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Active monitoring versus immediate abduction as treatment of stable developmental dysplasia of the hip: a systematic review of the literature

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ABSTRACT

Objectives This systematic review aims to compare the effects of active monitoring and abduction treatment on the Graf alpha angle, Acetabular Index (AI) and femoral head coverage in infants with stable developmental dysplasia of the hip (DDH).

Design Systematic review reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

Data sources A search of the PubMed, Embase, Cochrane and Web of Science databases was performed in January 2020 and updated in January 2021.

Eligibility criteria (Non-)randomised studies comparing active monitoring with abduction treatment in infants younger than 4 months with stable DDH were included.

Data extraction and synthesis All eligible articles were methodologically assessed using the Cochrane risk of bias tools. Data were extracted by summarising the study characteristics and results.

Results Of the six included studies, two randomised studies were of low risk and two of some concerns. Two non-randomised studies were of serious risk. In total, 544 dysplastic hips (439 infants) were investigated, of which 307 were observed and 237 were treated. Two studies reported a faster improvement of the alpha angle and average acetabular coverage in treated hips at 3 months. No differences in AI between the treatment and observation group after 3 months were reported. In total, 38 infants (12%) in the observation group switched to the treatment group. At the final radiograph, 21 observed hips and 32 treated hips were dysplastic.

Conclusions There were no differences in AI between the treatment and observation group after 3 months in infants up to 4 months of age with stable DDH hips. The switch of 38 infants (12%) from the observation to the treatment group corroborates that not all infantile DDH hips will spontaneously progress into normal hips. The small study population sizes and methodological heterogeneity warrant a large randomised controlled trial to study this research question.

PROSPERO registration number CRD4202123300.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ All identified studies, independent of the quality of the studies, were included in this systematic review. Thus, providing a complete overview of current literature.
- ⇒ Risk of bias of the included studies was extensively reviewd.
- ⇒ Great heterogeneity in measurement methods and measurement moments of the included studies, made it difficult to compare study results and impossible to perform a meta-analysis.
- ⇒ There was great heterogeneity in the quality of the included studies, since two non-randomised studies classified as serious risk of bias.

INTRODUCTION

Developmental dysplasia of the hip (DDH) is one of the most common paediatric orthopaedic disorders in newborns and young children.[1 2] DDH comprises a spectrum of developmental hip abnormalities ranging from mild dysplasia of the acetabulum to dislocation of the femoral head.[3 4] The incidence rate of DDH differs per geographic location, ethnic background and diagnostic definition and varies between 1/1000 and 20/1000.[2 4 5] Untreated DDH can result in short-term and long-term morbidity, such as, chronic pain, gait abnormalities and early hip osteoarthritis.[4 6] To detect DDH at an early age, screening programmes have been implemented worldwide.

Controversy exists on the optimal screening method to detect DDH (universal screening vs selective screening) and timing differs considerably worldwide.[7 8] In the Netherlands, all newborns are screened for DDH within the first month after birth by the Dutch national screening programme. When newborns present with an abnormal clinical examination (knee height, passive hip abduction and the Ortolani and Barlow manoeuvres) or when risk factors (family history, breech position) are present, the newborn is referred for an ultrasound at the age of 3 months. If there is a suspicion of luxation, the infant is referred for an ultrasound within 2 weeks.[8 9]

In Europe, selective screening is also used in Belgium, France, Portugal, Sweden, Norway, Hungary, the UK and Ireland. Conversely, Austria, Germany, Switzerland, Italy, Slovenia and Slovakia use a universal ultrasound screening method.[7] The timing of ultrasound screening ranges from week 1 to week 12.[7] A third screening method is universal screening including clinical examination only.[10] Existing literature comparing screening methods is scant and shows methodological heterogeneity.[7]

Limitations of clinical examination alone are the lower sensitivity, difficulty to identify subtle signs and the majority of positive Ortolani or Barlow manoeuvres will spontaneously resolve within 2–4 weeks after birth.[10 11] Ultrasonography according to the Graf method is one of the most used methods to diagnose and classify DDH.[12 13] The Graf method classifies type two hips as stable but dysplastic hips and type three hips as unstable or luxated hips.[9] Hip ultrasonography facilitates the ability to identify smaller anomalies, thereby possibly introducing overdiagnosis.[11] A study by Roovers *et al* suggests that 85% of infantile DDH will resolve by the age of 3 months without treatment initiation.[14] The hypothesis that stable hips tend to spontaneously progress into normal hips is supported by current literature.[6 15] Currently, abduction treatment is the most opted DDH treatment in children younger than 6 months.[16] However, it is debatable whether abduction treatment alters the natural course of stable hips.[6] A study by Pollet *et al* did not find a difference in acetabular development between abduction treatment and active monitoring in infants with stable hips at the age of 3 to 4 months.[2] Therefore, the preeminent question is whether stable hips (Graf type 2) are truly pathological and warrant abduction treatment.[6] Furthermore, abduction treatment might expose the infant to complications, such as avascular necrosis (AVN) of the femoral head and transient femoral nerve palsy.[3] A systematic review of the literature is needed to summarise existing studies comparing abduction treatment and active monitoring in stable hips. The results of this systematic review might impact current screening and treatment methods and will identify knowledge gaps.

The aim of this systematic review is to compare the effects of active monitoring and abduction treatment on the Graf alpha angle, Acetabular Index (AI) and femoral head coverage (FHC) in infants with stable DDH (Graf type 2).

MATERIALS AND METHODS

Search strategy and protocol

This systematic literature review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[17] (online supplemental appendix 1). A flowchart of this process is depicted in figure 1. The databases PubMed, Embase, Cochrane and Web of Science were systematically searched in January 2020. The search was updated in January 2021. Citation software (Endnote V.X9.3.3, Clarivate Analytics, Boston, Massachusetts) facilitated the search strategy. A Boolean for the search string with the used keywords and index terms (Mesh headings) is provided (online supplemental appendix 2).

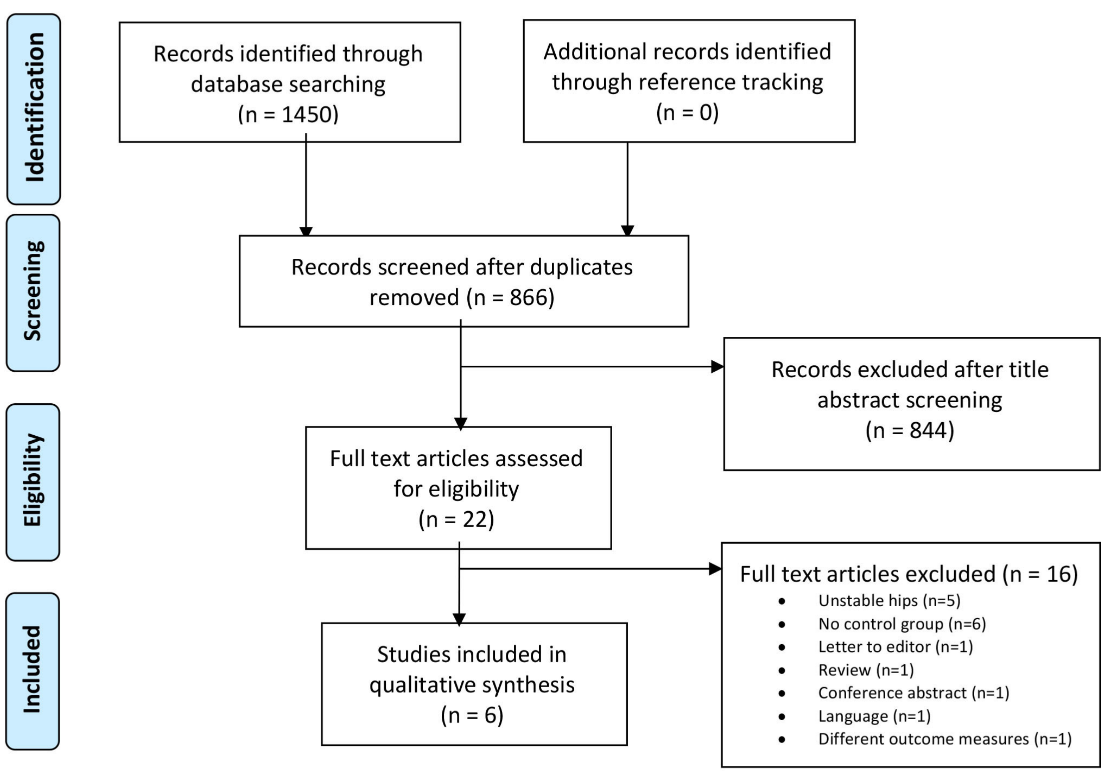

Figure 1 Flowchart of the selection process with reasons for exclusion based on full text.

Study selection

The search string was developed in consultation with a research librarian. After eliminating duplicates, the identified articles were screened by NMCM and MAW based on title and abstract. Interreviewer disagreements were solved by consensus and with assistance EMBP. Articles considered relevant by title and abstract were read in full text by EMBP, NMCM and MAW to determine final eligibility. To complete the search, reference lists of relevant articles were screened and Google Scholar was used for forward citations by EMBP.

Eligibility criteria

Studies investigating infants younger than 4 months of age presenting with stable DDH were included in this review. Studies were eligible for inclusion when presenting at least one of the following outcome values: Graf alpha angle, AI or FHC. Studies including participants with major congenital abnormalities, such as cerebral palsy or spina bifida, were excluded.

The search was restricted to the English and Dutch language. Randomised controlled trials (RCTs), pseudo-RCTs and non-randomised studies were included. For non-randomised studies, both prospective and retrospective studies with two groups (including case–control studies) were included. Studies without comparator (ie, not comparing active monitoring with abduction treatment), cross-sectional studies, case series and case reports were excluded to ensure the inclusion of high level of evidence studies.

Risk of bias

The quality of the studies was assessed by three reviewers using the revised Cochrane risk of bias tool for randomised trials (RoB 2.0) and the Cochrane tool for risk of bias in non-randomised studies (ROBINS-I). All items—that is, selection, performance, attrition, detection and reporting bias for randomised studies, complemented with confounding and recall bias for cohort studies—were rated accordingly. Since blinding of caregivers and patients was not possible due to the nature of the intervention, this aspect of performance bias was assessed less strictly for all studies. The overall risk of bias was attributed as low risk, some concerns or high risk for the randomised and low, moderate, serious or critical risk for the non-randomised studies (online supplementary appendices 3 and 4).[18 19]

Outcomes and data abstraction

To compare the included studies, one author extracted the following characteristics: inclusion and exclusion criteria (degree of dysplasia, age at time of inclusion, comorbidities, previous treatment), subject characteristics (gender, treatment allocation), used abduction device, follow-up moments, outcome measures (Graf alpha angle, AI and FHC), changes in treatment allocation and study conclusions. This process was reviewed by a second author. Effect sizes were calculated for each study based on means, SD and number of infants/hips using an online calculator.[20]

Patient and public involvement

Due to the nature of this study, patients were not involved in the development of the research question, design and conduct of this study. The outcomes of this systematic review will be reported to the Dutch patient association for developmental hip anomalies 'Vereniging Afwijkende Heupontwikkeling'.

RESULTS

Study identification

The initial search provided 1450 records of which 866 remained after removal of duplicates. No additional articles were obtained through reference tracking. All 866 articles were screened by title and abstract. Among these, 22 articles remained eligible for full text review, of which 6 were selected for quality assessment and data extraction. The reasons for exclusion by full text are outlined in the PRISMA flowchart (figure 1).

Selected articles

The six included studies consisted of four RCTs (Wood *et al*,[21] Rosendahl *et al*,[22] Brurås *et al*[23] and Pollet *et al*[2]) and two non-randomised studies, of which one was a retrospective (Sucato *et al*[24]) and one was a prospective cohort study (Kim *et al*[25]). One RCT (Brurås *et al*[23]) was a long-term follow-up of another eligible study (Rosendahl *et al*[22]).

Risk of bias assessment

Two of the four RCTs were rated as low risk of bias (Rosendahl *et al*[22] and Brurås *et al*[23]) and two of some concerns (Pollet *et al*[2] and Wood *et al*[21]). The two non-randomised studies[24 25] were rated as serious risk of bias (online supplemental appendices 3 and 4).

Cohort description

A total of 544 hips were investigated in the included studies. Of these, 307 were actively observed with ultrasound and radiograph and 237 were treated with an abduction device. These numbers do not comprise the 83 hips of Brurås *et al* since they were also included in the study of Rosendahl *et al*.[22 23] Of the 544 hips, at least 97 hips were Graf type IIb and 152 type IIc. However, not all studies reported Graf types (Wood *et al*,[21] Kim *et al*[25]) and one study included stable hips with other Graf types than IIb and IIc (Sucato *et al*[24]).

The total 544 hips belonged to 439 infants. Of these 439 infants, 357 were female and 82 were male (table 1).

Treatment strategies

All randomised studies assigned their patients to either observation (active monitoring), with ultrasound and radiograph evaluation, or abduction treatment, with Pavlik Harness or Frejka Pillow, at the time of inclusion.

Table 1 Overview of study characteristics of the included studies and the total number of included hips and infants

Reference	Study type	Inclusion and exclusion criteria	Subjects	Abduction device	Follow-up	Outcome measures
Wood *et al*[21]	RCT	Infants aged 2–6 weeks with shallow but stable hips on US (<40%–50% FHC) and clinical examination (Barlow and Ortolani and full abduction) without any previous treatment.	44 infants (29 F, 15 M) with 49 dysplastic hips (18 observed and 31 treated; type n.a.)	Pavlik harness	Baseline at 2–6 weeks, US and RTX at 3–4 months and RTX at 24 months	FHC, AI, number of hips dysplastic at final RTX
Rosendahl *et al*[22]	RCT	Infants aged 1–3 days with mild hip dysplasia (a-angle 43°–49°, Graf type IIc) and stable or instable but not dislocatable or dislocated hips, weighing>2.5 kg at birth and without major congenital abnormalities.	128 infants (97 F, 31 M) with 128 dysplastic hips (64 observed and 64 treated; 128 IIc); n=128 infants/dysplastic hips	Frejka pillow, with persistent dysplasia switch to custom fitted plastic cast	Baseline at 1–3 days, US at 6 weeks and 3 months, RTX at 6 and 12 months	a-angle, AI, number of hips dysplastic at final RTX
Brurås *et al* [23]	RCT	Same population as Rosendahl *et al*.	83 infants (67 F, 16 M; 83 IIc) with 83 dysplastic hips (41 observed and 42 treated; 83 IIc); n=83 infants/dysplastic hips	Same as Rosendahl *et al*	Same as Rosendahl *et al*. RTX at 6 years of age	AI, number of hips dysplastic at final RTX
Pollet *et al*[2]	RCT	Infants aged 3–4 months diagnosed with clinically stable DDH (Graf type IIb and IIc) from five Dutch hospitals, without comorbidities such as congenital deformities or previous treatment.	104 infants (93 F, 11 M) with 104 dysplastic hips (49 observed and 55 treated; 97 IIb 7 IIc); n=104 infants/dysplastic hips	Pavlik harness, with persistent dysplasia switch to abduction brace or spica cast	Baseline at 3–4 months, US at 5 and 6–7 months, RTX at 9 and 24 months	a-angle, AI, number of hips dysplastic at final RTX
Sucato *et al*[24]	Retrospective cohort	Infants younger than 1 month with clinically stable hips but at least one hip Graf type IIa or worse (a-angle<60° or FHC<40%–50%).	112 infants (92 F, 20 M) with 192 dysplastic hips (149 observed and 43 treated; 0 IIb 17 IIc 175 other); n=112 infants with 192 dysplastic hips	Pavlik harness	Baseline at 1–4 weeks (mean=12.7 days), final RTX between 3 and 50 months (mean=16 months)	FHC, a-angle, number of hips dysplastic at final RTX
Kim *et al*[25]	Prospective cohort	Infants younger than 12 weeks at presentation, with at least 3 months follow-up, a normal clinical hip examination (Barlow and Ortolani) and DDH at US (a-angle 40°–55° and FHC 10%–50%) without underlying syndromes, teratological abnormalities or previous treatment.	51 infants (46 F, 5 M) with 71 dysplastic hips (27 observed and 44 treated; type n.a.); n=51 infants with 71 dysplastic hips	Pavlik harness	Baseline US at 6 weeks, RTX at 2 years	FHC, a-angle, AI, number of hips dysplastic at final RTX
Total*			n=544 dysplastic hips of which 307 were observed and 237 were treated (with at least 97 IIb and 152 IIc); n=439 infants of which 357 were female and 82 were male			

*Totals were calculated excluding Brurås *et al*.[23]
a-angle, alpha angle; AI, Acetabular Index; DDH, developmental dysplasia of the hip; F, female; FHC, femoral head coverage; M, male; n.a, not applicable; RTC, randomised controlled trial; RTX, radiograph; US, ultrasound.

In the non-randomised studies, treatment was decided based on the discretion of the treating physician (table 1).

The age of the infant at inclusion varied from 1 day to 4 months. Follow-up was performed with ultrasound and radiograph and the maximum follow-up duration ranged from 3 months to 6 years (table 1). If sufficient progression of hip development was found, treatment was discontinued in the treated infants. Sufficient progression was defined as: the acetabular coverage to have become normal (greater than 50% cover) at 6 weeks or if the radiograph was normal (showing no signs of dysplasia and an acetabular angle of <30°) at 3 and 4 months[21]; an alpha angle>53° at 6 weeks or an alpha angle≥55° at 3 months or an AI of ≤2 SDs above the mean at 6 months[22 23]; improvement of the alpha angle at 6 or 12 weeks[2]; an alpha angle≥60°/Graf type 1/non-convex shape of the acetabulum/coverage of the femoral head of ≥50% in the non-stress view or ≥40% in the stress view or an AI of ≤2 SDs above the mean[24]; or an alpha angle≥60° and FHC≥50% or an AI≤2 SDs above the mean.[25] In case of insufficient progression or deterioration of the dysplasia, treatment was initiated in the observed infants or continued in the treated infants (table 2). The number of infants in the observation group that switched to the treatment group are reported in the 'Treatment switch' column in table 2.

Radiological results

Two studies reported statistically significant differences in alpha angle or average acetabular coverage between observed and treated infants at 3 months.[21 22] One of these two studies also showed an increased treatment effect of abduction treatment compared with observation at 1.5 and 3 months.[22] After 3 months, none of the studies showed statistically significant differences in AI between the treatment group and observation group. Also, one study did not show an increased treatment effect of abduction treatment compared with observation at 12 months.[22]

Three of the six included studies reported that infants in the observation group had switched to the abduction treatment group. Reasons for this switch were an alpha angle<50° at 6 (n=11) or 10 weeks (n=1), an alpha angle<55° at 3 months (n=12) or an AI>2 SDs above the mean (n=5),[22] deterioration of the alpha angle at six (n=3) or 12 weeks (n=7)[2] and persistent ultrasonic dysplasia (n=2).[25] In total, 38 infants (12%) in the observation group switched to the abduction group.

At the end of the follow-up duration, 21 observed hips and 32 treated hips were still dysplastic. One study, examining the long-term effects of abduction treatment and observation in the study population of Rosendahl *et al*, reported zero observed and one treated hip to still be dysplastic at the age of 6 years (table 2). From the treatment group, two infants received an arthrogram without further surgical intervention,[21] one infant had a Salter osteotomy,[23] and two infants were treated with closed reduction and spica cast.[2] None of the infants of the observation group had a surgical intervention.

DISCUSSION

This systematic review explores one of the most pressing questions in DDH care, namely whether abduction treatment alters the natural course of stable DDH hips. This systematic review suggests that there are no differences in outcome between abduction treatment and observation in infants up to 4 months of age with stable DDH hips. Two studies reported a faster improvement of the alpha angle and average acetabular coverage in stable DDH hips that received abduction treatment at 3 months.[21 22] However, none of the six studies reported differences in AI between the treatment and observation group after 3 months.

A total of 38 infants (12%) in the observation group switched to the abduction group. This finding supports current literature that 80%–85% of stable DDH hips will spontaneously progress into normal hips.[6 14] Thereby adding evidence to the hypothesis that ultrasonography is not able to differentiate between truly pathological hips and immature hips.[6] In all studies, treatment switch was based on radiological characteristics. Although exact radiological definitions differed between studies, complicating the comparison of results. Also, two of the three studies in which infants switched groups reported that results were analysed according to the intention-to-treat principle. This might result in more optimistic results of the observation group. However, the intention of active monitoring is to actively monitor and intervene when necessary. Therefore, the intention-to-treat principle might be the best approach to represent the clinical situation. The switch of infants from the observation group to the treatment group corroborates that not all infantile DDH hips will spontaneously progress into normal hips. Possible disadvantages of active monitoring are that if treatment is warranted at a certain point, treatment is initiated at a later age and the treatment duration might be longer. However, one study reported that the median treatment duration was similar in the observation group and treatment group, namely 12 weeks.[22]

One of the included studies found no correlation between the severity of Graf classification at birth and the subsequent presence of DDH.[24] None of the other studies examined predictors of final radiographic outcome. It might be argued that early screening results in the diagnosis of more infants with hips that will spontaneously progress into normal hips and that later diagnosis will include more truly pathological hips. This hypothesis is supported by a recent prospective cohort study.[26] This study proposes screening at the age of 2 or 3 months or implementation of a wait and see policy for immature hips. Active monitoring around 2 or 3 months of age might aid in detecting late and truly pathological DDH hips while limiting overtreatment, as supported by this systematic review. However, none of the included studies analysed the relationship between initial age at diagnosis and final radiological outcome.

Limitations

The principal limitation of this systematic review is the methodological heterogeneity between the included studies. Age at diagnosis, (radiological) criteria for diagnosis and classification, follow-up schemes and criteria to initiate treatment in the observation group showed great variety. For instance, although all hips included in this review were classified as stable, only some could be attributed to Graf type IIb or IIc. Also, definitions of sufficient hip progression on ultrasonography varied between the included studies. Currently, normal values and values for truly pathological hips in infant hip ultrasonography are lacking.[2] This heterogeneity has limited the comparison of study results and a meta-analysis was not feasible. Also, the study quality varied for the included studies, with two non-randomised studies classified as serious

Table 2 Overview of the results and conclusions of the included studies

Reference	Results					Treatment switch	Conclusion
Wood *et al*[21]	Time	Outcome measure	Observed (n=18 hips)	Pavlik Harness (n=31 hips)	Treatment effect (CI)	Unclear	This study found no evidence that splintage for stable but dysplastic hips in young infants confers lasting benefit. Therefore, they do not recommend treatment in this patient group in the first 6 weeks. The known risks of splintage do not cover for the slight acceleration in hip-joint development. A follow-up with US and RTX at 3 months or later is recommended to prevent overtreatment and overdiagnosis of DDH.
	2–6 weeks (B)	FHC (%)	32.8	36.7	n.a.		
	3–4 months	FHC (%)	48.6	54.3	n.a.		
	3–4 months	AI (°)	24.3	24.8	n.a.		
	2 years	AI (°)	23.5 (n=8)	21.6 (n=26)	n.a.		
	2 years	Hips dysplastic at final RTX (n)	0	2	n.a.		
Rosendahl *et al*[22]	Time	Outcome measure	Observed (n=64 infants)	Frejka pillow (n=64 infants)	Treatment effect (CI)	30 observed hips were treated after 6 weeks or 3 months because of insufficient progression of the a-angle	Although treatment from birth may cause more rapid normalisation in infants with stable but mild dysplastic hips, surveillance until the age of 6 weeks does not result in abnormal hips at 1 year of age. A strategy of active surveillance would reduce the overall treatment rate with 0.6% which has important implications for families and healthcare costs.
	1–3 days (B)	a-angle (°) (SD)	47.0 (±1.8)	47.0 (±1.7)	n.a.		
	6 weeks	a-angle (°) (SD)	55.2 (±0.51)	58.4 (±0.48)	6.5 (5.6 to 7.3)		
	3 months	a-angle (°) (SD)	59.0 (±0.48)	61.0 (±0.49)	4.1 (3.5 to 4.7)		
	6 months	AI (°) (SD)	24.7 (±0.42)	24.2 (±0.38)	–1.2 (–1.6 to 0.9)		
	1 year	AI (°) (SD)	24.2 (±0.40)	24.2 (±0.40)	0.0 (–0.3 to 0.3)		
	1 year	Hips dysplastic at final RTX (n)	4	7	n.a.		
Bruårs *et al*[23]	Time	Outcome measure	Observed (n=41 infants)	Frejka Pillow (n=42 infants)	Treatment effect (CI)	n.a.	Infants with mild dysplastic and potentially unstable hips who are randomly assigned to receive US observation or immediate treatment, have radiographically normal hips at the age of 6 years without evidence of avascular necrosis.
	1 year	AI (°) (SD)	R: 24.5 (±3.6) L: 24.9 (±3.0)	R: 24.5 (±2.8) L: 24.4 (±3.6)	R: 0.0 (–0.4 to 0.4) L: –0.2 (–0.6 to 0.3)		
	6 years	AI (°) (SD)	R: 14.9 (±3.9) L: 13.3 (±3.2)	R: 14.5 (±4.0) L: 13.6 (±3.2)	R: –0.1 (–0.5 to 0.3) L: 0.1 (–0.3 to 0.5)		
	6 years	Hips dysplastic at final RTX (n)	0	1			
Pollet *et al*[2]	Time	Outcome measure	Observed (n=49 infants)	Pavlik Harness (n=55 infants)	Treatment effect (CI)	6 hips in the observed group were treated after 6 weeks because of deterioration of the a-angle, 7 hips of the observed group were treated after 12 weeks because of persistent dysplasia	In this patient group, Pavlik harness treatment showed no difference compared with active surveillance after 12 weeks of observation. Treatment with Pavlik harness did not accelerate the improvement of the a-angle. Observation of well-centred sonographic hips up to 6 months seems sufficient to avoid overtreatment and to identify hips that do not stabilise spontaneously.
	3–4 months (B)	a-angle (°) (SD)	55.0 (±2.8)	54.2 (±3.3)	n.a.		
	5 months	a-angle (°) (SD)	58.0 (±5.2)	58.8 (±5.5)	0.1 (–0.2 to 0.5)		
	6–7 months	a-angle (°) (SD)	60.0 (±5.6)	60.5 (±3.8)	0.1 (–0.3 to 0.5)		
	9 months	AI (°) (SD)	26.2 (±5.0) (n=40)	26.4 (±4.6) (n=50)	0.0 (–0.4 to 0.5)		
	2 years	AI (°) (SD)	23.0 (±4.4) (n=31)	22.9 (±5.1) (n=40)	0.0 (–0.5 to 0.4)		
	2 years	Hips dysplastic at final RTX (n)	13	16	n.a.		

Continued

Table 2 Continued

Reference	Results					Treatment switch	Conclusion
Sucato *et al*[24]	Time	Outcome measure	Observed (n=149 hips)	Pavlik harness (n=43 hips)	Treatment effect (CI)	n.a.	Treatment of hips in infants younger than 4 weeks with a normal clinical hip examination without evidence of hip instability is not necessary at that time. Ultrasonography at that time is too sensitive and has no predictive value for the development of DDH. Ultrasonography should be used in an older age group (>1 month).
	<1 month (mean=12.7 days) (B)	a-angle (°) (SD)	56.4 (±6.6)	53.1 (±6.5)	n.a.		
	<1 month (mean=12.7 days) (B)	FHC (%) SD	42.9 (±9.0)	40.8 (±11.1)	n.a.		
	3–50 months (mean=15.9 months)	Hips dysplastic at final RTX (n)	2	0	n.a.		
Kim *et al*[25]	Time	Outcome measure	Observed (n=44 hips)	Pavlik harness (n=27 hips)	Treatment effect (CI)	2 hips in the observed group were treated after 4–8 weeks	Ninety-three percent of the observed infants had good outcome at 2-year follow-up suggesting that milder ultrasonic hip dysplasia can be observed with a good, expected outcome. An RCT is suggested to evaluate the role of abduction treatment for stable DDH.
	6 weeks (B)	a-angle (°) (SD)	48.9 (±3.9)	48.8 (±3.5)	n.a.		
	6 weeks (B)	FHC (%) SD	38.3* (±7.7)	32.2* (±9.1)	n.a.		
	2 years	AI (°) (SD)	22.1 (±3.5)	20.9 (±4.7)	−0.3 (−0.8 to 0.2)		
	2 years	Hips dysplastic at final RTX (n)	2	6	n.a.		
Total*			21 hips dysplastic at final RTX	32 hips dysplastic at final RTX		45 observed hips treated in study period	

Normal ranges: a-angle>60° beyond 3 months.[27] AI<25° beyond 1 year.[28] FHC >50%.[29]
*Totals were calculated excluding Brurås *et al*.[23]
AI, Acetabular Index; B, baseline; DDH, developmental dysplasia of the hip; FHC, femoral head coverage; L, left hip; n.a, not applicable; R, right hip; RCT, randomised controlled trials; RTX, radiograph; US, ultrasound.

risk of bias. After careful consideration, we have decided to include these two studies in this review to present a complete overview of current literature. Finally, the study of Burås *et al* is a 6-year follow-up derived from the study of Rosendahl *et al* and was included to gain insight on long-term outcomes. Since both studies included the same infants, the study of Burås *et al* was not used for calculating the total number of infants (female, male), hips (observed, treated, Graf type) and treatment switches reported in this review (tables 1 and 2).

Future directions

This systematic review suggests that abduction treatment and observation (±delayed treatment) do not result in different outcomes in infants up to 4 months of age with stable DDH hips. However, the included studies have small population sizes and show considerable methodological heterogeneity. Therefore, a RCT is warranted to study this research question in a large population. Ideally, RCTs would be embedded in current standard care follow-up routines. Since differentiating between truly pathological hips and immature hips that will naturally progress into normal hips is currently impossible, this research question remains the most pressing question in DDH care. Consequently, the development of an ultrasound classification system that will distinguish truly pathological hips from immature hips should be pursued. Also, the relation between patient demographics (e.g., age at diagnosis) and radiological criteria, as well as the relation between final radiological outcome and need to switch from observation to treatment group should be further explored. Prospective cohort studies using national registries might play an important role. Furthermore, the cost-effectiveness of observation compared with abduction treatment should be explored in a large trial.

Conclusion

Whereas two studies reported a faster improvement of the alpha angle and average acetabular coverage in stable DDH hips that received abduction treatment at 3 months, none of the six studies reported differences in AI between the treatment and observation group after 3 months in infants up to 4 months of age with stable DDH hips. The switch of 38 infants (12%) from the observation group to the treatment group corroborates that not all infantile DDH hips will spontaneously progress into normal hips.

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