabilitation OR exercise) AND ((clinicalstudy [Filter]) AND (adult[Filter] OR middleaged[Filter] OR youngadult[Filter])). We obtained 98 results in PubMed and 67 in ScienceDirect (Figure 1). Before proceeding to the selection of articles, the inclusion and exclusion criteria were defined.

Inclusion criteria

- Only clinical trials were included.
- Adults, young adults, and middle-aged adults (18-64 years).
- Subjects with flatfoot determined by the different valid methodologies for its diagnosis such as foot posture index or navicular drop.
- Articles in English or Spanish language.

Exclusion criteria

- Case studies, reviews, books, manuals, conference proceedings or symposia.
- Comorbidities to flatfoot such as peripheral and systemic vascular disease, neurological diseases, peripheral neuropathy, or other foot anomalies affecting locomotion or impeding foot mobility.
- Subjects with surgical treatment of the foot or ankle.
- Children or older adults.
- Pregnant women.
- Subjects with any type of cognitive or physical disability.

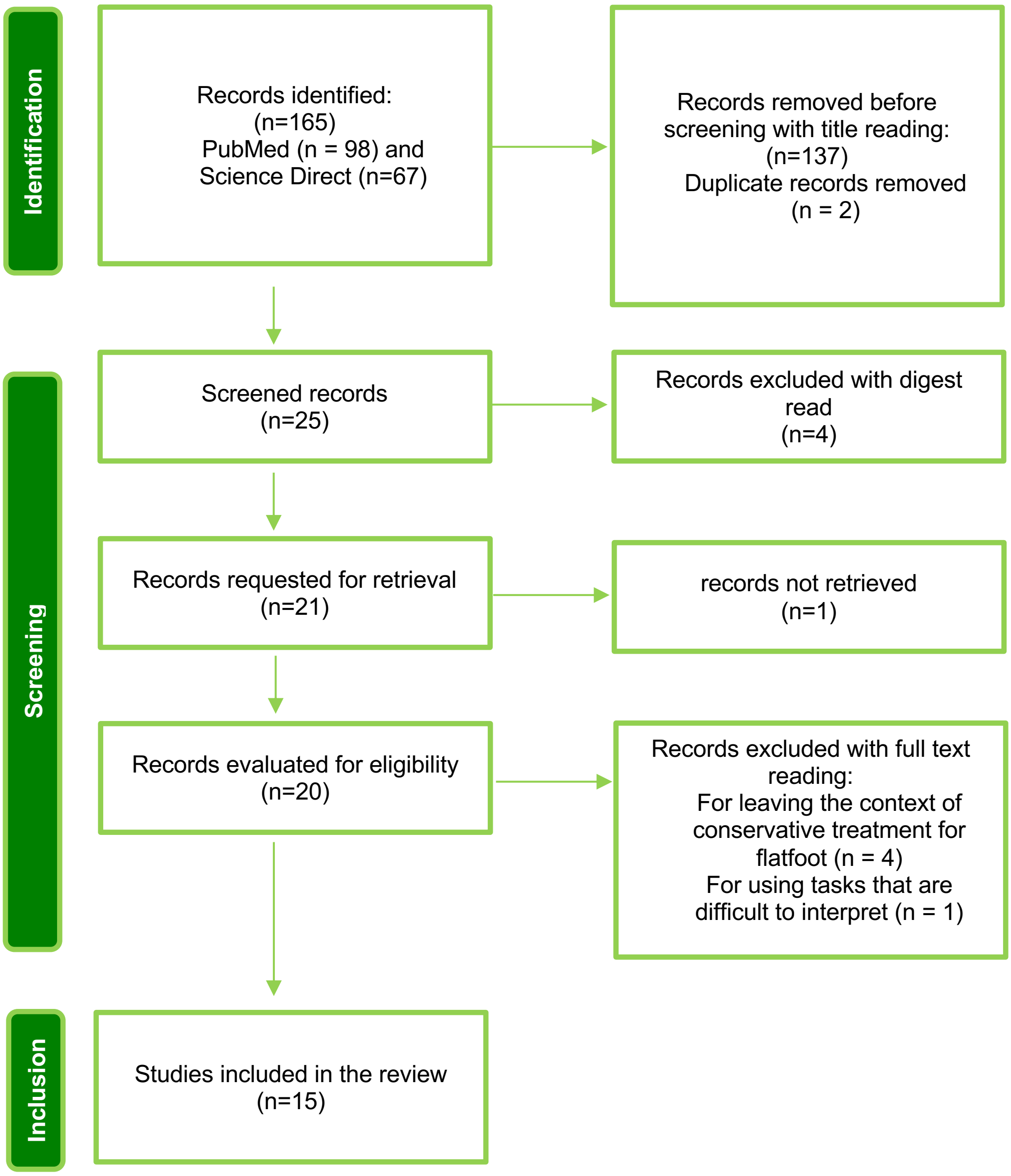

Figure 1. PRISMA flowchart of search strategy (15).

Considering these inclusion and exclusion criteria, with the reading of the titles obtained in the systematic review, 137 records were eliminated, in addition, another 2 were discarded because they were duplicated in both databases, leaving 25 potential articles for this review. After reading the abstract, another 4 articles were eliminated due to the objective of the study, or the variables declared in the methodology. Twenty articles were retrieved in full text (1 could not be retrieved by any means, institutional library, personal mail to the author for correspondence or different search engines). Of the full-text documents, during the reading, 4 articles were discarded because they considered the treatment of flatfoot as secondary to the main objective of the study, such as analysis of the effect of footwear, orthoses, exercises or bandages on protocols or biomechanical techniques, not on the patient. One article was discarded due to difficult understanding of the methodological design and because it did not state the method and values of the degree of flatfoot of the patients. Finally, 15 articles met the inclusion criteria and were selected for this systematic review. All articles in this review are clinical trials that have patients or subjects with flatfoot evaluated with a valid methodology that assesses the effect of different existing or novel conservative treatments on flatfoot. Finally, Google Scholar was used with different combinations of the previously mentioned search terms to check any possible article that could be included in this review. This search did not reveal any studies that met the above criteria or that are not already included.

Bias assessment

The Measurement to Evaluate Systematic Reviews tool was used to assess the quality of the articles included in the review (16) (https://amstar.ca/Amstar_Checklist.php). On the other hand, 3 researchers independently carried out the process of the systematic search, selection, and analysis process of the included studies.

RESULTS

Conservative treatments used for flatfoot are applied in isolation or in combination, these include strengthening exercises, stretching, orthotics, taping, footwear modification, and electrical stimulation (Table 1). Below, we describe the results of the review by type of treatment.

From our review, two studies analyzed the effect of foot muscle strengthening exercises (11, 17) as the only treatment. In this sense, Sánchez-Rodríguez et al. (11) analyzed the influence of a 9-week program to improve the strength of the intrinsic and extrinsic muscles of the foot and the core in healthy subjects with prone feet, they performed strengthening and proprioception exercises, finding that the exercises contribute to improving the foot posture index.

On the other hand, Unver et al. (17) in a 6-week program studied the effects of short foot exercises on navicular drop, foot posture, pain, disability, and plantar pressures in subjects with flatfoot. The short foot exercise showed improvements in all the variables studied.

Other studies, in addition to analyzing the effect of exercise on the foot musculature, include other variables such as stretching (18), orthotics (19-21), feedback (22, 23), electrical stimulation (23, 24) and footwear (25).

Alam et al. (18) analyzed the effects of selective posterior tibialis (PT) strengthening and iliopsoas stretching on navicular drop, dynamic balance, and lower extremity muscle activity in young adults with pronated feet in collegiate students, after a 6-week training program of conventional exercises for flatfoot such as towel curls plus PT strengthening exercise and iliopsoas stretching, dynamic balance and muscle activation are improved, suggesting that to improve results In the treatment of flatfoot, conventional exercises should include strengthening of the PT and stretching of the iliopsoas.

Regarding orthoses for flatfoot, Jung et al. (19) examined the effects of combining the use of an orthosis and the short foot exercise on the cross-sectional area of the abductor hallucis muscle and the strength of the flexor hallucis in subjects with flatfoot, the intervention lasted 8 weeks, they found that combining foot orthoses and short foot exercise is more effective than wearing only orthoses for abductor hallicus muscle cross-sectional area enlargement and flexor hallucis strength.

In this sense, Kulig et al. (20) studied the influence of footwear with a foot orthosis on the activation of the PT in people with flatfoot. The participating subjects performed a foot adduction exercise, using footwear and orthosis, they reported that barefoot activates others lower leg muscles in addition to PT, with shoes and foot orthoses 5 of the 6 participants activated only PT and, furthermore, PT activation was greater than when performing the adduction exercises barefoot.

Foot exercises in addition to orthoses and footwear have been combined with other modalities, in this regard Namsawang et al. (24) investigated the effects of short-foot exercise with neuromuscular electrical stimulation on navicular height, cross-sectional area, and abductor hallucis muscle activity in subjects with flexible flatfeet. Combining neuromuscular electrical stimulation with short-foot exercise had no effect on changing navicular height or increasing abductor hallucis muscle cross-sectional area but did increase its muscle contractile activity.

In a similar context, Okamura et al. (23) evaluated the effects of performing the short-foot exercise on the static alignment of the foot, as well as its kinematics during gait in university students with flatfoot, in this work, the participants performed an 8-week unilateral short-foot exercise intervention, progressively increasing the intensity of the exercise in the development of the intervention. EMG biofeedback was used throughout the short-foot exercise session of 5 minutes, where the level of muscle activity of the abductor hallucis was transmitted to the participant via a five-light indicator, simultaneously, EMG-controlled electrical stimulation was provided. At the end of the intervention, foot stance index scores with respect to calcaneal inversion/eversion improved, in addition, the time required for navicular height to reach the minimum value decreased.

Kim and Lee (22) analyzed the effects of short-foot exercise using visual feedback on static balance and proximal joint function in subjects with flexible flatfoot, to perform visual feedback during short-foot exercise, a custom air-cushioned insole, intervention lasted 5 weeks, short-foot exercise with visual feedback improved static balance and the accuracy of knee joint movements in closed kinetic chain exercise in flatfeet subjects, but not in the open kinetic chain exercise.

Taspinar et al. (25) determined changes in plantar pressure and the effects of wearing internal and external shoe modifications and exercise on foot pain, disability, and consequently function and quality of life in patients with flatfoot. Each patient had the opportunity to choose the treatment 1) footwear with internal modification, using more resistant polyform material according to the measurements of the foot, and with transverse arch support, 2) footwear with external modification, with a circular toe cap that covered the entire foot and was comfortable enough for daily use, it was adapted with Thomas's heel made of polyurethane-derived material, and 3) perform exercises for the foot, the routine consisted of a foot strengthening exercise for the invertor and intrinsic muscles and stretching of the gastrocnemius and evertors, the intervention lasted 3 months. Regardless of treatment, perception of foot pain, foot function index, and quality of life improved in all study groups; however, the greatest improvement was in patients treated with internal shoe modification, followed by the external modification of the footwear and later by the exercises for the foot. No differences were observed in terms of patient satisfaction for footwear with internal or external modification. There were no differences in the static and dynamic pedobarographic studies at the end of the intervention between the treatments used.

Yurt et al. (21) compared the effects of a computer-aided design/computer-aided manufacturing insole and a conventional versus a sham insole on pain and health-related quality of life in patients with painful flatfoot. Patients with flexible flatfoot pain, used either design-assisted, conventional, or sham insoles and performed gastrocnemius stretching exercises, tibialis posterior strengthening and intrinsic muscles for 2 months. Reported that the computer aided design/manufacturing insole computer-assisted and conventional insoles together with an exercise program are more effective in controlling flexible flatfoot pain compared to just performing the exercise. Physical health improved at the end of the intervention, but there were no differences between the type of insole used.

Franettovich et al. (26) wondered if taping and an anti-pronation support brace would reduce the demands on the muscular system (by providing external support) and thus reduce the activity of the lower leg muscles, particularly the posterior tibialis, during walking in individuals with flatfoot, to evaluate this hypothesis they used an increased low-Dye tape type bandage and a semi-rigid commercial ankle brace, first they were asked to walk barefoot, then they randomly walked with the low-Dye bandage raised or with anklet. They reported that the augmented low-Dye taping and the Push Aequi semi-rigid commercial ankle brace may have clinical utility in reducing tibialis anterior muscle activity. posterior tibial and peroneus longus during walking. However, if the tibialis posterior is specifically targeted, the taping has a significantly greater effect in reducing the activity of this muscle.

Hurd et al. (27) set out to quantify the effectiveness of a new standard orthosis in normalizing forefoot and rearfoot mechanics relative to an existing standard orthosis and a motion-controlled running shoe, in this study involved subjects with flexible flatfoot secondary to forefoot uncompensated varus had to be asymptomatic and able to run at least 1 mile without pain and all self-reported as recreational athletes. They walked and ran wearing 1) the New Balance 1122 motion-control running shoe, 2) wearing that shoe in conjunction with the newer commercially available orthotic insole (Hickory brand, for flatfoot), and 3) with the shoe and with the semi-rigid insole existing on the market with arch support (Iplus Footcare brand). When walking the new Hickory insole and motion-control shoe placed the forefoot in a position with less eversion than the Implus Footcare insole. Forefoot jogging kinematics were similar with both insoles, as was hindfoot movement when walking or jogging. But hindfoot eversion time was shorter with the Hickory insole when walking or jogging.

Jung et al. (28) examined the effects of the standing wall stretch with and without medial arch support on displacement of the medial gastrocnemius muscle-tendinous junction, hindfoot angle, and navicular height in neutral aligned and flatfoot subjects. The gastrocnemius stretch was performed standing, with wall support in a preset area in condition with and without medial longitudinal arch support on displacement of the gastrocnemius myotendinous junction. Stretch duration was 30 s, performed once with and without medial arch support, standing wall stretch with medial arch support reported to maintain subtalar joint in neutral position and increase gastrocnemius length in subjects with flatfoot, highlighting the importance of using a medial arch support to make stretching the gastrocnemius more efficient in subjects with flatfoot.

Lee et al. (29) investigated the two currently used orthopedic treatments for Achilles tendinopathy that is a custom arch support orthosis and orthopedic heel lift for reduction of Achilles tendon loading and index in flatfoot amateur runners, the participants walked or ran without orthoses, with the orthotic heel lift, and with the custom arch support orthosis, found that both orthotic treatments used reduced peak Achilles tendon load and index compared to not wearing an orthosis.

Tang et al. (30) evaluated the therapeutic effect of total contact insole with forefoot medial post orthosis in patients with flexible flatfoot. Subjects with symptoms of foot or leg pain with flexible flatfoot participated in the study, with the customized total contact insole with forefoot medial posting insole, each subject walked at a self-imposed speed that was comfortable under three conditions 1) walking barefoot, 2) with athletic shoes and the customized forefoot medial post total-contact insole and 3) with athletic shoes. The use of a total contact insole with a medial forefoot post for patients with flexible flatfoot decreased the maximum valgus movement of the hindfoot, pressure was reduced in critical areas of the foot and the foot was repositioned in a more neutral biomechanical condition.

Table 1. Characteristics of the reviewed studies.

Author	Type of treatment	Sample	Procedures	Results
Alam et al. (18)	Strengthening and stretching exercises	28 collegiate students aged 18-26 (14 EG stretching and strengthening group; 14 CG conventional exercise group) with bilateral foot pronation and iliopsoas tension	6-week training program in both groups. The CG performed the towel crul exercise, the EG, in addition to the towel crul, performed an exercise to strengthen the PT muscle and stretch the iliopsoas. The strengthening and stretching exercises were performed 3 times a week and the towel crul daily	↑ AT and AbdH muscle activity, ↑ posterolateral foot activity, ↑ dynamic balance. Significant interactions group x time for the navicular drop, in all components of dynamic balance and in the activity of AT and AbdH
Franettovich et al. (26)	Augmented low-Dye taping and Push Aequi commercial ankle brace	27 adult subjects with flatfoot (13 M and 14 W) between 18-37 years of age.	They used 2 types of external anti-pronation ankle support: bandage with increased low-dye tape and a commercial semi-rigid Push Aequi ankle brace. They were asked to walk barefoot, with the augmented low-Dye taping or with the ankle brace. Each condition (barefoot, anklet or bandage) was performed 6 times	With respect to walking barefoot, the maximum EMG amplitude of the PT ↓ 22% and 33% with the ankle brace and taping (respectively); for the PL, the maximum amplitude ↓ 34% and 30% and for the AT 19% and 13% with the ankle brace and taping (respectively). EMG amplitude was found for PT and AT with the 2 types of support compared to barefoot. The effect of the taping and the ankle brace was only different for the maximum EMG amplitude of the PT, being reduced by 15% with the taping compared to the ankle brace

Author	Type of treatment	Sample	Procedures	Results
Hurd et al. (27)	Motion Control Shoes and insoles	15 subjects self-reported as recreational athletes (4 M and 11 W; mean age: 34, range, 10-51; ± 10 years) with flexible flatfoot secondary to uncompensated forefoot varus (≥ 5 degrees). Subjects had to be able to run at least 1 mile without pain	They performed 3 repetitions of walking and running wearing: 1) New Balance 1122 motion-control running shoe, 2) wearing those shoes in conjunction with a new commercially available standard orthotic insole (Hickory brand), and 3) wearing the running shoe with the existing semi-rigid insole on the market with arch support (SofSole, Implus Footcare). Everything was done in one session	The Hickory insole with the motion-control running shoe placed the forefoot in a position with less eversion when walking than the standard SofSole insole. There were no differences in forefoot kinematics when jogging, nor were there differences in hindfoot movement when walking or jogging. When walking or jogging, hindfoot eversion time was ↓ with the Hickory insole compared to running shoe and the SofSole insole
Jung et al. (28)	Gastrocnemius stretch	15 subjects with neutral foot and 15 with flatfoot (20 M and 10 W), age 24.0 ± 3.7 years	The gastrocnemius stretch was performed standing, with wall support in a preset area in condition with and without MLA support over the displacement of the gastrocnemius myotendinous junction (DMTJ). Stretch duration was 30 s, performed once with and without medial arch support	Significant interactions of MLA support for DMTJ foot type, hindfoot angle, and navicular drop. Standing wall stretch with MLA support ↑ DMTJ compared with stretching without MLA support in neutral foot subjects (9.6 vs 10.5 mm) and in flatfoot subjects (10 vs 12.7 mm). When comparing without and with MLA support the difference in the DMTJ of the medial gastrocnemius was ↑↑↑ in subjects with flatfoot than in subjects with neutral foot
Jung et al. (19)	Foot orthotics and short foot exercise	28 subjects with flatfoot randomly assigned to the foot orthosis (FO) group, or the foot orthosis combined with short foot exercise (FOCSFE) group	Personalized orthoses for the 2 groups were used for 8 weeks in daily activities. FO group did not perform any foot and ankle exercises during the intervention. The FOCSFE group, in addition to using the orthoses, performed the short foot exercise. They performed 3 series of 5 reps of 5 s duration, 2 times/day, resting 2 min between series	Significant group-by-intervention interaction effects were observed on AbdH cross section and FH strength. AbdH muscle CSA and FH strength ↑↑↑ after intervention in both groups. The mean CSA of the AbdH muscle and FH strength was ↑ in FOCSFE subjects compared to FO subjects

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Author	Type of treatment	Sample	Procedures	Results
Kim and Lee (22)	Short foot exercise with visual feedback	Flexible flatfoot group: 15 subjects (8 M and 7 W; with more than 10 mm of navicular drop) of 22.0 ± 2.1 years of age and normal foot group: 15 subjects (7 M and 8 W; 5-9 mm of navicular drop) of 22.1 ± 1.5 years of age. No pain in feet	Visual feedback during the SFE was performed using a custom air-cushioned insole, starting each stage of the SFE with 20 mmHg air pressure from the insole. The SFE was divided into 5 stages, it was carried out 5 days/week, 20 min per session x 5 weeks, in each stage the MLA was held for 5 s and another 5 s of rest. Three sets were performed with 1 min rest between sets	There was a significant difference in static balance before and after the exercise in the flatfoot group, but not in the normal-footed group. Furthermore, in the flatfoot group, the accuracy of knee joint motions was significantly different between pre- and post-exercise in the closed chain but not in the open chain.
Kulig et al. (20)	Orthosis and posterior tibial activation exercise	Six healthy, pain-free adult subjects with an arch index at least 2 standard deviations below normative values participated in the study. The age was 25.0 ± 2.0 years	A barefoot adduction exercise session and another session with shoes and complete orthoses with control in the hindfoot and midfoot were performed. Baseline and post-exercise MRI were performed. Subjects completed 3 sets of 30 reps, with a 1-min rest between sets. The exercise consisted of adducting the foot in a closed kinetic chain	Barefoot, 5 of the 6 subjects activated other lower leg muscles in addition to the PT. When wearing the foot orthoses and shoes, 5 participants activated only PT. In addition, the activation of PT ↑ when the exercises were performed with shoes and orthoses compared to barefoot
Lee et al. (29)	Customized arch support orthotics and orthotic heel lift	12 recreational runners aged 25.3 ± 1.2 years with flatfoot (run at least once a week 11.8 ± 3.4 km/week), with excessive prone foot (FPI of 6-12) and with a pattern of hitting the hindfoot on landing	They were fitted with a custom arch support orthosis (CASO) and an orthopedic HL. Subsequently, the participants ran: (1) without orthosis, (2) with HL, and (3) with CASO. They performed 5 acceptable trials with each orthosis. Rested for 3 min between each type of orthosis	Participants who ran with CASO or HL ↓ ATL compared to running without orthoses. There was no difference between the 2 types of orthotics. Peak ATL was slightly lower with CASO. The ATL index with both orthoses (CASO and HL) was ↓ than barefoot running, but similar, although CASO showed a slightly lower load index than HL

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Author	Type of treatment	Sample	Procedures	Results
Namsawang et al. (24)	Short foot exercise with neuromuscular electrical stimulation	36 people with flexible flatfoot formed 2 groups of 18 subjects each. ExpG: SFE + NMES (20.1 ± 1.2 years of age; navicular height 32.5 ± 4.1 mm), CG: SFE + NMES placebo (19.7 ± 1.59 years of age; navicular height 32.7 ± 4.1 mm)	For the SFE, 30 reps/day were performed, with 5 s duration in each repetition. Then, the participants received the NMES treatment on the AbdH muscle using the bipolar technique with a high voltage pulsed current, the NMES sessions lasted 30 minutes, the intensity was adjusted to the maximum tolerance of the participant. Both techniques were performed on consecutive days (3 per week) for 4 weeks	No differences in the height of the navicular or the CSA of the AbdH between CG and ExpG, however, the activity of the AbdH ↑ in the ExpG (SFE = 73.9 ± 11.0% of the maximum voluntary isometric contraction [MVIC]; SFE+NMES = 81.4 ± 8.3% of MVIC). AbdH CSA showed ↑ after treatment in the SFE group with NMES (pretreatment = 218.6 ± 53.2 mm^2; posttreatment = 256.9 ± 70.5 mm^2)
Okamura et al. (23)	Short foot exercise, feedback and controlled electrical stimulation	Twenty university students participated, with a score ≥ 6 on the 6-point Foot Posture Index (FPI-6) on flatfoot alignment. Two groups were formed: CG (n=10, 8 W and 2 M; 20.2 ± 1.5 years; 9.0 ± 2.1 of FPI-6 and 10.9 ± 2.9 mm of navicular drop) and EG (n=10, 9 M and 1 H 19.7 ± 0.9 years; 9.7 ± 1.9 of FPI-6 and 12.5 ± 3.3 mm of navicular drop).	EG performed the unilateral SFE for 8 weeks, the CG did not receive any intervention. The SFE was performed for 5 s, without flexing the toe and/or lifting the foot off the ground. The difficulty of the SFE increased progressively. The SFE was performed using EMG biofeedback. Simultaneously, EMG controlled electrical stimulation was provided.	FPI-6 scores regarding calcaneal inversion/eversion improved. In addition, the time required for the height of the navicular to reach the minimum value ↓
Sanchez-Rodriguez et al. (11)	Strengthening exercises intrinsic and extrinsic muscles of the foot and core	36 healthy adults with pronated foot aged 18 to 40 years, 15 M and 21 W. Two groups were formed: ExpG: n=18, performed strength exercises; CG: performed daily activities	They performed 10 exercises: 1) walking on heels and forefoot; 2) walking on the lateral and medial edge of the foot; 3) pick up small objects with fingers; 4) inversion and eversion with elastic band; 5) hip abduction; 6) strength of the erector spinae; 7) abdominal strength; 8) abdominal oblique strength; 9) balance on an unstable base; 10) equilibrium on an unstable base with destabilization. Exercises were performed for 1.5 min per limb. Eighteen sessions of 40 min were carried out	After 9 weeks, the ExpG showed FPI ↓ from 8.1 ± 1.7 to 6.4 ± 2.1; the CG maintained the same score as before the intervention (FPI 8 ± 1.2)

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Author	Type of treatment	Sample	Procedures	Results
Tang et al. (30)	Full contact insole with medial forefoot support	10 subjects with symptoms of foot or leg pain with flexible flatfoot formed the flatfoot group and 15 subjects with normal foot participated in the CG. Age range 15-45 years. M and W participated	A customized total contact insole with forefoot medial posting (TCIFMP) orthosis was designed. Each subject was measured walking at a self-imposed speed that was comfortable under three conditions (walking: barefoot, with athletic shoes, and with the TCIFMP plus athletic shoes. A minimum of 3 repetitions were performed for each condition	The maximum pronation angle in the CG was 9.1 ± 2.1°, with a difference when walking barefoot (13.9 ± 5.1°), but not when wearing sports shoes (11.3 ± 3.5°). With the use of sports shoes and TCIFMP, the valgus angle tends to decrease more and is similar to subjects with normal feet (9.2 ± 2.7°). Foot pressure with the use of TCIFMP and sports shoes was reduced in hallux and heel areas compared to those who wore sports shoes only
Taspinar et al. (25)	Footwear with internal and external modification and foot exercises	60 patients with flatfoot (45 W and 15 M), between 15 and 65 years, formed 3 groups: 1: used footwear with internal modification; 2: used externally modified footwear; 3: performed exercises for the foot. Non-random group assignment	The patients freely chose the group. Group 1 used more resistant polyform material according to foot measurements and transverse arch support. Group 2 wore comfortable shoes for daily use with a circular toe that covered the entire foot and adapted the heel of Thomas. Group 3 performed at home exercises to strengthen the invertor, evertor and intrinsic muscles of the foot and stretching of the gastrocnemius muscles, they performed 6 exercises of 3 series of 10 reps 3 times/day	↓ foot pain, ↑ foot function index and quality of life in all study groups, the highest ↑↑↑ was observed in the group of patients with internally modified footwear, followed by the externally modified and shoe groups. exercise. Patient satisfaction was similar in the internal and external modification groups. The changes after the static and dynamic pedobarographic studies were not different between groups
Unver et al. (17)	Short foot exercises	41 participants 18-25 years of age with flatfoot according to the navicular drop test and FPI-6 were voluntarily assigned to either the short-foot exercises EG (n = 21) or the CG (n = 20)	They performed daily SFE for 6 weeks, 2 days/week under supervision and 5 days/week at home to strengthen intrinsic foot muscles. The elevation of the MLA in the SFE was maintained for 5 s in each repetition, 3 series of 15 reps/day were performed. The SFC started from a sitting position (week 1 and 2), progressing to double stance (week 3 and 4) to single foot stance (week 5 and 6). CG did not perform any intervention	In the SFE group ↓ navicular drop, FPI, pain and disability scores, ↑ the maximum plantar force of the midfoot. In the control group there was no change at the sixth week with respect to their initial assessments

3

Author	Type of treatment	Sample	Procedures	Results
Yurt et al. (21)	Computer-designed insole and exercises	67 people with flexible flatfoot pain, age: 18-45 years were divided into 3 groups. Three study groups were randomly formed: the insole computer-aided design/computer-aided manufacturing (CAD-CAM) group (n=22), conventional (n=22) or sham insole (n=23)	Each group used a type of insoles and did exercises at home to stretch the gastrocnemius, strengthen the PT and intrinsic muscles. Stretching was done from a standing position for 20 s. For PT strength exercises, the heels were raised, and for intrinsic foot muscles, a towel was held with the toes. They did 10 reps, 2 times/day. The intervention lasted 2 months	Pain intensity on the visual analogue scale ↓ more in the group with the CAD-CAM insole (27.8 ± 18.4 mm) and with the conventional one (27.0 ± 16.8 mm) than in the group with the simulated insole (46.4 ± 20.2 mm). Similar results between conventional and CAD-CAM insole. All groups ↑ physical health at the end of the intervention, but there were no differences in physical health between groups

↑: Biggest increase/improvement; ↓: Smaller increase/decrease; AT: anterior tibial; PT: posterior tibial; PL: peroneus longus; AbdH: Abductor hallucis; FH: flexor hallucis; EMG: electromyography; MLA: medial longitudinal arch; CSA: cross-sectional area; SFE: short foot exercise; s: seconds; min: minutes; CG: control group; EG: exercise group; ExpG: experimental group; W: women; M: men; FPI: foot posture index; FPI-6: foot posture index of 6-item; MRI: magnetic resonance imaging; reps: repetitions; HL: heel lift; ATL: Achilles tendon load; NMES: neuromuscular electrical stimulation.

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DISCUSSION

Conservative treatments for flatfoot are diverse and limited mainly to asymptomatic and sedentary subjects, in this review we set out to review existing conservative treatments for flatfoot in young and middle-aged adults. First, most studies include strengthening exercise of the intrinsic and extrinsic muscles of the foot, alone or combined with stretching, orthotics, feedback, electrical stimulation, and footwear.

Strengthening exercises are characterized by strengthening the extrinsic muscles of the foot such as the posterior tibial, anterior tibial (18) and intrinsic such as the abductor and flexor hallucis (18, 19, 24). The most widely used exercise for flatfoot is the short-foot exercises (17, 19, 22-24). This short-foot exercise is characterized by elevating the medial longitudinal arch, shortening the feet in an anteroposterior direction, and actively attempting to approximate the first metatarsal head toward the heel without toe flexion. The forefoot and heel should be kept on the ground during this exercise (19). This exercise is usually performed in sets 2-3 of 5-15 repetitions 1-2 times a day on each leg, raising the medial longitudinal arch for 5 seconds on each repetition, with 1-2 minute rests between sets (17, 19, 22), the intensity is increased progressively, increasing the number of sets, or the time of the repetition, maintaining the contraction form 5 to 10 seconds (19, 23).

Other exercises used for strengthening include towel curls (18), as well as foot adduction exercise (20). Other studies include stretching exercises for the gastrocnemius (21, 28) and psoas iliacus (18). One of the most interesting studies of short-foot exercise was that of Unver et al. (17), in that study they performed this exercise daily for 6 weeks, 2 days/week under supervision and 5 days/week at home to strengthen the intrinsic muscles of the foot. The elevation of the medial longitudinal arch in the short-foot exercise was maintained for 5 s in each repetition, 3 sets of 15 reps/day were performed. Short-foot exercise was started from a seated position (week 1 and 2), progressing to double footing (week 3 and 4) to single foot stance (week 5 and 6), they found a decrease in navicular drop, foot posture index, decreased pain and disability scores, and increased midfoot maximal plantar force. However, the subjects were not randomized into the groups to be studied, as the assignment to one of the groups was carried out based on the willingness of the participants to increase exercise adherence, nor was the long-term efficacy of short-foot exercise evaluated and it had a low number of participants.

Another interesting study performed with exercises was that of Sánchez-Rodríguez et al. (11), subjects with flatfeet conducted 10 exercises: 1) walking on heels and forefoot; 2) walking on the lateral and medial edge of the foot; 3) pick up small objects with toes; 4) inversion and eversion with elastic band; 5) hip abduction; 6) spinal erector strength; 7) abdominal strength; 8) abdominal oblique strength; 9) balance on an unstable base; 10) balance on an unstable base with destabilization. The exercises were performed for a time of 1.5 min per limb. Eighteen 40-min sessions were carried out. After 9 weeks, strengthening of intrinsic and extrinsic foot and core muscles contributed to improved foot posture. Although these results are interesting, it is not stated if the subjects presented any symptoms or pain due to flatfoot, the study only lasted 9 weeks, therefore, it is not known if strengthening has a medium and long term effect, nor is the level of physical condition of the participants stated.

The duration of the exercise programs has been 4 (24), 5 (22) and 6 weeks (17), even up to 8-9 weeks (11, 19, 23). Insole-type orthoses can be custom-designed (19, 21, 30), or standard and off-the-shelf (20, 27). Both appear to be effective in treating flatfoot. Regarding the effectiveness of different custom insole techniques, one article analyzed the effect of using computer-designed and manufactured insoles or conventionally designed custom insoles in conjunction with exercise, finding that regardless of the type of insole, combining either insole with exercise appears to provide the best results in terms of pain control of flexible flatfoot (21), although the results were interesting, compliance with the home exercise program was not controlled, this lack of control may have influenced the effect of these insoles on pain.

Another type of orthosis are bandages and ankle braces (26), they showed that the augmented low-Dye taping and the Push Aequi ankle brace may have clinical utility in reducing muscular activity of the anterior and posterior tibial, and peroneus longus during the gait. However, if specifically targeting the posterior tibial, taping has a significantly greater effect in reducing the activity of this muscle. Although interesting this effect of taping on selectivity in reducing posterior tibial activation the study was limited by only analyzing muscle activity when walking barefoot rather than in footwear conditions, which with footwear may have a different effect, furthermore, the subjects were asymptomatic, although according to the study researchers, comment that previous research supports the extrapolation of their results to symptomatic cohorts, such as the effect of augmented low-Dye taping, which has been observed to have a similar effect regardless of whether or not there are symptoms from flatfoot.

Motion-control footwear and insoles (27) or footwear with internal or external modification and exercises (25) are also treatments used for flatfoot. In the work of Taspinar et al. (25) reported that internal modification of the footwear produces better results than external shoe modification (a Thomas heel was added). It should be noted that the study had important limitations that could condition the results, since the assignment of the participants was not randomized, the BMI was not standardized, nor age, neither the pain assessment scale. The patients with worse BMI condition and older age with probably greater margin for improvement, chose the footwear with internal modification, this fact deserves the results of this study to be taken certain reservations. For their part, Hurd et al. (27) measured the effect of wearing a New Balance 1122 motion control running shoe in conjunction with a Hickory flatfoot orthotic and an Implus Footcare semi-rigid insole during walking or running. They found that wearing the Hickory orthotic biomechanically neutralizes the components of a decompensated varus forefoot in asymptomatic subjects when used in conjunction with a motion control running shoe. A major limitation is that it used asymptomatic participants and the effect of these devices on symptomatic flatfoot pain and function is unknown.

Of the main characteristics of the studies reviewed is that they were conducted with subjects with asymptomatic flatfeet, 15 articles of this review only 4 were performed with people with foot pain. Another characteristic is that the level of physical activity of the subjects was unknown in almost all the articles. In this regard, only one article was carried out with people who considered themselves recreational athletes, highlighting that it does not state any variable related to the volume of training that helps to determine the performance level of the participants (27). In fact, only a single study was conducted with recreational runners with a low training volume per week (11.8 $\pm$ 3.4 km/week and 6.5 $\pm$ 2. 5 years of running experience) where it was determined that the use of orthoses in subjects with flatfeet may serve as a preventative in the incidence of Achilles tendon pathologies in amateur runners (29), however, these subjects were asymptomatic, and it is not known whether the effects of a foot orthosis may have long-term positive effects on the force exerted by the Achilles tendon. Therefore, the results presented in these articles can hardly be extrapolated to other populations or age groups, such as middle-aged adult athletes with flatfoot. In addition, with current information, we do not know which is the best conservative treatment in middle-aged subjects with symptomatic flatfoot, nor if there is any difference in the results of conservative treatment depending on the initial strength level, the type of sport or the motor skills performed by the subject with flatfoot.

Of interest, is the fact that there is not a single article of conservative treatment for middle-aged athletes with an outstanding level of physical conditioning, probably because it is not common for a flatfoot subject with a high level of physical conditioning to present symptoms, or that the own pain symptoms caused by flatfoot at some point cause middle-aged adult subjects to abandon sports practice once flatfoot problems appear or worsen. This point is worth investigating, as a middle-aged athlete presenting with stage II of posterior tibial tendon dysfunction with flatfoot is considered a candidate for surgery with one or even several surgical procedures (31). The cost of a surgery of this type is high, recovery is slow, uncertainty about the conditions in which one return to sports practice, more if the flatfoot condition is limiting but not disabling, in addition, the surgery requires a long time of rest and recovery than middle-aged individual may not be able to afford it due to his professional obligations. All these factors most likely cause the middle-aged athlete to drastically reduce his level of physical activity or even abandon it permanently, enhancing other problems such as diseases derived from sedentary lifestyle and physical inactivity.

Practical application

The simultaneous combination of different conservative treatments seems to be the best option for the treatment of flatfoot. An exercise program that including intrinsic muscle strengthening such as short-foot exercise or toe curl, extrinsic foot exercises such as heel raises or ankle dorsiflexion, accompanied by stretching of the gastrocnemius and psoas iliacus, together with a customized insole orthosis with medial longitudinal arch support, as well as good heel and first metatarsal support, inserted in an appropriate shoe for daily life or with a motion control shoe for sports practice, seems to be the best option to prevent, or recover foot function in subjects with flatfoot. In case of flatfoot symptoms, furthermore of the physiotherapy, exercises should be applied 3-5 times a week, as the function and execution of the exercises improves, the intensity and volume of the exercises should be increased, exercise programs should be 5-9 weeks long. As maintenance, it is important to perform at least 2 times a week the exercises for flatfoot with an intensity according to the level of the subject. During sports practice, in addition to using appropriate footwear, it is advisable to apply a specific bandage type augmented low-Dye taping, that supports the medial longitudinal arch.

LIMITATIONS AND FUTURE PATHS

This review was limited to clinical trials and adult subjects, young adults, and middle-aged adults with flatfoot and without comorbidities; therefore, the results and recommendations of the practical application may not be extrapolated to other populations with different levels of physical fitness. Future studies should be focused on knowing the population of middle-aged subjects with flatfoot, level of physical condition and quality of life, who systematically perform sports, or who participate in leagues and tournaments of sports associations or federations, if there is a difference in the number of participants with flatfoot in intermittent or continuous sports. To analyze whether the protocols and results of the studies in this review can be extrapolated to subjects with different levels of physical fitness or body composition. To analyze whether flatfoot is an important cause of abandoning sports practice. To know the influence of an exercise program, or orthotics, or taping or the combination of these modalities in the treatment and prevention of foot posture index or navicular drop in subjects with flatfoot.

CONCLUSIONS

Conservative treatments used for flatfoot in young and middle-aged adults include strengthening exercises of the intrinsic and extrinsic muscles of the foot, alone or combined with stretching, orthotics, feedback, electrical stimulation, and footwear. Conservative treatments studies in middle-aged adults with symptomatic flatfoot are needed to evaluate the short- and long-term effect of current protocols in populations with different levels of physical fitness.

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