Non-invasive methods of treating hip dysplasia in infants – a scoping review

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Abstract

Background: Developmental dysplasia of the hip (DDH), characterized by abnormal development and maturation of the hip joint components, is one of the most common orthopedic problems in pediatrics.

Aims: The aim of this paper was to present and discuss, based on a scope review of the literature, non-invasive methods of DDH treatment in infants.

Material and methods: The literature review was conducted according to the 2020 updated PRISMA protocol using the extension for literature coverage review. The publication search process was conducted using the PubMed medical database.

Results: Overall, 121 publications were identified. A total of 18 full-text articles were investigated, 13 of which met the inclusion criteria. The reviewed articles describe the results of treatment with the Pavlik harness, Frejka pillow, as well as Tubingen and Denis Brown splint.

Conclusions: The choice of treatment depends primarily on the attending physician, who pays attention to the process of the disorder progression and the parents' needs. In the reviewed studies, the results of treatment with the selected methods were not found to be significantly different. Moreover, it was emphasized that systematic observation and assessment of dysplastic hips, and therefore deferral of treatment, in many cases allows orthotic treatment to be avoided due to the frequent normalization of hip parameters in the first months of life.

Key words

developmental hip dysplasia, infants, Frejka pillow, Pavlik harness, Tübingen splint.

Introduction

Developmental dysplasia of the hip (DDH) is characterized by abnormalities occurring between the femoral head and acetabulum with often associated joint capsule flaccidity [1]. It is one of the most common orthopedic problems in pediatrics, with an incidence ranging from 1 to 6 cases per 1,000 newborns, depending on a region and ethnic factors [2]. In Poland, DDH occurs in about 6% of the newborns (2% of which are congenital hip dislocations), affects girls more frequently, and involves the left hip joint three times more often [3]. Risk factors for DDH are primarily the breech positioning of the infant at birth, being female (about 75% of developmental DDH occurs in female infants), primiparity, and a higher risk family medical history. The risk of DDH also depends on environmental and cultural factors related to how an infant is cared for and carried [4].

Diagnosis of DDH includes physical examination using clinical tests, as well as X-ray and ultrasound imaging. A correct physical examination should include checking for differences in the length of the lower limbs, lack of symmetry of the femoral or gluteal sulcus, as well as Ortolani and Barlow test [4]. The Ortolani test involves guiding the head of the femur back into the acetabulum (reduction of hip dislocation). The test is positive if the hip joint relocates with the usually accompanying 'clunk' sound. Barlow maneuver is a screening test used to identify DDH with or without instability. The test is positive if the hip joint relocates (displacement of the femoral head from the acetabulum), often without a palpable or audible click. Another sign of a dislocated hip joint is a positive Galeazzi sign manifested by an apparent limb length discrepancy [4, 5]. Nevertheless, it is important to remember that mild cases of DDH defined by a lateral center-edge angle (LCEA) of 18° - 25° may not produce any symptoms or be physically visible in infants or older children, so the diagnosis is worth supplementing with imaging testing [4,6].

Ultrasound is a commonly used method of diagnosis because it provides detailed static and dynamic imaging of the hip joints even before the femoral head ossifies [4]. Graf classification is based on ultrasound results, the purpose of which is to assess the morphology of the hip joint quantitatively and qualitatively [7]. The classification includes a critical assessment of the anatomical features of the hip joint and the results of two measurements: the alpha angle (α), which is a measure of the slope of the superior surface of the acetabulum, and the beta angle (β), which evaluates the acetabular cartilage. Based on the measurements obtained, the type of hip joint is determined (**Table 1**) [8].

The International Hip Dysplasia Institute (IHDI) has developed a radiographic classification system for quantifying the degree of femoral head displacement. IHDI's proposed classification uses the position of the proximal femoral epiphysis (instead of the ossification center) as an important reference point [9].

Ultrasound imaging also makes it possible to calculate the percentage of femoral head coverage (FHC), an indicator that is also significant in determining the normal development of the hip joint. According to the method developed by Morin et al. [10], FHC is defined as the ratio of the acetabular width to the maximal femoral head diameter. In a normally developing hip joint, FHC reaches approximately 50% [11].

Radiographic screening of the hip joints is recommended for infants with risk factors, such as a family history of postural defects or abnormal physical examination results at 4 months old. However, it should be emphasized that there is no justification for performing ultrasound before 3-4 weeks old in newborns with suspected DDH, due to physiological flaccidity, which usually disappears by the age of 6 weeks [4].

In infants with DDH, early detection of the disorder and treatment referral allows for appropriate intervention, which may help prevent the need for reconstructive surgery [4]. Whether making a diagnosis or planning DDH therapy, clinicians should follow evidence-based medicine (EBM) and evidence-based practice (EBP). The quest for effective methods, should include a thorough analysis of current scientific reports and critical evaluation, taking into account clinical and practical knowledge, with the aim of selecting solutions that are best for the patient and his family. Hip orthoses such as the Frejka pillow, Denis Browne splints, von Rosen splints, Craig-Ilfeld splints, and the Tübingen orthosis are used in the treatment of DDH [12], but the most common treatment in children under 6 months old with imaging or clinical symptoms of significant DDH is Pavlik bracing [13]. It involves the use of Pavlik Harness (PH), which keeps the hip joints in flexion and abduction, positioning the femoral head in the acetabulum to facilitate its reshaping [13]. The Tübinger splint, on the other hand, is a rigid fixation-abduction orthosis that positions the hip joints in 90-110° of flexion and limits their inversion to 40-50°. In this position, the pressure in the hip joint is distributed evenly with less tension on the vessel walls, reducing the frequency of avascular necrosis associated with DDH treatment [14, 15]. The Frejka pillow is a type of orthotics, made up of foam rubber and a fabric cover. It is worn by the child and attached with straps that covers the shoulders and waist so that the hip joints are kept in flexion and abduction [16]. It is worth mentioning that regardless of the method used, the reduction of deformed hip joints should not be treated in a forced manner and with extreme positions [4].

Aims

The aim of this research was to present and discuss, based on a scoping review of the literature, the types of non-invasive treatment methods for DDH in infants.

Material and methods

The literature review was conducted in accordance with the 2020 updated PRISMA protocol [17], using the extension for *scoping review* [18]. The search for scientific publications was conducted using the PubMed medical database in the advanced search model by entering the phrases/keywords: hip dysplasia and infants found in the title and/or abstract of the article (search link used on: 09.03.2021: *https://pubmed.ncbi.nlm.nih.gov/?term=%28%22hip+dysplasia%22%5BTitle%2FAbstract%5D%29+AND+%28infants%5BTitle%2FAbstract%5D%29&filter=years.2000-2021*).

The inclusion criteria for the review were the use of a non-invasive treatment method for DDH, children's age - infants, and years of publication - from 2000 to 2021. Publications on imaging methods, diagnosis, screening, and epidemiology of DDH, as well as articles in languages other than English were excluded. For each included study, the level of methodological value was estimated according to Sackett's categories [19, 20].

Results

A total of 121 scientific publications were identified. Based on title and abstract, 103 papers were excluded. The full content of 18 articles was analyzed, 13 of which met the inclusion criteria (**Figure 1**). Nine papers representing research with treatment were selected and analyzed in detail in **Table 2**. The following information was extracted from each study: first author and year of the study, study objectives, characteristics of the participants, type of equipment/therapy used, details of the intervention, results, and conclusions. All the included papers were classified in category 5 according to Sackett's classification.

Table 1. The Graf ultrasound classification [8].

Type	Angular values	Description
Ia	α 60° β < 55°	Fully mature joints with a well-developed acetabular roof, the cartilaginous roof and articular rim cover the femoral head and are not elevated. 7x more common than type Ib; narrow and long cartilage roof covers the femoral head broadly
Ib	α 60° < β > 55°	Cartilaginous roof short with a wide base
IIa	α 55-59° β > 55°	Joints of children up to 3 months of age, acetabular roof not fully developed, rounded outer bone edge, expanded cartilaginous roof is not raised and includes the femoral head
IIb	α 55-59° β > 55°	When the above angles occur after 3 months of age
IIc	α 43-49° β > 55°	Joints with significant dysplasia at the border of femoral head decentration and with defective formation of the acetabular roof; rounded/flat outer bone margin; short cartilaginous part of the roof with a wide base covering the femoral head
D	α 43-49° β 70-77°	Joints with decentration of the femoral head, a malformed acetabular roof, a flat external bone edge, and a short with a wide base and a raised cartilaginous roof
IIIa	α < 43° β > 77°	Poorly formed acetabular roof with flat outer edge, widened and elevated cartilaginous roof with normal vitreous cartilage of the roof
IIIb	α < 43° β > 77°	Poorly formed acetabular roof with flat external edge, widened and upwardly elevated cartilaginous roof with fibrous transformation of the vitreous cartilage of the roof
IV	α < 43° β > 77°	The cartilaginous roof and the articular labrum compressed by the displaced femoral head

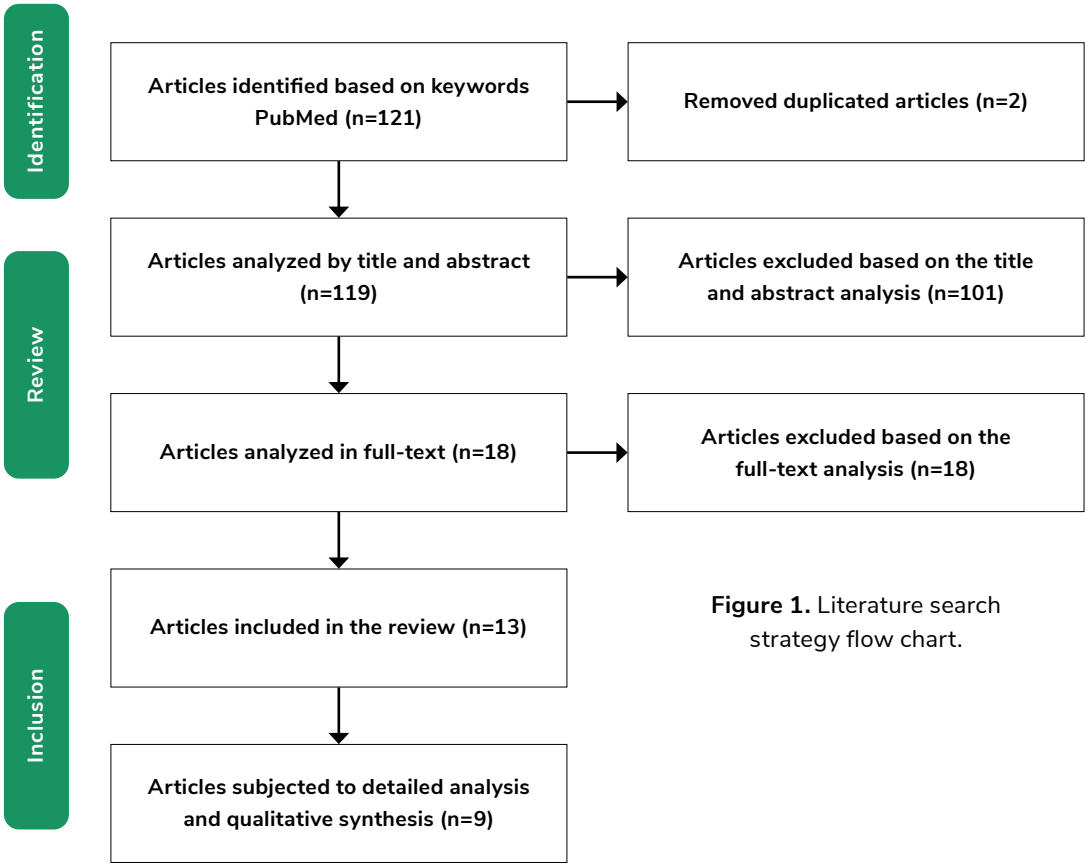

Figure 1. Literature search strategy flow chart.

Table 2. Review of studies describing non-invasive treatments for hip dysplasia in infants.

Author and year of publication	Recommendation categories according to Sackett / Sackett levels	Purpose of the study	Characteristics of the study group	Type of equipment / therapy used	Details of the intervention	Results	Conclusions
Tegnander et al. (2001) [16]	5	Evaluation of the results of hip dysplasia treatment with the Frejka pillow.	N=108 patients (94♀, 14♂) **Age:** no data (ND) **Number of joints:** 144, including: 36 infants with bilateral dysplasia. **Additional information:** Positive Barlow or Ortolani test at baseline.	Frejka pillow	Treatment with the Frejka pillow lasted 4 months and was started immediately after abnormal results were obtained in the child's hip ultrasound. First follow-up: 2-3 months of age, second follow-up: 4-5 months of age, third follow-up: 12-14 months of age. In addition, a pelvic X-ray was performed.	N=97 infants had a normal hip joint (assessed by ultrasound and X-ray) at 4-5 months of age. N=5 abnormal findings at 4-5 months of age, of which: spontaneous normalization occurred in 2 children. Ineffective treatment in N=3 children (3%). Aseptic necrosis of the femoral head occurred in one patient (1%).	The treatment outcomes for infants using the Frejka pillow have been good, with a few therapeutic failures and treatment complications. It is recommended that the Frejka pillow be used when treatment begins within the first few days of life. It is the easiest tool for the child's parents to use and requires fewer follow-up visits compared to other tools.
Hakan Atalar et al. (2014) [21]	5	Presenting the treatment results of infants with DDH who were treated with the Tübingen splint.	N=49 patients (45♀, 4♂) **Age** (at start of treatment): 18 weeks **Number of joints:** 60 **Additional information:** Hip joint types according to Graf classification: Type IIb: N= 19 Type IIc: N= 27 Type IIIa: N= 10 Type IIIb: N= 2 Type D: N= 1 Type IV: N=1	Tübingen splint	Procedure protocol: Duration of orthosis use: Wear time: Graf type IIc or worse: 24h/day, Graf type IIb: >23h/day Follow-up examinations: I: after 3 or 4 weeks. II: after another 2-4 weeks. Treatment was continued until the maturity of the acetabulum was demonstrated. Initial use of the orthosis was followed by a period of gradual weaning.	Treatment was successful for 56/60 hip joints (93%). Median total treatment time (from initial orthosis insertion to completion of withdrawal) = 17 weeks (range 14-20). Median duration of treatment (not including subsequent withdrawal period) with the Tübingen splint = 8 wks.	In infants with an early diagnosis of DDH, the Tübingen splints an effective form of treatment. There is no difference between successfully and unsuccessfully treated hips in terms of age at onset, initial hip stability scores, Graf type, or number of hips treated.

Hakan Meroglu et al. (2016) [22]	5	Determine whether variables such as age, gender and lateralization, comorbid risk factors, including family history, location and severity of hip dysplasia, as determined by ultrasound, are associated with differences in PH treatment efficacy in infants with DDH.	N=130 patients (106♀, 24♂) **Age** (at diagnosis and start of treatment): 108 ± 41 days (range 26-207 days) **Number of joints:** 181 **Additional information:** Distribution of dysplasia Right-sided: N=28 patients Left-sided: N=51 patients Bilateral: N=51 patients	Pavlik harness	Treatment protocol: Treatment was started as soon as dysplasia type IIa or worse was found. Interval between follow-up ultrasound examinations 3-4 weeks. Successful treatment: obtaining a Type I hip joint according to Graf. Treatment ineffective: hip joint initially Graf type D, III or IV did not progress to a better hip type within each 3- to 4-week follow-up period, or hip joint initially Graf type IIa, IIb or IIc did not progress to a better hip type within 8 weeks.	Treatment with PH was successful in 92 (71%) patients (130 of 181 hips). The average treatment period was 59 ± 31 days (range, 16-168 days). The highest success rate was achieved in children less than 3 months old (37 of 40 [93%]), and the lowest in those older than 5 months (9 of 24 [37%]). An age of more than 120 days or more was the threshold for an unsuccessful outcome (sensitivity 66% and specificity 77%). An initial angle of α= 46° and less was the threshold for an unsuccessful outcome (sensitivity 47% and specificity 86%). Treatment efficacy according to Graf types: Type IIa = 27 of 29 (93%) Type III = 5 of 19 (26%) Type IV = 2 out of 4 (50%). Treatment success by type of hip stability: stable hip joints: 112 of 142 (79%]; unstable hip joints: 18 of 39 (46%). Treatment success rate for unstable hip joints: dislocated hip joints: 7 of 23 (30%) decentered hip joints: 11 of 16 (69%).	Treatment with PH has a high probability of failure in older infants, in hip joints with displacement and with severe acetabular bone defects. The threshold values in terms of age and α-angle associated with an increased risk of failure are 4 months or older and 46° or less, respectively. Parents of such patients should be informed of the high risk of treatment failure.

Alex Aarvold et al. (2019) [23]	5	Compare methods and outcomes of treating infants with hip dislocations to optimize treatment. Analyze variables associated with increased risk of treatment failure in this patient group.	N=52 patients (41♀, 11♂) **Age** (at diagnosis): 1.9 months (range 0.1 to 5.9 months). **Number of joints:** 59 **Additional information:** Distribution of dysplasia: left-sided: N=33 patients, right-sided: N=12 patients, bilateral: N=7 patients	Pavlik harness, Rhino Cruiser brace, Denis-Browne splint	1) Management protocol for patients treated with orthopedic devices: treatment with PH minimum 23h/d). After treatment failure (21 hip joints) in PH, alternative braces were used in 5 patients (5 hip joints): N=1 Denis-Browne splint, N=4 Rhino orthosis. Closed (7 hip joints) or open (12 hip joints) reduction was used in 19 hip joints where treatment with braces failed. 2) For 13 hip joints (12 patients), treatment methods other than PH were used. In the case of 3 hip joints (2 patients), alternative braces were used first (unsuccessfully) and then PH or reduction surgery, and in 10 patients only primary open or closed reduction surgery was performed.	48 hip joints were treated with PH. Treatment of 27 hip joints was successful with normalization of parameters assessed by ultrasound. The total treatment time in PH ranged from 43 to 106 days. IHDI classification at final follow-up: 53/59 hip joints grade 1, 6/59 grade 2. A higher acetabular index (AI) was found in hip joints not treated with PH (mean, 26°; range, 10° to 40°).	Treatment with PH has been shown to be a safe and reasonable first-line treatment option for infants with dysplastic hip joints.
Cook et al. (2019) [1]	5	Determine whether a protocol for deferring PH-assisted treatment in infants with a positive Barlow test reduces the need for PH or other treatments at an equivalent rate of effective hip stabilization.	N=30 patients (26♀, 4♂) **Age:** ND **Number of joints:** 39 **Additional information:** Positive Barlow score within the first 2 weeks of life. Distribution of dysplasia: left-sided N=18 patients, right-sided N=3 patients, bilateral N=9 patients.	Pavlik harness	Management protocol: Postponement of treatment with PH - return to clinic between 4 and 6 weeks of life: I. Determination of instability - initiation of PH treatment. Treatment time: a minimum of 23 hours; II. Determination of stable hip joint with angle α<60°- defer treatment again; III. Determination of clinically stable hip joint with angle α> or equal to 60°-no treatment. Follow-up visit at 12 weeks of age for infants in group II	Of the 19 infants (25 hips) who had stable hip joints at 4-6 weeks of age. 7 (23%) (8 hip joints) required treatment with PH at 12 weeks due to persistent dysplasia found on ultrasound. 11 infants (37%) (14 hip joints) required treatment with PH at 4-6 weeks due to persistent instability (all 14 hip joints stabilized with PH treatment). Average duration of PH treatment according to the age at which treatment was started: age 4-6 weeks: average 7 weeks (range 3-11	Treatment with PH before 4 weeks of age is not necessarily a necessity. Deferring harness treatment for infants with Barlow-positive hips can benefit both the infant and the parents.

					1) Graf I - postponement of PH treatment again 2) α<60° - start treatment with PH for at least 6 weeks until α angle normalizes to greater than or equal to 60°.	weeks); age 12 weeks: average 8 weeks (range 6-10) before harness withdrawal. n=12 (40%) (17 hips) completely avoided treatment with PH using this protocol.	
Michal Zídka et al. (2019) [24]	5	Comparison of effectiveness and duration of DDH treatment depending on the orthosis used (Frejka pillow or PH).	N=282 patients (sex: ND): N=145 patients treated with Frejka pillow; N=137 patients treated with PH **Age:** (at the start of treatment): 40 days patients treated with the Frejka pillow; 35 days patients treated with PH **Number of joints:** ND **Additional information:** Joint types according to Graf classification: Type IIa and IIc: N=208 patients, Type D: N= 41 patients Type IIIa: N= 32 patients Type IV: N= 1 patient	Pavlik harness / Frejka pillow	The choice of abduction device was decided by the attending physician. Milder deformities (e.g., acetabular dysplasia without instability) - most often treated with a Frejka pillow. More severe dysplasia (e.g., unstable and decentered hip joints) - most often treated with PH. Follow-up examinations: every 3-6 weeks. Treatment continued until an α angle of at least 60° was found on ultrasound (Graf I).	Treatment was successful in all 282 cases Average treatment time: Frejka pillow: 95 days (4-28 weeks); PH: 119 days (5-34 weeks). Mean treatment time by Graf type with Frejka pillow and PH: IIa and IIc: 13.2 (± 4.5) and 16.3 (± 5.6) weeks, respectively; Type D: 14.3 (± 3.7) and 18.7 (± 4.0) weeks, respectively; Type III: 19.6 (± 4.4) and 18.7 (± 4.3) weeks, respectively. A statistically significant correlation was found between nonadherence to the treatment regimen in patients treated with PH compared to those treated with the Frejka pillow.	Both methods have shown the same good efficacy. There are no clear-cut criteria for choosing a particular treatment aid for a particular pathology and a particular patient. The doctor's decision depends mainly on personal experience with a particular device, the severity of the disease, the size of the child, the presence of any muscle contractures, and the level of expected cooperation with the parents of the treated child. A significant tendency to neglect the treatment protocol (spontaneous discontinuation of treatment or "switching" to another specialist) was found in patients treated with PH, while treatment with the Frejka pillow showed no such tendency.

Pollet et al. (2020) [2]	5	Objectification of the effect of treatment with PH versus active monitoring in infants aged 3 to 4 months.	N=104 patients (sex: ND): N=49 patients under active monitoring, N=55 patients treated with PH **Age:** 3 to 4 months of adjusted age **Number of joints:** 114 **Additional information:** Patients with a diagnosis of clinically stable hip dysplasia according to Graf classification type IIb and IIc.	Pavlik harness, active monitoring	Random assignment of participants to treatment with PH or to active surveillance group. Ultrasound follow-up: after 6 weeks and after 12 weeks of follow-up. After 6 weeks of follow-up, 3 patients in the active surveillance group received PH due to deterioration of the α angle. In another 7 patients, it was decided to start treatment with PH after 12 weeks of follow-up due to persistent dysplasia (Graf IIb).	After 12 weeks of follow-up, the mean α angle was 60.5° ± 3.8° in the PH treatment group and 60.0° ± 5.6° in the active surveillance group (p=0.30). Progression of α angle was calculated for both the treatment group and the active surveillance group after 6 and 12 weeks. There was no difference in treatment effect between the two groups.	The α angle was corrected in both groups at a similar rate. Treatment with PH of stable but dysplastic hip joints on ultrasound imaging has no effect on acetabular development. 80% of patients will have normal hip joint development after twelve weeks.
Zhou et al. (2020) [15]	5	Evaluation of the efficacy and safety of the Tübingen splint in the treatment of DDH in infants aged 0-6 months.	N=153 patients (sex: ND) **Age** (at the time of diagnosis and initiation of treatment): 8.6 ± 5.6 weeks (range: 1-29 weeks). **Number of joints:** 203 **Additional information:** Graf classification Type IIc: N=67 patients (81 hip joints) Type D: N=36 patients (50 hip joints) Type III: N=23 patients (35 hip joints) Type IV: N=27 patients (37 hip joints).	Tübingen splint	Management protocol: Patients were fitted with a Tübingen splint with hip flexion 90-110° and hip joint abduction <60°. 1) Type IIc - wearing the splint for at least 22 hours a day; 2) Type D, III or IV - wearing the splint for 24 hours a day.	Treatment was considered successful (normal hip X-ray) in 128/153 patients (165/203 hip joints). Mean treatment time 4.2 ± 2.2 months (range: 1-12 months). Treatment failed in 25 patients (38 hip joints including: 2 type IIc hip joints, 4 type D hip joints, 6 type III hip joints and 26 type IV hip joints). Perivascular necrosis occurred in 3 patients. The cutoff value for age at onset in relation to treatment success was 12 weeks (sensitivity 40% and specificity 88.3%).	The Tübingen splint has been shown to have good efficacy and safety in the treatment of DDH in infants aged 0-6 months. A family history of DDH, type IV according to the Graf classification, bilateral joint involvement, and starting treatment after 12 weeks of age are risk factors for treatment failure.

Bram et al. (2021) [13]	5	Comparison of x-ray findings of two groups of infants with DDH treated with PH; 1) with harness weaning protocol and 2) with withdrawal weaning.	N=53 patients (7♂, 46♀) Group I (treatment with withdrawal protocol): N=27 (5♂, 22♀) Group II (abrupt discontinuation of PH after normalization of parameters in ultrasound): N=26 (2♂, 24♀) **Age:** (at the start of treatment) Group I: 16 days Group II: 17 days **Number of joints:** 64 (32 dislocated and 32 with stable dysplasia) **Additional information:** ND	Pavlik harness	Management protocol: 1) use of PH a minimum of 23 hrs/day until normalization of ultrasound parameters (α ≥ 60°, FHC ≥ 50%): Group I infants move to a gradual withdrawal of treatment protocol. Group II infants - abrupt withdrawal - treatment is discontinued without treatment withdrawal protocol.	Comparison of results between: A. stable hip groups: - FHC: 54 ± 3 for patients without withdrawal protocol, 61 ± 8 for patients with withdrawal protocol - α: 66 ± 4 for patients without withdrawal protocol, 66 ± 4 for patients with withdrawal protocol - Number of hours spent in harness: 1066 ± 146 hours for patients without withdrawal protocol, 1540 ± 150 hours for patients with withdrawal protocol B. hip dislocation groups: - FHC: 52 ± 3 for patients without the withdrawal protocol, 62 ± 11 for patients with the withdrawal protocol - α: 64 ± 3 for patients without withdrawal protocol, 63 ± 6 for patients with withdrawal protocol - Number of hours spent in harness: 1363 ± 264 hours for patients without withdrawal protocol, 1597 ± 230 hours for patients with withdrawal protocol.	Despite the longer total treatment time with PH, infants with the additional withdrawal protocol showed no significant differences in x-ray imaging at 1 year of age compared to those who were discontinued immediately after improvement in ultrasound imaging.

Discussion

The reviewed articles describe the outcomes of treatment using Pavlik harness, Frejka pillow, Tübingen orthosis, Denis Brown splint, and Von Rosen splint, and point out the advantages of deferring treatment.

Pavlik harness is the most common method used to treat DDH. It allows for hip and knee joint movement, with the hip joints positioned in flexion and abduction, making it easier to care for the child without having to remove the orthosis. [16]. In a study conducted by Omeroglu et al. [22], treatment with PH was effective in 71% of patients. The authors pointed out a high failure rate in the following cases: starting treatment when the infant is 120 days old, and in the treatment of hip joints with severe acetabular bone defects. Treatment success rate, in children younger than 3 months old, was more than 90%, but this figure dropped to about one-third in patients older than 5 months. The threshold value that increases the rate of treatment failure with PH is an infant's age of 4 months or more [22]. Furthermore, there were no significant differences in joint radiographs in one year old toddlers treated with PH with a withdrawal protocol when compared to patients in whom withdrawal of treatment followed immediately after improvement in ultrasound imaging [13]. Aarvold et al. [21], supported the argument that treatment with PH is safe if accompanied by continuous monitoring. The research did not suggest that age, gender, or bilateral DDH were associated with success or failure of the treatment. One of the limitations of this study was that the patient follow-up data covers only 2 years. Although no patient required subsequent surgery for residual DDH, this one may persist or occur beyond this time period [23]. The disadvantages of treatment with PH are undoubtedly the need for weekly hospital visits in order to adjust the belts to the changing growth of the child and, although rare, serious complications of treatment such as femoral nerve palsy, lower hip dislocation and avascular necrosis [16]. The relatively high incidence of femoral avascular necrosis with PH use (up to 30%) can be attributed to excessive hip joint(s) abduction, due to the not-so-rigid design of this orthosis [15]. Treatment with PH is a safe and reasonable first-line treatment for infants with a hip joint referred to in the English literature as D/I (dislocated irreducible), however, close clinical observation and ultrasound imaging should be maintained [23]. Moreover, patients' families should be properly trained, as parents' failure to follow the treatment protocol could have serious consequences. Understanding the principles and necessity of the treatment by the newborn's parents is crucial to the success of the treatment [24]. An interesting point of view was presented by Cook et al. [1], who recommended postponing the treatment with PH, claiming that treatment with a harness before the fourth week of life is not a necessity. The authors of the research that compared the effects of treatment with PH against active monitoring in infants between 3 and 4 months old reached similar conclusions. In the study conducted by Pollet et al. [2], progression of the α angle was achieved in both the PH-treated group and the actively monitored group (without the use of any orthosis), and correction occurred at a similar rate. The authors recommended observation, rather than treatment, of all well-centered and stable hip joints according to current ultrasound classifications [2], which is in line with the findings of a research conducted by Sakkers and Pollet in 2018 [25], where over 80% of type IIa to IIc hip joints were shown to normalize without treatment. This will help avoid a significant number of interventions that put a strain on both families and the health care system [25].

One other recommended tool for the treatment of DDH is the Frejka pillow, effective especially when therapy is introduced within the first few days of life. Tegnander et al. [16], achieved a 93% success rate for treatment with the Frejka pillow with a complication rate of only 1%, which was the

occurrence of avascular necrosis of the femoral head in one patient. One advantage of the pillow is the simplicity of application and use, good tolerance by the child and low cost. The disadvantages are parents' deviation from the treatment protocol, especially during months characterized by high temperatures, due to the frequent occurrence of skin lesions from contact with the pillow, and poorer effectiveness when compared to rigid tools. It has also been observed that limiting hip mobility has a negative impact on the function of the digestive system, and the need to change to a larger sized pillow as the child grows, increases medical costs. These disadvantages can lead to parental noncompliance, slowing down the course of treatment [24]. Although the Frejka pillow is the simplest hip joint abduction tool to use by parents, it has a high rate of treatment failure. More rigid tools, including the von Rosen splint, have a lower rate of treatment failure, however, they are associated with an increased risk of avascular necrosis of the femoral head due to compression of blood vessels by excessive hip joint abduction [16, 26].

Zídka and Džupa [24], did not demonstrate that one tool, such as PH or the Frejka pillow, was more effective than the other. Their research favored the Frejka pillow in patients with milder degrees of DDH, without muscle contractures and treated in an outpatient setting. In contrast, PH was more often recommended in cases of unstable hip joints, in children with muscle contractures, and in patients treated in outpatient clinics with 24-hour accessibility [24]. Patients treated with PH exhibited a clear tendency to neglect the treatment protocol, while the Frejka pillow treatment process did not show such a tendency, which means that the comfort of the used abduction orthosis may be an important factor in the success and effectiveness of treatment.

The use of the Tübingen splint has good effectiveness and safety in the treatment of DDH in infants aged 0-6 months. Factors that may contribute to a negative treatment outcome may include: bilateral hip involvement, a family history of DDH, and the patient's age of more than 12 weeks at the start of treatment [15]. The later the start of the intervention, the lower the treatment success rate. Research conducted by Zhou et al. [15], showed that patients in whom treatment was successful started using the splint significantly earlier (by almost a month) than patients in whom treatment was unsuccessful. Another factor that affects the results of DDH treatment with the Tübingen splint is the severity of the disorder. The percentage of intervention failures for Type IV hip joint according to Graf was significantly higher than for other types of hip joint based on this classification. In the study conducted by Atalar et al. [21], the intervention was successful in 56 out of 60 hip joints (93%). Successfully and unsuccessfully treated hips did not differ in terms of the patient's age at the start of treatment, initial hip stability scores, Graf type, and the number of hip joints undergoing surgery. Treatment with the Tübingen splint has a high success rate, but more detailed research needs to be done on the effects of various parameters on treatment outcomes.

Limitations of the papers included in the review

The studies included in the review aimed at evaluating the effects of the applied therapy with a comparison of pre- and post-intervention results, without a control group, and whose methodological value and strength of scientific evidence were low. Limitations of the discussed studies were primarily: the small number of intervention failures which limited statistical power, different times of patients wearing the orthoses, the withdrawal of some infants' parents from the treatment, and the short follow-up time. Several of the analyzed papers were merely series of case studies and did not include a control group due to lack of data or resources. It is worth diversifying the demographic group of patients, increasing the number of analyzed cases and creating a control group of patients whose treatment was not deferred, in the future research. Analyzing the control group in future studies would allow for an investigation of

how delaying treatment affects the required duration of therapy and its effectiveness. Moreover, it is necessary to conduct large, prospective, randomized studies involving homogeneous data with long-term follow-up and to compare the course and effectiveness of the Tübingen splint with PH treatment, the Frejka pillow and other orthoses.

Involving patients and their families early in the process of developing a management algorithm will be crucial to identifying their priorities and addressing their main concerns in future interventions. Efforts to improve care of children with DDH in different settings require a broader, global, and holistic approach, which will be achieved mainly through the preparation and development of international records on the standards of practice of different health systems [27].

Conclusions

A primary topic of discussion in the treatment of infants with radiologically detected DDH and with dysplastic but clinically stable hip joints is whether orthotic treatment significantly improves therapeutic outcomes. There are no clear criteria for choosing a specific DDH treatment [24]. Given the lack of strong scientific evidence on the effectiveness of particular methods, the physician's decision should depend mainly on personal experience with a particular tool, the severity of the disorder, the child's age, the presence of possible muscle contractures, and the cooperation with the parents of a treated infant [24]. Due to frequent and spontaneous resolution of DDH in early infancy and rapid changes in ultrasound indices during the first 12 weeks, observation alone may be as effective as the use of orthoses in this population [27]. Based on the existing literature, the following questions require advanced examination: does the Pavlik method serve as the first-choice method for treating Type IV hip joints according to the Graf scale and is it the best choice for conservative treatment of DDH [28].

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