ETIOPATHOGENETIC ASPECTS, DIAGNOSIS, AND MODERN REHABILITATION STRATEGIES FOR FLATFOOT IN CHILDREN AND ADOLESCENTS

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Abstract. *Flatfoot (pes planus) is a common condition in pediatric orthopedics characterized by collapse of the medial longitudinal arch, often accompanied by hindfoot valgus. Its prevalence reaches 44–54% in preschool children and decreases with age due to musculoskeletal maturation. However, distinguishing physiological flexible flatfoot from pathological forms requiring intervention remains clinically challenging. This review summarizes current evidence (2001–2025) on etiopathogenesis, risk factors, diagnosis, and treatment strategies in children and adolescents aged 3–18 years. Major risk factors include younger age, male sex, increased body mass index, joint hypermobility, and urban living. Obesity and ligamentous laxity show the strongest association with persistent deformity. Functional consequences include impaired balance, reduced core muscle endurance, altered gait biomechanics, and increased injury risk. Diagnosis should combine clinical assessment (Jack's test, navicular drop test), radiography, plantography, and the Foot Posture Index (FPI-6). Conservative management remains the first-line approach, including custom orthoses, structured exercise therapy, and weight control. Surgical treatment is reserved for rigid or refractory cases. Early identification and individualized rehabilitation are essential to prevent long-term musculoskeletal complications.*

Keywords: *flatfoot, children, adolescents, diagnosis, treatment, risk factors, body mass index, orthotics, biomechanics.*

Relevance

Flatfoot (pes planus) remains one of the most common and widely discussed problems in pediatric orthopedics. This condition is characterized by a decrease or collapse of the medial longitudinal arch of the foot, often accompanied by valgus deformity of the hindfoot. Epidemiological data indicate a high prevalence of this pathology: up to 44–54% among preschool-aged children, with a tendency to decrease to 15–25% with age and maturation of the osseous and ligamentous apparatus. Despite its high incidence, debate persists in the medical community regarding the boundary between the physiological norm (flexible flatfoot in children under 6–8 years of age) and a pathological condition requiring correction. The relevance of the problem is heightened by the fact that untreated flatfoot can lead to long-term negative consequences, including impaired gait biomechanics, decreased postural stability, chronic pain in the lower extremities and back, and the development of secondary deformities of the proximal joints. Furthermore, modern research reveals a link between flatfoot and decreased functional capacities, such as reduced core muscle endurance and static balance. The aim of this review is to systematize current data on the etiology, risk factors, diagnostic approaches, and effectiveness of treatment methods for flatfoot in children and adolescents.

Materials and Methods

This study included an analysis of scientific literature published between 2001 and 2025. The literature search was conducted in the electronic databases PubMed, Scopus, Web of Science, Cochrane Library, and eLIBRARY.RU. The review included systematic reviews, meta-analyses, randomized controlled trials (RCTs), and cross-sectional studies. The inclusion criteria were as follows: patients aged 3–18 years; a diagnosis of flatfoot (flexible or rigid) confirmed by clinical or instrumental methods; and analysis of risk factors (BMI, sex, hypermobility) or treatment methods (conservative or surgical). In total, more than 20 sources were analyzed, including large meta-analyses covering data from thousands of patients.

Results and Discussion

Classification and Etiology

In pediatric practice, flatfoot is classified as flexible and rigid.

Flexible flatfoot: This is the most common form and is characterized by restoration of the arch of the foot in the absence of weight-bearing or during functional tests (e.g., standing on the toes). Most authors consider it a physiological condition in young children caused by ligamentous weakness and the presence of a plantar fat pad.

Rigid flatfoot: This form is characterized by persistent flattening of the arch and limited mobility in the tarsal joints. It is often associated with congenital anomalies (vertical talus, tarsal coalitions) or neurological disorders.

Risk Factors

Modern meta-analyses have identified key factors that contribute to the development and persistence of flatfoot:

Age: The incidence of flatfoot is inversely correlated with age. Children under 6 years of age are 3.11 times more likely to develop flatfoot than older children, supporting the theory that arch flattening occurs physiologically in early childhood.

Sex: Boys are more likely to develop flatfoot than girls (OR = 1.35). This may be due to later skeletal maturation in boys compared to girls of the same age.

Body mass index (BMI): Obesity and overweight are strong predictors of foot pathology. Excess weight increases the load on the medial longitudinal arch, leading to its collapse. A meta-analysis showed that obese children have a 2.3-fold higher risk of flatfoot (OR = 2.3), and in some samples this figure reached 9.08.

Joint hypermobility: Systemic weakness of the ligamentous apparatus (joint laxity) significantly increases the risk of developing deformity (OR = 4.82).

Environmental factors: Living in an urban environment is associated with a twofold increased risk of flatfoot (OR = 2.10) compared to living in rural areas. This is explained by constant walking on hard, flat surfaces and wearing shoes that limit the natural function of the foot muscles.

The Impact of Flatfoot on Functional Status

Flatfoot has a broad impact on the musculoskeletal system. A 2025 study showed that young people with flexible flatfoot exhibit significant functional deficits compared to the control group:

Decreased static balance: Foot deformity disrupts proprioceptive feedback, making it difficult to maintain balance.

Core weakness: A significant decrease in the endurance of the abdominal and back extensor muscles was observed. Changes in foot biomechanics (pronation) trigger a chain reaction,

including internal rotation of the tibia and femur, which alters pelvic position and requires compensatory stabilization of the trunk, thereby depleting muscle resources.

Reduced movement quality: Functional Movement Scale (FMS) scores are significantly lower in individuals with flatfoot, indicating an increased risk of injury and inefficient movement patterns.

Diagnosis

The modern diagnostic approach should be multimodal.

Clinical tests: The toe stand test (Jack's test) is used to assess arch mobility, along with visual assessment of posterior valgus (the "too many toes" sign) and the navicular drop test, which is considered positive when the height of the navicular bone decreases by more than 10 mm.

Instrumental methods:

Radiography: This remains the gold standard for assessing bone architecture, including the anterior longitudinal arch angle and calcaneal inclination angle.

Plantography and podometry: Analysis of footprints (Chizhin and Shtriter indices) allows estimation of the support area, although the method depends on the soft tissues of the foot.

Foot Posture Index (FPI-6): This is a comprehensive foot position assessment scale that includes palpation and visual inspection at six points. The FPI demonstrates high reliability but may overdiagnose flatfoot in mild forms of pronation.

Modern Treatment Methods

Treatment tactics range from dynamic observation to surgical intervention and depend on the symptoms and severity of the deformity.

Conservative treatment:

1. Orthotics (insoles): The use of orthotic insoles is the most common method. A 2023 systematic review found that insoles with medial arch support effectively reduce pain and improve biomechanics in children with symptomatic flatfoot. Custom-made orthoses demonstrate advantages over prefabricated ones due to better pressure distribution and adaptation to the foot. However, there is concern that continuous use of arch supports without active training may weaken the foot's natural muscles.

2. Physical rehabilitation and exercise therapy: Exercises are aimed at strengthening the muscles that support the arch, including the tibialis posterior and the intrinsic muscles of the foot. Walking on the toes and heels, grasping objects with the toes, and walking on uneven surfaces are effective. Particular attention is given to game-based exercise programs for preschoolers (e.g., "Play Labyrinths") to improve compliance. Therapeutic swimming has also been shown to be effective in strengthening the muscular system without axial loading.

3. Additional tools: The use of toe separators and night orthoses can promote passive correction and stretching of shortened structures, such as the Achilles tendon.

Surgical treatment: Surgical treatment is indicated for rigid deformities, severe pain, and ineffective conservative therapy. The primary methods include subtalar arthroereisis (implant placement in the sinus tarsi), calcaneal osteotomies, and arthrodesis in cases of severe arthrotic changes.

Conclusion

Flatfoot in children and adolescents is a heterogeneous condition requiring a differentiated approach. Flexible, asymptomatic flatfoot in young children should be considered a stage of physiological development that does not require aggressive correction. However, the presence of

risk factors such as obesity and hypermobility, as well as persistence of the deformity into adolescence, requires active intervention.

The mainstay of treatment is a conservative approach, combining appropriate footwear or custom orthoses, when symptoms are present, with active physical rehabilitation (exercise therapy and core strengthening). Weight management and encouragement of physical activity are important preventive measures. Surgical treatment remains reserved for severe cases. Further standardization of diagnostic criteria, such as the implementation of uniform FPI cutoff values, is needed to improve the quality of clinical research and practice.

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