DETECTING AND MANAGING FLAT FEET IN CHILDREN: A COMPLEX APPROACH

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ABSTRACT
This paper presents the complex phenomenon of flat feet (pes planus) in children by providing a comprehensive process, from detecting flat feet in children to adapting behavioural patterns in parents and children to address the challenges posed by flat feet. The empirical research consisted of two stages: the detection of flat feet in children using an innovative Elinvision scanner and interviews with parents of children whose feet showed symptoms of pes planus. The analysed cases revealed four different parental behavioural patterns, ranging from Ignorance to Providing complex support to the child, with intermediate models such as Quick solution and Seeking specialised help. Empirical research unequivocally shows that tools for managing flat feet cause discomfort for children; thus, this issue requires a complex, multi-stakeholder approach.

Keywords: *flat feet; children; parental behaviour patterns; Elinvision scanner; 3D printing*

1. INTRODUCTION
A child's foot, which consists of 26 bones connected by joints, ligaments, and muscles, is a complex and constantly developing part of the body whose main purpose is to support body weight, aid movement, and ensure balance. Although a child's foot is similar in structure to that of an adult, it is not yet fully mature and changes as the child grows. One of the most important elements of the foot is ***the arch***. It acts as a natural shock absorber when moving. The arch of a child's foot is still developing, so at an early age, the foot often appears flat. This is due to the soft fat pad in the sole and muscles and ligaments that are not yet strong enough. Children's foot bones are initially partly made of cartilage, which makes them more flexible than those of adults. As the child grows, the bones gradually ossify, the muscles and ligaments strengthen, and coordination improves. These changes alter the shape and function of the foot, and the arch usually forms by school age, approximately by 6-10 years old [5].

Flat feet (pes planus) could be defined as a reduction or disappearance of the inner longitudinal arch of the foot when standing. It could be noted that all newborns are born with flat feet due to the fatty pad in the sole, underdeveloped muscles, and immature nerve-muscle control. As the child grows, muscles strengthen and physical activity increases, the arch of the foot gradually forms. Thus, the prevalence of flat feet (pes planus) in children aged 7–10 is a significant health problem, as the foot arch should already be formed at this age [14]. Studies show that the prevalence of flat feet in children decreases with age [12]. However, according to World Health Organisation (WHO) data, the prevalence of flat feet among children aged 7-10 is 16-22%.
It should be stated that the diagnosis of flat feet is more often indicative of a functional or structural foot problem rather than a temporary developmental stage [11]. It can have many long-term consequences, such as poor posture, knee and hip

pain, and increased fatigue, which can affect children's overall growth and quality of life [10].

Flat feet in children are classified as flexible and rigid [4]. *Flexible flat feet* are the most common form. They are characterised by the arch of the foot being visible when the foot is unloaded or when standing on the toes, but disappearing when standing on the whole foot. This form is usually asymptomatic and is considered a normal variant of foot development. In contrast, *rigid flat feet* are always present when the entire foot is flat on the ground; they are stiffer and more difficult to move, and the cause is often a bone or nerve disorder.

The muscles that support the inner arch of the foot and help the foot adapt to different surfaces are particularly important. As children move, run, and play, these muscles strengthen, and the foot develops naturally. Proper movement, an active lifestyle, and natural foot loading are important factors in helping the foot develop properly. The problem of flat feet is exacerbated by the fact that modern children are increasingly exposed to risk factors such as excess weight, insufficient physical activity, and inappropriate footwear, which further increase the likelihood of flat feet. If not diagnosed and corrected in time, this condition can persist into adulthood, causing chronic pain and increasing the risk of orthopaedic problems [7]. For these reasons, the assessment and prevention of flat feet in children are of great significance and involve various actors, including children, family members, representatives of preschool and primary education institutions, health care institutions, and business enterprises. From a scientific point of view, this issue requires the cooperation of scientists across different research fields, such as medicine and health sciences, technology sciences, and social sciences, to adopt a complex approach. Thus, the main scientific questions could be formulated as follows: 1) What are innovative methods to detect flat feet in children? 2) What are the behavioural models to deal with children who have the diagnosis of flat feet? Accordingly, **the research aims to reveal the phenomenon of flat feet in children, from the detection of flat feet to the behavioural patterns of parents and children in such cases**.

Research methods: scientific literature analysis, scanning feet with the Elinvision scanner, case study, interviews, and content analysis.

2. MATERIALS AND METHODS

This section of the paper is divided into two parts: the research methodology for detecting flat feet in children and a multiple-case strategy to define the behaviour patterns of parents and children in cases of flat feet.

Detecting flat feet in children. The research was conducted at a primary school in Kaunas with 7-year-old children. Twenty-four pupils participated in the study after receiving their parents' permission. Each of these children got their feet scanned using an Elinvision scanner.

The Elinvision scanner (Figure 1) is an advanced three-dimensional foot-scanning device developed in Lithuania, designed for highly accurate recording of foot shape, dimensions, and biomechanical characteristics, and used in orthopaedics, podiatry, custom footwear manufacturing, and various areas of motion analysis.

Figure 1. Elinvision scanner [2]

This scanner stands out because it can quickly create a highly detailed 3D model of the foot, allowing specialists to assess anatomical structures, deformities, arch height, foot load zones, and other important parameters necessary for both medical diagnosis and the design of personalised orthopaedic devices or footwear. The device is based on modern optical and digital technology, often using high-resolution sensors and FPGA or MPSoC architectures, which allow large amounts of information to be processed in real time and converted into an accurate three-dimensional model with millimetre or even sub-millimetre precision.

Elinvision scanners are designed to be as convenient as possible for clinics, laboratories, and footwear fitting centres—they are fast, require no complex calibration, and are stable, reliable, and durable, providing consistent, objective data unaffected by human factors. The scanner data is often integrated with specialised software that allows specialists to analyse the foot's geometry, compare it with normative parameters, predict load distribution, monitor changes during treatment, or modify the 3D model for the production of custom insoles or orthopaedic footwear.

This technology is particularly useful in situations where the patient has complex foot deformities, pain, orthopaedic problems, or comorbidities, such as diabetes, and needs to control loads to avoid ulcers precisely. Its use in sports medicine is also extremely valuable – the scanner can help athletes choose the most suitable footwear, assess biomechanics, identify imbalances, and prevent injuries. Elinvision devices are also widely used in the footwear industry, where products need to be quickly and accurately adapted to different foot types or require fully customised solutions. They help reduce the likelihood of errors, optimise production processes, shorten the design time for insoles or shoes, and improve the ergonomics and comfort of the final product. Due to their accuracy, convenience, and technical stability, Elinvision scanners are considered among the most advanced devices of their kind in the region and are becoming increasingly popular in both medical institutions and commercial enterprises seeking to provide high-level, personalised services based on accurate, objective, and quickly obtained 3D data.

The Elinvision scanner was assembled according to the manufacturer's instructions and connected to a computer with special scanning software installed. The device and

cameras are checked for operation. The procedure is explained to the children. They take off their shoes and socks so that their entire feet are visible. The child steps onto the scanner platform, positions their feet correctly, and stands still. During the procedure, the foot is scanned in a few seconds. Immediately after scanning, a 3D image of the foot is displayed on the computer screen and the foot dimensions are automatically calculated. This process is quick, safe, and comfortable for children, enabling an accurate assessment of the foot's shape and dimensions [3].

The foot-scanning procedure during empirical research followed the following steps: Preparation, Positioning, Scanning, and Result Evaluation.

Preparation. The scanner is connected to the computer (USB), and the special Elinvision software is launched. The child takes off his shoes and socks (feet must be clean). The scanning mode is selected: full weight-bearing (the child stands on both feet).

Positioning. The child places one foot on the scanner's glass surface. It is monitored to ensure that the heel, 1st, and 5th metatarsal heads are at the same level, and that the Achilles tendon is vertical.

Scanning. The scanner uses multiple cameras and laser triangulation or structured light to capture a 3D model and a 2D colour texture. The process takes just 5-15 seconds.

Result analysis. A precise 3D foot model (accuracy ~0.5–1 mm) with a coloured texture is obtained, which can be viewed in the program. The model is exported in STL format, suitable for CAD programs for insole design or 3D printing. The program can automatically measure parameters (length, width, arch height, etc.) or analyse problems (flat feet, high arches, plantar fasciitis, etc.).

A multiple case strategy to detect behavioural patterns of parents and children in the case of flat feet condition. These four cases of children with flat feet are analysed further using a multiple-case strategy. The parents of these children with flat feet syndrome were asked to answer the interview questions. The interviews were conducted online, via MS Teams. One of the parents - father or mother - participated in the interview. The interview questions were formed on the following tasks:

- *To reveal the time and notice the symptoms of potential flat feet in children.* The parents were asked the following questions: “When did you notice that your child might have flat feet? What symptoms indicate that your child might have flat feet?”
- *To reveal the actions of the parents to deal with the condition. T*he parents were asked the following questions: “What measures did you take to improve your child's condition? What orthopaedic technical measures did you use and are you using to improve your child’s condition?”
- *To reveal children's reactions to the condition and treatment of their feet.* The parents were asked questions, such as: “How did your child react when you started using certain measures?”

Thematic analysis was used to analyse the interview data. The cases were coded and transcribed; no personal data was revealed.

3. RESULTS AND DISCUSSION

Four cases of flat feet were detected using the Elinvision scanner.

The significance of innovative technologies in scanning the feet. According to [1], the development of miniature, lightweight, and low-power electronic circuits for

healthcare sensor systems is becoming an increasingly important area of research. Rapid advances in health monitoring devices, microfabrication technologies, and wireless communications drive this. One area that has received considerable attention in biomedical and sports sciences is the analysis of plantar pressure, which enables the distribution of pressure between the foot and the shoe to be determined. Foot pressure measurements are used in footwear design, analysis of children's foot performance and injury prevention, balance control, and disease diagnosis. In recent years, these measurements have also been used for human identification, biometric systems, posture monitoring, and rehabilitation support systems. This shows that accurate and effective foot pressure measurement methods are very important for the further development of this field. The foot pressure measurement systems currently in use differ in sensor arrangement and operating principles. They are usually divided into three main groups: pressure measurement platforms, imaging technologies with complex image processing software, and in-shoe systems. The most important criteria in developing such systems are spatial resolution, measurement frequency, accuracy, sensitivity, and calibration. In-shoe foot pressure sensors offer greater mobility, flexibility, ease of use, and lower cost. For such a system to be suitable for monitoring daily activities, it must be wireless and consume little energy. Wireless foot pressure measurement systems are promising not only in medicine but also in the development of miniature sensors and data transmission systems. Platform systems consist of a flat, rigid matrix of pressure sensor elements arranged in a grid (matrix) pattern and integrated into the floor to enable natural gait measurements. These systems can be used for both static and dynamic studies, but are most often used only in research laboratories. One of the main advantages of platform systems is their ease of use, as they are stationary and flat. However, their disadvantage is that the subject needs a period of adjustment to ensure a natural gait. In addition, to obtain accurate measurement data, the foot must be centred in the sensor's measurement zone. The limitations of platform systems include the space required, the need to measure indoors, and the patient's ability to step accurately onto the platform. Figure 2 shows platform-type pressure sensors.

Figure 2. Platform-based foot pressure sensor system developed by Zebris Medical GmbH [13]

According to [6], feet are most often measured manually using devices such as Brannock measuring devices, Ritz rulers (Figure 3), or callipers to determine foot length and width. These manual devices have been in use for over a century and are widely used to assess footwear fit. Their advantages include ease of use, relatively low cost, and familiarity with those being measured. However, using manual methods when six or more measurements are required, especially if they are repeated, can be slow and therefore expensive. Alternatively, making plaster casts of the foot to produce therapeutic footwear can be a very time-consuming process for both orthopaedic technicians and patients. A large number of devices have been developed to scan patients' feet and obtain various foot measurements. One such device is the 3D foot scanner. A 3D foot scanner is a device that combines cameras and lasers to capture a person's foot dimensions and morphology.

Figure 3. Ritz ruler [8]

Parental behaviour patterns. Empirical data analysis revealed four different parental behaviour styles: Ignorance, Quick Solution, Seeking specialised help, and Providing complex support to the child.

Ignorance. This behavioural pattern is based on the parental attitude that there is nothing serious to deal with, as the parents did not recognise the issue. The mother, who participated in the interview, sees the child's foot condition as a genetic trait (“the child is walking like his father”). Accordingly, the parents do not initiate any actions because it is a natural matter (“the child will grow up, and all that will disappear with age”).

Quick solution. This behavioural pattern is based on the efforts to find the fastest solution. The parents recognised some issues (“The child started to get tired quickly,

he does not enjoy walking. He wears out the inside of his shoes"). The parents initiated some actions - they bought orthopaedic shoes and other supplements ("We bought shoes with a harder heel. We bought orthopaedic insoles") under the guidance of a family doctor (any other specialist is not mentioned).

Seeking specialised help. As in the case above, the parents recognised the issue ("The kid did not want to play active games") and brought the child to an orthopaedist, rather than a family doctor, as in the previous case. Following the orthopaedist's consultations, the parents bought orthopaedic shoes and arch supports.

Providing complex support to the child. This behavioural pattern is the most complex, which involves various means and stakeholders - *from family doctors to physical therapists, from shoes to training.* In this case, the flat feet were mentioned by a family doctor. The parents also recognised that a problem is there ("Weak knees, the legs have a form of X"). The parents ordered special shoes at the doctor's recommendation. In addition, the parents and the child are working together with a physical therapist.

It could be stated that a complex behaviour should be seen as an exemplary case in dealing with flat feet in children to avoid irreversible flat feet cases, as it is presented in Figure 4.

Figure 4. Irreversible flat feet [9]

Behaviour of the children. Case studies revealed that pes planus is an uncomfortable and quite painful issue: "The child sometimes feels pain in his legs/feet".

The children search for ways to avoid uncomfortable means to manage flat feet by removing the orthopaedic tools partially ("The child sometimes wants to take the insoles out of the shoes") or fully, especially while not at home ("The child wants to run barefoot in the class").

4. CONCLUSIONS AND RECOMMENDATIONS

Flat feet or pes planus, a condition in which the arch of the foot drops and the foot becomes flatter, causes various forms of discomfort, including pain in the feet, inward turning of the ankles, swelling around the ankles, uneven wear of the shoes, etc. Without preventive measures, flat feet in children may persist into adulthood.

The research was conducted with 24 children aged 7 while scanning their feet with the Elinvision scanner, an advanced, Lithuanian-developed three-dimensional foot-scanning device. Four cases of flat feet were detected.

The case study, during interviews with the parents of these four children, revealed four distinct behaviour patterns among the parents when dealing with flat feet in their children. The cases revealed varying degrees of parental involvement, from non-

existent (“Ignorance”) to complex involvement (“Providing complex support to the child”). At the same time, other behavioural patterns reflect the desire for quick solutions from the first /closest medical specialist (“Quick solution”) or from a specialised doctor (“Seeking specialised help”), but without complex solutions.
More comprehensive research could be conducted to analyse behavioural patterns, their consequences, and their preconditions in depth.

Recommendations

Flat feet are one of the most common foot development disorders in children, especially noticeable in children of primary school age. In first grade, a child’s foot is not yet fully formed, so it is especially important to focus on prevention and early rehabilitation during this period. Timely measures can help prevent the progression of flat feet and related gait and posture disorders. At this age, the reduction in the arch of the foot is often functional in nature and related to insufficient foot muscle strength. However, in some cases, flat feet can cause pain in the feet, calves, or knees, faster fatigue when walking, altered gait, or even posture disorders. In such cases, it is necessary to assess the child's feet promptly and implement targeted preventive and rehabilitative measures.
One of the most important factors in ensuring proper foot development is selecting appropriate *physical activity*. Regular active games, gymnastics, swimming, cycling, or climbing strengthen the feet and the whole body, improving balance and coordination. On the other hand, long-distance running on hard surfaces or intense jumping can increase the load on the feet, especially if the child feels pain or gets tired quickly.
Proper footwear is just as important. Shoes for first graders should be comfortable, the right size, have a sturdy heel reinforcement, and be flexible at the front of the sole. Shoes with completely flat or overly soft soles are not recommended. At home, it is particularly beneficial to let the child walk barefoot, as walking on uneven surfaces activates the foot's muscles and promotes the natural arch formation. If flat feet are diagnosed, an orthopaedic doctor may recommend individual orthopaedic insoles. These help improve the foot's position, reduce stress, and make walking easier, but should not be considered the main treatment.
Active rehabilitation, especially kinesitherapy focused on strengthening the foot's muscles, is of utmost importance. The rehabilitation process involves specialised exercises designed to strengthen the foot and calf muscles and improve coordination. Walking on toes and heels, picking up small objects with toes, rolling the foot on a ball or massage roller, and pulling a towel with toes – these are simple but effective exercises recommended for daily practice, presented in a way that is understandable and appealing to the child.
Parents play an important role in preventing and rehabilitating flat feet. They should monitor their child’s gait, posture, and general well-being, encourage physical activity, and develop healthy daily habits. Since flat feet and the tools to manage them are uncomfortable for children, parents and teachers should spend time educating and interacting with children by explaining the importance of healthy feet in terms children can understand.
If there is pain, rapid fatigue, or worsening of foot deformity, consult an orthopaedist or physical therapist promptly. In summary, the first grade is a particularly important period for foot development. Proper prevention, regular physical activity, and timely rehabilitation help ensure proper foot formation and reduce the risk of future musculoskeletal disorders. Thus, organising regular activities for children in

kindergartens and primary education institutions regarding healthy feet and prevention tools would be of great significance.
It is necessary to educate parents and society via social media (Instagram, TikTok, especially influencers) about flat feet in children and the prevention tools.
Among other measures, ensuring annual foot testing for children and providing clear, comprehensive, and visual medical information on the websites of health institutions and businesses selling orthopaedic tools, etc., should be implemented.

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