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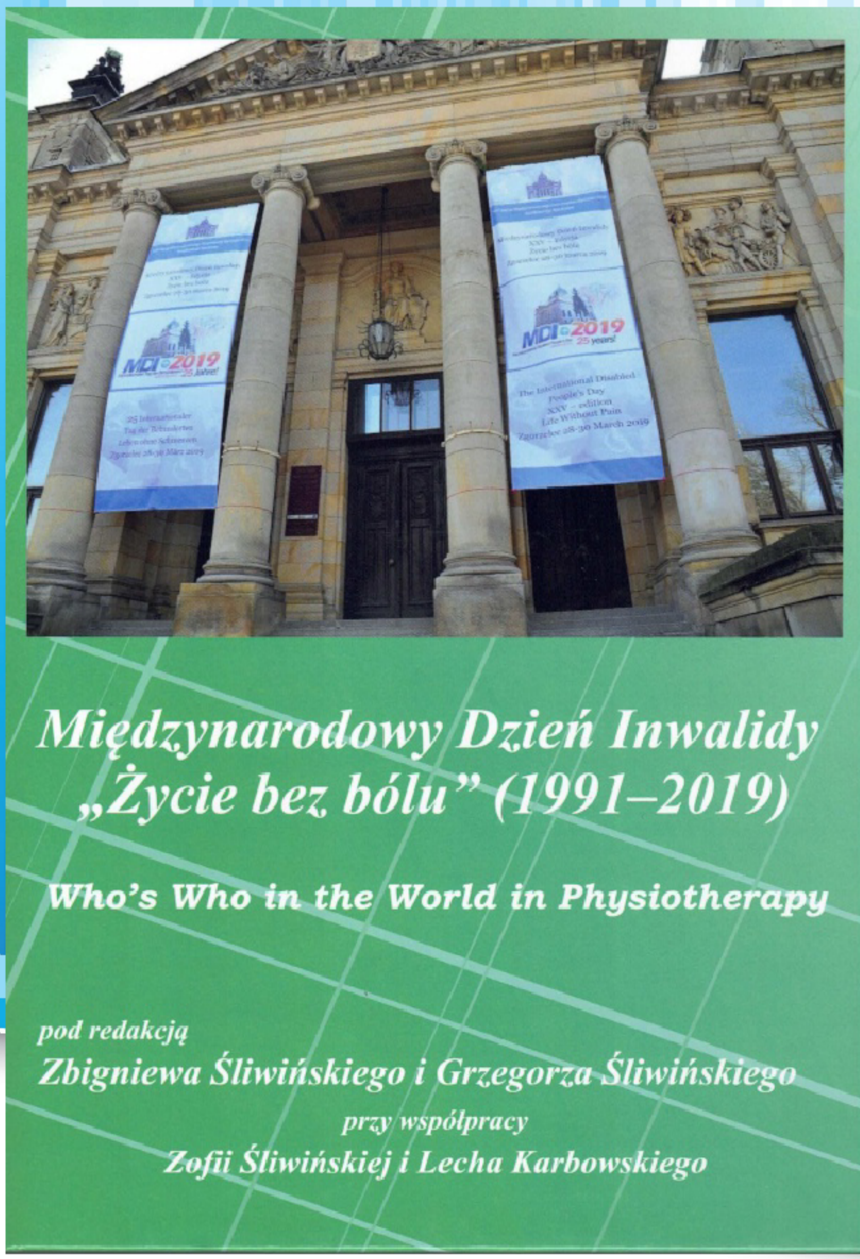

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Orthotic management in the rehabilitation of children with plano-valgus foot

Postępowanie ortotyczne w rehabilitacji dzieci ze stopą płasko-koślawą

Agnieszka Ciukszo[1(A,B,D,E,F)], Mateusz Curyło[2(A,C,D,E,F,G)], Ewa Kucharska[3(G,F)], Marcin Mikos[4(G,F)], Jan W. Raczkowski[2(G,F)]

[1]Katedra i Zakład Adaptowanej Aktywności Fizycznej i Sportu, Wydział Nauk o Zdrowiu w Katowicach, Śląski Uniwersytet Medyczny w Katowicach / Department of Adapted Physical Activity and Sport, School of Health Sciences in Katowice, Medical University of Silesia in Katowice, Poland
[2]Uniwersytet Medyczny w Łodzi / Medical University of Lodz, Poland
[3]Akademia Ignatianum w Krakowie / Jesuit University Ignatianum in Krakow, Poland
[4]Zakład Analiz ekonomicznych i systemowych Narodowy Instytut Zdrowia Publicznego PZH – Państwowy Instytut Badawczy / Department of Economic and Systemic Analyzes National Institute of Public Health, National Institute of Hygiene – National Research Institute, Poland

Abstract
Plano-valgus foot is a common three-plane deformity that appears at developmental age. It is characterized by the eversion of the calcaneus in relation to the tibia, foot pronation and lowering of the medial longitudinal arch under load. Joint hypermobility and significant body weight are believed to increase the prevalence of plano-valgus foot at all ages. There is no consensus on the proper management of flat feet. This disagreement is primarily due to the fact that there is no clear-cut approach to distinguishing pathological or physiological flat feet and to determining who needs treatment. One of the methods of supporting foot correction is the use of orthopaedic equipment in the form of shoe insoles or SMO/RING orthoses. The introduction of repositioning in the lower ankle joint is intended to restore the natural foot support system and to reduce the compensation at higher levels in the joints of the lower limbs, in the pelvis and torso.

Key words:
plano-valgus foot, posture defect, orthopaedic insole, orthosis

Streszczenie
Stopa płasko-koślawa jest częstą deformacją trójpłaszczyznową pojawiającą się w wieku rozwojowym. Charakteryzuje ją ewersja kości piętowej w stosunku do piszczeli, pronacja stopy i obniżenie łuku podłużnego przyśrodkowego podczas obciążenia. Przyjmuje się, że hipermobilność stawów oraz wysoka masa ciała zwiększają częstość występowania stopy płasko-koślawej w każdym wieku. Brak jest konsensusu w dziedzinie prawidłowego zarządzania płaskostopiem. Ten brak porozumienia wynika przede wszystkim z tego, że nie ma jednoznacznego podejścia do odróżniania patologicznego lub fizjologicznego płaskostopia i do określania, kto wymaga leczenia. Jedną z metod podtrzymujących korekcję stopy jest stosowanie zaopatrzenia ortopedycznego w postaci wkładek do obuwia czy ortez typu SMO/RING. Wprowadzenie repozycji w stawie skokowym dolnym ma na celu odtworzenie naturalnego systemu podparcia stopy oraz zmniejszenie kompensacji na wyższych poziomach w stawach kończyn dolnych, w miednicy i tułowiu.

Słowa kluczowe:
stopa płasko-koślawa, wada postawy, wkładka ortopedyczna, orteza

Introduction

Disorders resulting from incorrect foot positioning affect many adults. The effects of these changes include pain while walking, calluses, hallux valgus, joint pain, back pain, sports injuries and many others [1]. The first problems appear in childhood, and their early diagnosis and treatment give a chance for the proper development of the foot and reduction of unpleasant ailments in adulthood [2]. Moreover, the growing obesity rate among children predisposes to overload changes and problems with the locomotor system in the future [3].

Objective

The objective of the study is to present a common foot defect and the current methods of correction of plano-valgus foot thanks to the support of orthopaedic equipment.

Definition of plano-valgus foot

Plano-valgus foot (PV) is a common three-plane deformity that appears at developmental age or, less frequently, a congenital defect. According to the ICD-10 classification, this is M21.0 – valgus deformity not elsewhere classified, as well as M21.4 – acquired flat feet (pes planus) and Q66.5 – congenital flat feet, Q66.6 – congenital valgus metatarsus. This structural and/or functional abnormality of the foot can cause mechanical damage to the lower limbs when walking. They are characterized by the eversion of the calcaneus in relation to the tibia, foot pronation and lowering of the medial longitudinal arch (MLA) under load. Despite their importance in the diagnosis and classification of plano-valgus foot, little information is available on the functional changes in the major joints including the medial longitudinal arch - that is, the metatarsus and tarsometatarsal joints. MLA begins developing at 2 years of age and becomes structurally mature around 10–13 years of age [4].

Epidemiology

The prevalence of PV varies with age: it occurs in approximately 37–60% of children aged 2–6, and in approximately 16–19% of adolescents aged 8–13, after the closure of growth plates [5]. It is assumed that the features of the foot arch influence the biomechanics of the lower limbs while walking and running, and are considered a contributing factor in the occurrence of injuries. Low foot arches are common in young children, while the exact prevalence in older children is a controversial topic. Current systematic reviews indicate the prevalence of approximately 4–15% of flat feet in school-age children [6]. It is generally recognized that the symptoms of PV decrease with age [7].

Risk factors

Joint hypermobility and significant body weight are believed to increase the prevalence of plano-valgus foot at all ages. Clinically, plano-valgus metatarsus in children deforms under load [8]. Therefore, it has been postulated that the metatarsus remains in eversion and dorsiflexion for longer during the late support phase, which in turn leads to a less effective rebound phase [9]. Flatfoot screening is a very important step in determining the need for further radiographic assessments, early intervention, or monitoring of children to ensure that flexible flatfoot does not develop into pathological flatfoot, which has many different aetiologies, such as fusion of the tarsal bones, excessively valgus heel, knee valgus, lower limb torsion, excess body weight, generalized joint relaxation and pain. Lack of heel inversion while standing on toes indicates stiff flatfoot. It is therefore a complex problem [10]. The presence of joint laxity in children with flat feet is believed to be the primary mechanism of plano-valgus foot deformity. Moreover, risk factors include lowering of the medial longitudinal arch, pain in the foot area, heel valgus, and an incorrect BMI value [11]. Obesity puts more strain on the feet when walking, increasing the risk of foot pain and discomfort. Running is a common form of physical activity in children and generates more strain on the musculoskeletal system than walking. The study conducted by Song-huaa et al. was aimed at assessing the influence of obesity in children on the course of plantar pressure and showed that obese children generated much higher peak pressure in the metatarsus, forefoot and toes [2, 11]. Obese children also had a greater contact surface under all foot regions. These results provide evidence that childhood obesity is associated with increased plantar pressure during running, and support the concept that obese children are more likely to experience foot discomfort and pain [3]. The medical community has still not developed a consensus on the proper management of flat feet. This disagreement is primarily due to the fact that there is no clear-cut approach to distinguishing pathological or physiological flat feet and to determining who needs treatment. It is clear that early intervention in the treatment of musculoskeletal disorders in children would be beneficial. However, there is no evidence to support an estimate of the proportion of children that would benefit from this practice [12].

Flat feet in scientific research

Several studies have investigated the relationship between the morphology of the foot arch and the biomechanics of the lower limbs when walking. Only a few studies have looked into paediatric populations showing longer steps in children with high arches and altered knees, and hip kinetics in children with low arches [13]. The study conducted by Pfeiffer et al. [14] concerned the occurrence of pathological flat feet. The aim was to establish the prevalence of flat feet in a population aged 3-6 in order to assess co-factors such as age, weight and gender, and to estimate the number of unnecessary surgeries. In total, 835 children (411 girls and 424 boys) participated in the study. The clinical diagnosis of flat feet was based on the position of the calcaneus and the poor shape of the medial longitudinal arch. The prevalence of flexible flatfoot in the group of 3-6-year-old children was 44%. The prevalence of pathological flatfoot was 1%. About 10% of children wore medial arch lifting insoles. The prevalence of flatfoot decreases significantly with age: 54% of 3-year-old children had flatfoot, while only 24% of 6-year-old children. The mean valgus angle of the foot was 5.5°. Boys had a significantly greater tendency to have flatfoot than girls: the prevalence of flatfoot in boys was 52% and 36% in girls. 13% of the children were overweight or obese. Significant differences were observed in the prevalence of flatfoot in overweight, obese and normal weight children. The data shows that the prevalence of flatfoot is influenced by three factors: age, gender and weight [14]. Older children were the subject of research by Iranian scientists who examined a total of 667 children (327 girls and 340 boys) aged 7-14 years. The diagnosis of flatfoot was based on clinical observations and measurements using a systematic protocol. The prevalence of pathological flat feet was 10.3% in children aged 7-14, but decreased with age. There was no difference in the prevalence of pathological flat feet between the sexes. Children with a high BMI were more likely to have pathological flat feet. Approximately 46% of identified cases of flexible flatfoot had medical indications that required care or treatment [14]. The distribution of plantar pressure (PP) on the ground can be used to characterize the function of the foot. According to the researchers, it changes during the normal development of a child. For example, several studies report that maximum PP (PPmax) increases under the entire foot, hindfoot, and forefoot between starting independent walking and 13 years of age, but does not increase under the metatarsus. Age-specific foot loading patterns for toddlers learning to walk show the highest PPmax under the big toe; whereas in 7-year-olds the highest PPmax is under the hindfoot. These clearly identified foot loading patterns are considered to be part of the normal developmental stage of the growing foot [5].

Arch Index

The arch index is the ratio of the foot contact area with the ground to the area of the foot that does not touch the ground, expressed as a percentage. High values of the dynamic arch index (Fig. 1) represent the arch of a flat foot, low values of the index characterize a hollow foot [15].

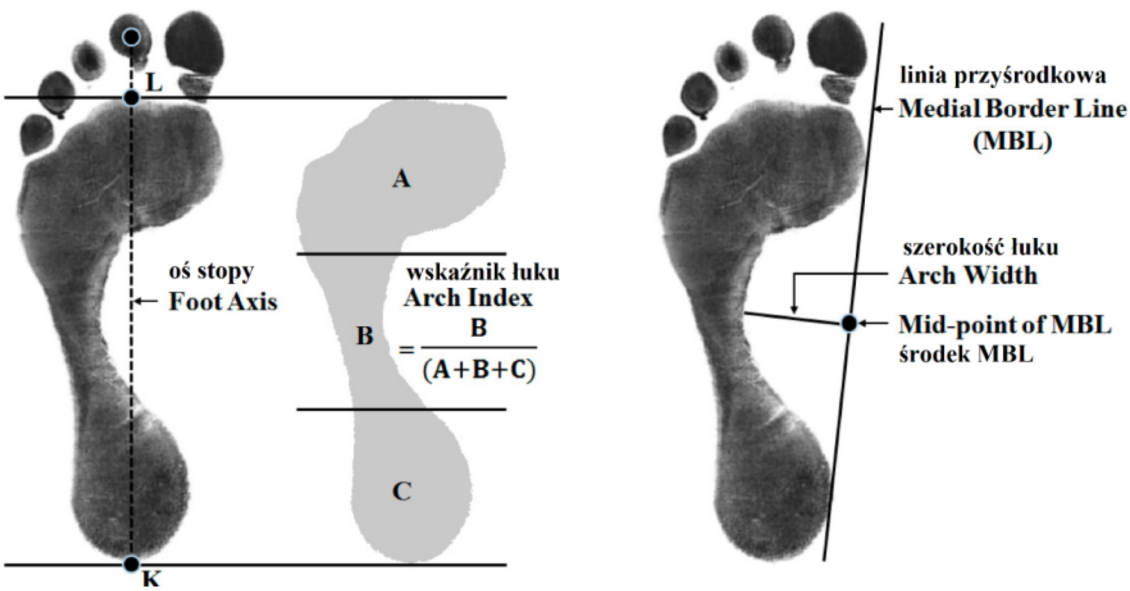
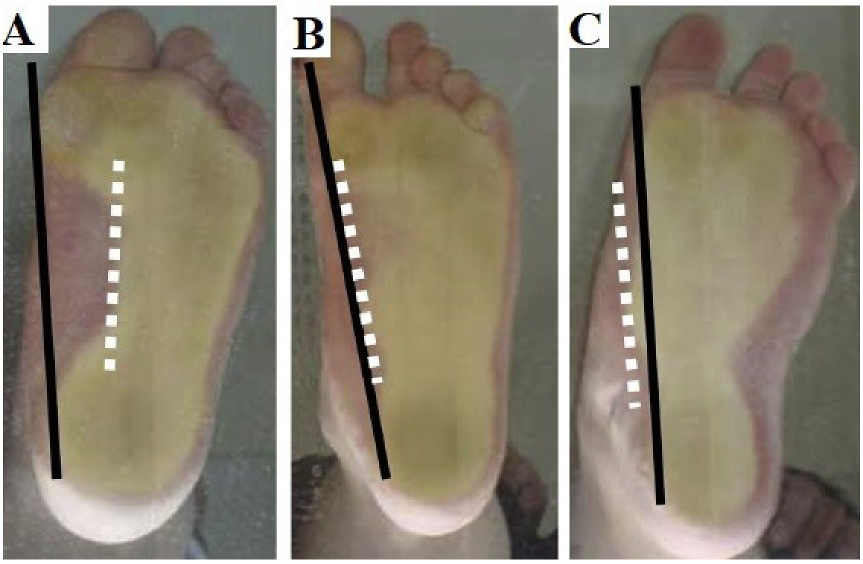


Fig. 1. Arch index [15]

Foot Progression Angle in contact with the ground is significantly related to the dynamic arch index. Higher arch indexes (= flat foot) correspond to higher angles of foot progression (= increased external rotation). These results are consistent with the association of low arches (in pes planus) with excessive external rotation and high arches (in pes cavus) with excessive internal rotation [6]. The same association was found in barefoot children in another study [16]. Literature describes many foot deformities among patients with Down's syndrome (DS), such as hallux valgus, increased space between the first and second toes, syndactyly. The presence of plano-valgus foot (Fig. 2) turns out to be more common in patients with DS compared to the control group [17].



Ryc. 2. Podometryczna reprezentacja stopy płasko-koślawej: (A) stopień I, (B) stopień II, (C) stopień III [17]
Fig. 2. Podometric representation of plano-valgus foot: (A) grade I, (B) grade II, (C) grade III [17]

Orthotic methods of foot correction – footwear and orthopaedic insoles

One method of treating a foot deformity is the widespread use of orthoses. Foot orthoses (FO) are used to correct skeletal misalignment, improve sensory feedback, increase comfort, and change biomechanical characteristics. Orthopaedic insoles are the most common method used for the correction of plano-valgus foot. In combination with the right footwear, they provide the basic support in the proper development of a child's foot. Footwear used with the insole should meet several parameters: a soft sole, flexible forefoot, slightly stiffened heel, the ability to easily open up the shank to adjust the insole to the shoe. Footwear should stabilize the lower ankle joint, so the shank must cover the foot at least up to the ankle height (lateral and medial). The higher the footwear, the less mobility in the upper ankle joint. Do not stiffen the foot, unless absolutely necessary (e.g. in flaccid or spastic paralysis). The footwear itself also has a supporting and stabilizing function. With minor foot defects, it can be used as the so-called prophylactic footwear to prevent deepening of the foot deformity. Within prophylaxis attention should be paid to how children wear off the sole of the footwear they wear every day. This observation provides a lot of data about the type of defect and its severity. It is the responsibility of the parent as well as the GP who assesses the child's posture during check-ups and measurements.

To quantify the impact of foot orthoses (FO) on lower limb biomechanics, Alavi-Mehr's (2018) research focused mainly on three measurement techniques: electromyography (EMG), kinematics and kinetics. Regarding EMG, evidence was presented that FO increased the activity of some lower limb muscles (peroneus longus, tibialis anterior) and decreased activation of others (gluteus medius, biceps femoris, vastus lateralis, vastus medialis) compared to the condition when wearing the footwear only. In addition, when using FO, the activation time of the tibialis anterior, soleus, musculus gastrocnemius, and peroneus longus is shorter than when walking without FO. In terms of kinematics, FO has been reported to: extend the support phase time; increase the angle of dorsiflexion of the ankle joint; reduce the internal rotation of the tibia, hip adduction; it reduces calcaneus conversion from 1° to 6.7° and the maximum angle of plantar flexion of the ankle joint. Regarding the kinetics and/or plantar pressure, FO was found to reduce frontal force moments in the ankle joint, inversion moment, knee adduction moment, peak ankle flexion moment, peak vertical ground reaction force, and foot load values. For both limbs, the amplitude of the three frequency components of the GRF ground reaction forces when walking wearing FO was lower than during walking without FO. The reduction of this phenomenon caused by FO in children with plano-valgus foot suggests less irregular application of ground reaction forces during walking [9].

SMO/RING orthosis

Foot defects, which cannot be corrected with footwear with an orthopaedic insole, are provided with SMO (Supramalleolar Orthosis) orthoses, dynamic orthoses covering the shin and foot, or RING repositionable lower ankle orthoses (Fig. 3).

Fig. 3. RING orthosis

The biomechanical principles of lower limb correction relate to the three-point support system. This means that the force applied at one point must be balanced by corrective forces acting at the other two points on the opposite side. The key factor is the length of the lever arm through which the applied force acts (Fig. 4). The longer the lever arm, the less force must be used to obtain a similar effect by applying a lot of force to the short lever.

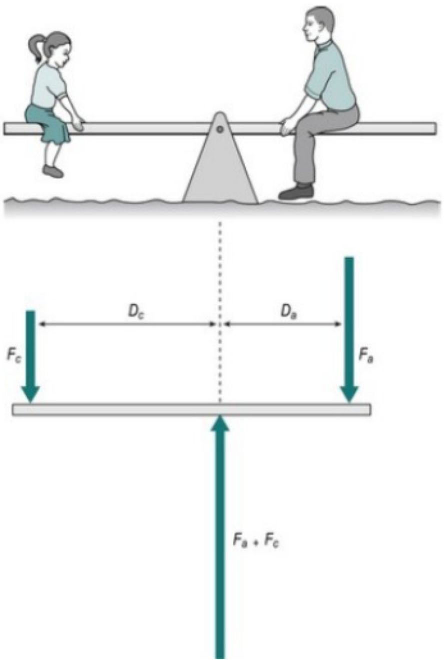


Fig. 4. Moment of force (M = F × D)

SMOs are prescribed to patients who have soft, flexible and flat feet (pes planovalgus). The SMO is designed to keep the heel vertical or neutral while supporting the arches of the foot. SMO (Fig. 5) can improve balance while standing and walking.

Ryc. 5. Orteza typu SMO
Fig. 5. SMO orthosis

SMO orthosis requires no special footwear. However, the shoe insole should be removed to relieve pressure on the dorsal part of the foot. You may need a shoe one size larger or wider. The RING orthosis covers the lateral ankle and the base of the fifth metatarsal head, and ends at the Chopart line from the medial side. Underneath, at the height of the calcaneal tuberosity, an opening is left through which the heel is in contact with the ground, thus maintaining sensitivity to proprioceptive stimuli from the ground.

Summary

World literature on the subject discusses heterogeneous treatment of plano-valgus foot. There is clinical data on individual cases, showing wide discrepancies. Therefore, the community is divided into supporters of the use of orthoses for foot correction and opponents of such forms of treating plano-valgus foot. The best results in the treatment of plano-valgus foot are achieved by the use of custom-made insoles and orthoses, which take into account parameterization and adaptation to the patient's individual anatomical features. Additive technologies, commonly known as 3D printing, support the possibility of a safe fit through the use of materials for medical applications. Moreover, computer design of orthoses gives greater control over the shape and individual fit thanks to the acquisition of a measure with an optical scanner that captures a three-dimensional image of the human body in high resolution, which faithfully reproduces the anatomical structures. Individual orthoses should be used if the prefabricated ones do not provide adequate support for the child's foot [18].

Adres do korespondencji / Corresponding author

Mateusz Curyło

E-mail: mateusz_curylo@o2.pl

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