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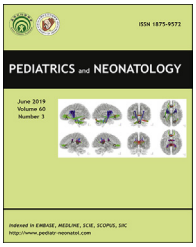

Original Article

Ultrasound screening for developmental dysplasia of the hip after 4 weeks increases exam accuracy and decreases follow-up visits

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Key Words
hip dysplasia;
pediatric orthopedics;
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Background: Developmental dysplasia of the hip (DDH) is a preventable and treatable disorder in children. Hip ultrasound is recommended for early detection of affected hips. The timing of the initial hip ultrasound and the frequency of subsequent ultrasounds are controversial topics when considering costs and efficiency.
Methods: Registry data from the Taiwanese Screening and Audit System for Developmental Dysplasia of the Hip were obtained for biometry of hip ultrasounds using the Graf classification and relevant demographic data from 2016. Initial screening results and final case management outcomes were compared to determine screening accuracy and the number of visits needed to determine final outcomes.
Results: In total, we screened 1683 newborns in 2016. Of the initial cases screened within 28 days (n = 1168), 86.6% were negative, 10.1% positive, and 3.3% intermediate, while of the cases screened after 28 days (n = 515), 97.3% were negative, 0.8% positive, and 1.9% intermediate. Screening of the newborns' final hip outcomes revealed that 1641 (97.6%) were negative, treatment was administered in 8 cases (0.4%), and 34 (2.0%) cases were lost to follow-up. When comparing screening times, screening after 28 days improved specificity (89%–97%), and later screenings were associated with fewer visits needed to confirm hip outcomes (aOR = 0.19, CI95% = 0.10–0.38, $p < 0.001$) and improved accuracy (aOR = 13.84, CI95% = 4.23–45.26, $p < 0.001$).
Conclusion: This study provides evidence of the benefits of screening for DDH after 28 days, namely: reduced false positives, improved screening accuracy, and a reduced requirement

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for follow-up visits. Delaying screening can also potentially reduce unnecessary parental anxiety, eliminate unnecessary healthcare burdens, and reduce costs. We recommend performing hip ultrasound screening for newborns after 28 days.

1. Introduction

Developmental dysplasia of the hip (DDH) is a common pediatric musculoskeletal disorder and can lead to lifelong hip dysfunction and chronic pain. The incidence of DDH depends on the definition and timing of the diagnosis. In the earliest report in Taiwan by Huang et al., in 1988,[1] the incidence was 2.7/1000 in newborn nurseries, including 1.0/1000 positive by the Ortolani test and 1.7/1000 with manual hip laxity. The incidence at a one1 year follow-up was 1.2/1,000, including the cases with a positive Ortolani test and the other remaining 0.2/1000 occurring after neonatal manual screening.

Early detection by hip screening and early splinting are recommended to prevent surgery and future comorbidities.[2,3] In a nationwide survey for incidence of DDH that required surgical treatment, there were stationary incidences of 0.49, 0.48, and 0.47/1000 in birth year cohorts from 1997, 1998, and 1999, respectively.[4] Hip screenings remain a serious issue in public health promotion, due to high rates of surgical intervention.

Ultrasonography was first introduced as a method to evaluate the infant's hip structure in the 1980s.[5,6] The Graf classification of hip development has gained popularity due to its improved early detection and accuracy.[7,8] However, ultrasonography is not a complete solution for hip screening; late developing DDH can occur even though initial screening revealed negative results.[9] Conversely, cases identified early often resolve spontaneously a few weeks later.[10] There is evidence that screening after 3 months can increase the rate of surgery,[11] although others have found that delayed screening improves the results.[12,13] Conversely, Roovers et al.[6] found evidence that earlier screenings led to better detection of abnormal hips. National Health Services (NHS) from the United Kingdom's Newborn and Infant Physical Examination (NIPE) Programme suggests performing an ultrasound hip screening within 2−6 weeks.[2] However, there is no consensus on the ideal time to perform ultrasound screenings,[12,14] and there is also controversy regarding whether to employ a universal screening or selective screening method.[15,16]

We conducted a review of the database in the Taiwanese Screening and Auditing System (TSAS) for DDH in 2016. The auditing system consisted of a professional training group, led by a pediatric orthopedic doctor, which coordinated lectures, training, and reporting to improve hip ultrasound screening performance. The database collected data from manual tests and hip ultrasounds from six participating healthcare providers. Our objectives were (1) to report on employing a registry to screen newborns using ultrasonography and (2) to identify the optimal timing for hip ultrasound screening.

2. Methods

2.1. Samples

The samples included data on newborns who attended one of the six health centers that took part in data collection in Taiwan. The screening institutions varied from specialist ultrasound clinics to obstetrics departments in private hospitals. Newborns received ultrasound screenings at postnatal checks at their hospital of birth or attended a health checkup between January 1, 2016 and December 31, 2016 at one of the participating health centers. Parents or guardians signed informed consent forms for newborns' data to be included in the screening registry. Overall, 1683 newborns were screened during the study period. This retrospective review of the database of the TSAS for DDH was approved by the Institutional Review Board of the Chang Gung Medical Foundation (201800670B0).

2.2. Hip ultrasound

Hip ultrasounds were assessed using the Graf classification, which uses alpha and beta angle measurements of a standard coronal section of the hip.[8] Alpha angles are formed between the acetabular roof and the vertical cortex of the ilium and reflect development of the bony acetabular roof. Beta angles are formed between the vertical cortex of the ilium and the triangular labral fibrocartilage and measure the cartilaginous coverage over the femoral head.

Alpha and beta angles are continuous measurements that are determined by angles formed during ultrasound hip imaging. The angles are then coded to obtain hip type (Ia, Ib, IIa, IIb, IIc, III, IV, or D).[7] A hip with an alpha angle $>60^\circ$ was classified as a mature type I hip. If the beta angle was $<55^\circ$, the hip was further classified as a type Ia hip, while a beta angle $>55^\circ$ represented a type Ib hip. A child with an alpha angle between 50° and 59°, and who was less than 3 months old at examination was classified as having a physiologically immature type IIa hip, whereas if they were over 3 months old, their hips were categorized as delayed ossification type IIb. Hips with an alpha angle between 43° and 49° were classified as dysplastic type IIc. Furthermore, hips with an alpha angle below 43° were labeled as eccentric type III or type IV. Hips with a beta angle $>77^\circ$ were decentering and were categorized as type D hips.

2.3. Screening protocol

The hip screening protocol was ultrasound-based and considered the results of a manual test and DDH risk factors as described in Fig. 1. Newborns with a Graf type Ia or Ib who did not screen positive by physical exam or have other risk factors were classified as negative and were deemed not at risk for developing DDH. However, if newborns had a negative Graf classification (Ia, Ib) and a positive physical examination or a risk factor, they were categorized as an intermediate case and were followed up after one month to monitor progression. Manual tests used included the Barlow test, the Ortolani test, limited abduction of the hip, the Galeazzi sign, and the Allis sign. Risk factors included a family history of DDH, breech presentation, oligohydramnios, and any postural deformities of the neck or lower extremities. . Newborns with a Graf type IIa hip were immature and flagged for follow-up one month later, while cases with Graf type IIc, III, IV and D hips had more severe dysplasia and were transferred to a pediatric orthopedic specialist. After the initial screening, the patients were asked to return for reexamination if deemed necessary. Upon reexamination, some cases were still found to be positive or inconclusive due to risk factors or results of a physical examination. These cases were followed-up at up to four additional screenings, as was required on a case-by-case basis. Patients that were deemed positive or intermediate upon their last visit, did not return for follow-up examination, and were unable to be reached for confirmation were deemed lost to follow-up. A designated nurse coordinated the screening program and contacted parents by telephone to inform about any late-diagnosed DDH cases or unconfirmed outcomes.

2.4. Data analysis

Cases were first distributed based on the time at which the initial ultrasound exam was conducted, in weeks. As most screenings were performed either in the first week or after 28 days, a threshold of 28 days was chosen, and cases were placed into one of two categories: before or after 28 days post-birth. Baseline variables were: sex, parental nationality (Taiwanese parents or $\geq$1 foreign-born parent), parity (first-born, or second-born or more), family history of DDH (yes or no), gestational count (singleton, multiple pregnancy), breech delivery (yes or no), and preterm birth (yes or no). Possible results from the screening protocol were: negative screen, positive screen (IIa and above or intermediate), or lost to follow up. Case management outcomes were: negative, DDH treatment received, or lost to follow-up. Additionally, a flow chart segregated by the timing of the initial screen ($\leq$28 days vs. $>$28 days) was created to report initial screening outcomes, subsequent follow-up ultrasound screens, and case management outcomes.

Descriptive variables and percentage data were reported, and we employed Pearson's chi-squared (X^2) test to

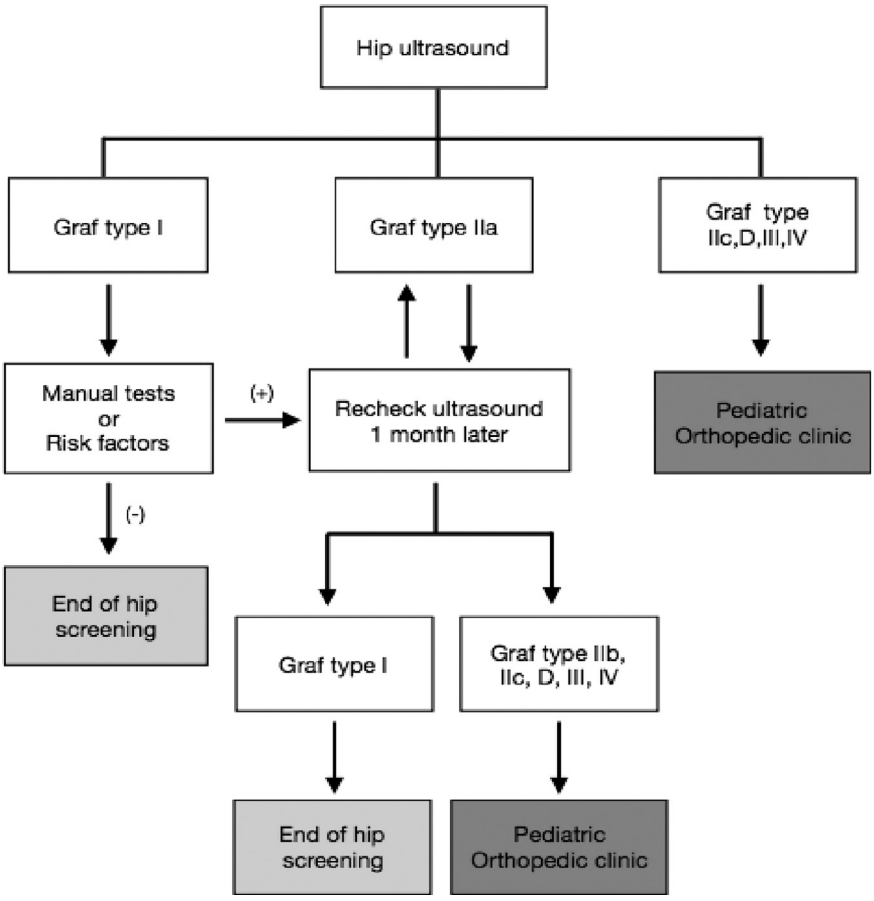

Figure 1 Flowchart for DDH case screening and diagnosis.

compare study variables by age at which initial screening was performed. Efficacy of the initial screening program between the two age groups was evaluated by the true negative (TN), true positive (TP), false negative (FN), and false positive (FP) counts and column percentages. Sensitivity, specificity, and accuracy were also reported and compared between groups using Pearson's chi-squared test. Accuracy was defined as the ability of the initial screening ultrasound to correctly predict final outcomes. Case management outcomes were coded as accurate if the initial and final screening results were negative or if the initial screening was intermediate or positive and at the final screening, the patient required DDH treatment. Case management outcomes were deemed inaccurate if the initial screening result was negative, but the patient required further DDH treatment, or if the initial screening result was positive (or intermediate), but the case was screened as negative upon a follow-up examination.

Binary logistic regression analyses controlling for sex, parental nationality, gestational count, and interobserver differences were conducted to predict association with the requirement for greater than one visit to confirm DDH outcome (1 or $\geq$1) as well as the accuracy of the screening results (not accurate vs. accurate). All comparisons were described using adjusted odds ratio (aOR), 95% confidence interval (CI), and p-values. Results were adjusted for sex, parental nationality, gestational count, and interobserver differences. A threshold for significance was set *a priori* at $p < 0.05$. All analyses were conducted using SPSS V21.0.

3. Results

In total, 1683 newborns were screened. The majority of cases were screened within the first week, while the second largest group consisted of cases screened after 4 weeks (Supplementary Materials, Fig. S1). Accordingly, newborns were categorized by the timing of their first ultrasound exam using a cut-off of 28 days. Overall, 69.4% (n = 1168) of neonates were screened within the first 28

Table 1 Comparisons of descriptive variables of newborns' initial screening for DDH (n = 1683).

Variables	Age at Initial Screening				Chi-squared (X^2)	*p*	*Sig.*
	≤28 days (n = 1168)		>28 days (n = 515)				
	Count	%	Count	%			
Sex					1.0	0.319	…
Female	577	49.4%	268	52.0%			
Male	591	50.6%	247	48.0%			
Nationality					8.672	0.003	**
Both Taiwanese Parents	1139	97.5%	513	99.6%			
1 or more Foreign Parents	29	2.5%	2	0.4%			
Family History of DDH[1]					1.1	0.288	…
None	1042	98.9%	512	99.4%			
Present	12	1.1%	3	0.6%			
Gestation Number					2.792	0.095	…
Singleton	1143	97.9%	510	99.0%			
Multiple Pregnancy	25	2.1%	5	1.0%			
First-born Child[1]					22.4	<0.001	***
No	992	94.1%	511	99.2%			
Yes	62	5.9%	4	0.8%			
Preterm Birth[1]					3.9	0.047	*
No	1011	95.9%	504	97.9%			
Yes	43	4.1%	11	2.1%			
Breech Delivery[1]					18.7	<0.001	***
No	981	93.1%	506	98.3%			
Yes	73	6.9%	9	1.7%			
Initial Screen Results					18.5	<0.001	***
Negative (-ive)	1012	86.6%	501	97.3%			
Positive (+ive)	118	10.1%	4	0.8%			
Intermediate (-ive, w/risk)	38	3.3%	10	1.9%			
Case Management Outcomes					48.6	<0.001	***
Negative (-ive)	1126	96.4%	515	100.0%			
Referral to orthopedic doctor (+ive)	8	0.7%	0	0.0%			
Lost to follow-up	34	2.9%	0	0.0%			

days after birth, while 30.6% (n = 515) were screened after 28 days (Table 1). Parental nationality (p = 0.003), being first-born (p < 0.001), preterm birth (p = 0.047), and breech delivery (p < 0.001) were all significantly higher in the group that was screened within 28 days. However, sex, gestational count, and family history were not significantly different.

Fig. 2 shows initial screening results and case management outcomes for cases screened before or after 28 days. Among the 1168 newborns screened within 28 days, 1012 were Graf type I without any risk factors (86.6%). The remaining 153 newborwns were screened as abnormal (13.4%), including: 98 newborns with Graf IIa hips, 20 newborns with Graf IIc, III, or D hips, and 38 newborns with intermediate hips. Among the 515 newborns screened after 28 days, 501 were Graf type I (97.3%). Among the remaining 14 newborns, 2.7% were screened as abnormal, including 4 newborns with Graf IIb hips and 10 with intermediate hips. Overall, case management results show final hip outcomes as follows: 1641 (97.6%) cases screened were negative, 8 cases (0.4%) received treatment, and 34 (2.0%) cases were lost to follow-up. Among those newborns with intermediate hips, almost all (n = 45) screened as negative by follow-up ultrasounds. However, of the patients with Graf type II hips, 4 required treatment and 69 were screened as negative. Only patients screened before 28 days had severe Graf type hips (IIc, D, III, IV). Four newborns were referred and needed treatment, while 14 cases went on to be screened as negative. All cases lost to follow-up were screened before 28 days. Newborns lost to follow-up were initially screened as follows: intermediate (n = 3), Graf type II (n = 29), and severe hips (n = 2).

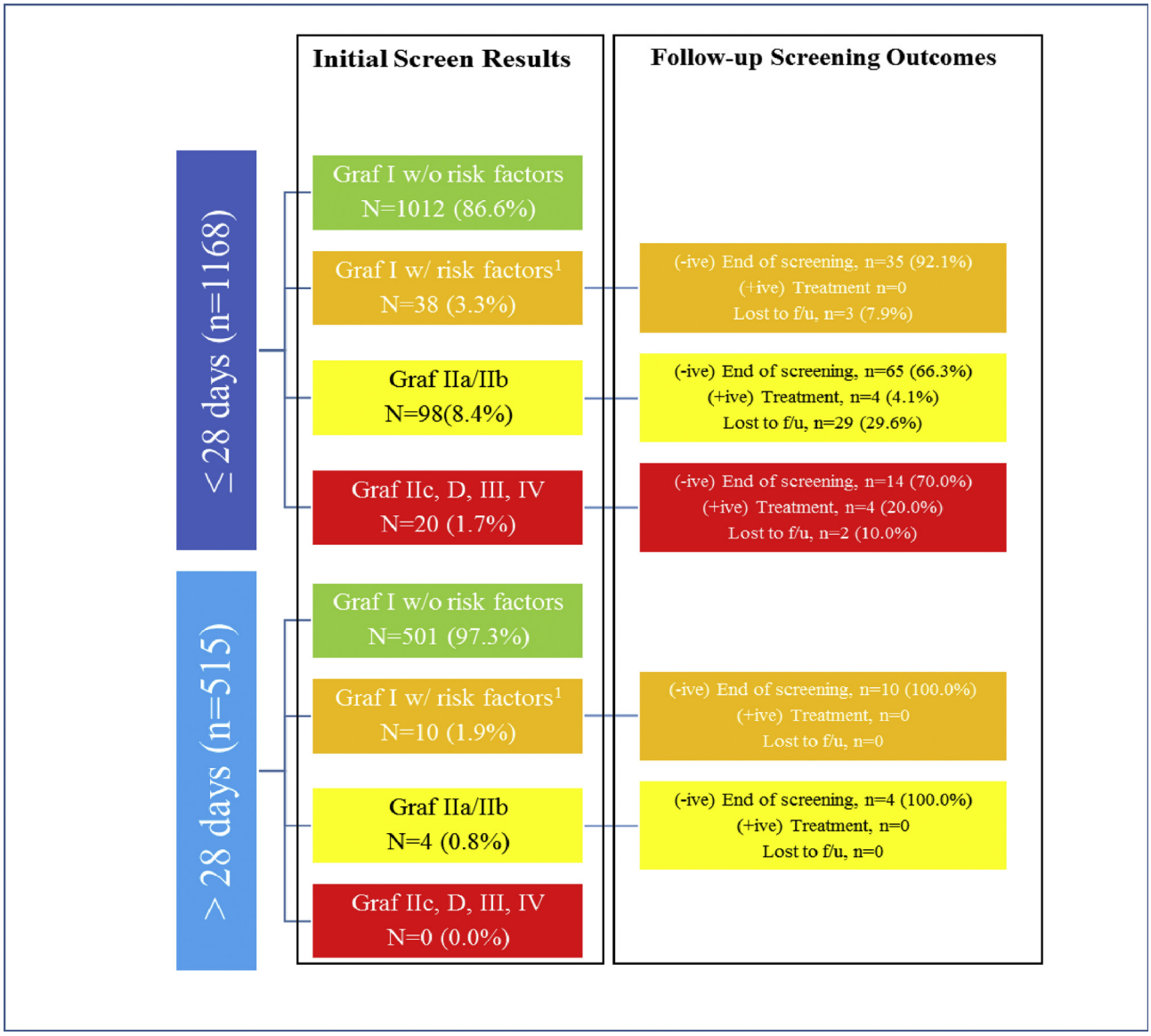

Figure 2 Flowchart of newborns screened for DDH. Notes. f/u = follow-up, US = ultrasound. [1] Clinical decision by physician: Graf classification screened negative, with risk factors or a positive physical exam.

Table 2 Analysis of the efficacy of initial screening in predicting hip outcomes (n=1649).

	≤28 Days (n = 1168)	>28 Days (n = 515)	Chi-squared (X^2)	Sig.
False Positive (FP)	148 (12.7%)	14 (2.7%)	25.22	***
False Negative (FN)	0 (0.0%)	0 (0.0%)	…	…
True Positive (TP)	8 (0.7%)	0 (0.0%)	3.54	…
True Negative (TN)	1012 (86.6%)	501 (97.3%)	44.54	***
Sensitivity (TP/TP+FN)	1.00	0.00	n/a	
Specificity (TN/TN+FP)	0.89	0.97	n/a	
Accuracy (TP+TN/FP+FN+TP+TN)	0.93	0.99	28.39	***

Notes. ***p < 0.001; n/a: Chi-squared analysis is not suitable for comparison.

The efficacy of hip screening was compared between the groups as defined by initial screening time (Table 2). The following values were obtained for cases screened within 28 days: false positive (FP): [n = 148, 12.7%], false negative (FN): [n = 0, 0.0%], true positive (TP): [n = 8, 0.7%], and true negative (TN): [n = 1,012, 86.6%]. Newborns screened after 28 days had the following rates: FP: [n = 14, 2.7%], FN: [n = 0, 0.0%], TP: [n = 0, 0.0%], and TN: [n = 501, 97.3%]. A Pearson chi-squared test showed that FP and TN were significantly different between screening times (both $p < 0.001$). Sensitivity was perfect (100.0%) in the group screened within 28 days or earlier, with no cases detected using scans done after 28 days. Specificity increased from 89% to 97% in cases screened before and after 28 days, respectively. Accuracy differed significantly between screening timing groups (93% vs. 99%; $X^2 = 28.39$, $p < 0.001$).

Table 3 shows the multivariate associations between timing of the initial screening, the number of exams needed to confirm final outcomes, and initial screening accuracy. Logistic regression models controlled for sex, parental nationality, gestational count, and interobserver differences. Cases screened after 28 days were more likely to have an accurate screen compared to cases screened within 28 days after birth (aOR = 13.84, CI95% = 4.23–45.26, $p < 0.001$). Furthermore, newborns screened after 28 days required more than one examination less frequently than those screened within 28 days after birth (aOR = 0.19, CI95% = 0.10–0.38, $p < 0.001$).

4. Discussion

Initial screening for DDH was more frequent in the first week and after 4 weeks. Screening within 28 days had a high sensitivity; however, false positive rate, specificity, and accuracy were improved for newborns screened after 28 days of age. Cases in which newborns screened after 28 days also required fewer follow-up visits to confirm the final diagnosis, displayed a higher screening accuracy, and had fewer losses to follow-up compared to cases screened within the first 28 days after birth.

In total, 1683 cases were screened in our study. All cases of DDH were from the group of cases screened within 28 days from birth. Screening within 28 days resulted in perfect sensitivity and all 8 DDH treatment cases were correctly screened as positive upon subsequent follow-up visits. Ultrasound screening for DDH is more effective at detecting the disease than physical evaluation.[17] Perfect sensitivity from ultrasound screenings was not unexpected. Physicians or radiological technicians followed institutional practices, which require immediate screening of at-risk newborns (i.e., breech, family history, female sex, vaginal delivery, positive physical exam, etc.),[3] and would have been more likely to recommend an early DDH screening test.

False positives were significantly more common in screening performed in the first 28 days than in screening performed 28 days or later. When compared to our study a

Table 3 Associations between the age at initial screening, screening accuracy, and the number of screenings required to reach final decision.

	Inaccurate	Accurate	*aOR*[a]	*CI 95%*	*p-value*	*Sig.*
Accuracy of Initial Screening						
≤28 days	7.0%	93.0%	1.00	…	…	…
>28 days	0.8%	99.2%	13.84	4.23–45.26	<0.001	***
	1	≥1	*aOR*[a]		*p-value*	*Sig.*
# of visits for Final Decision						
≤28 days	91.4%	8.6%	1.00	…	…	…
>28 days	97.3%	2.7%	0.19	0.10–0.38	<0.001	***

Notes. aOR = adjusted odds ratio, CI95% = 95% confidence interval, ***p < 0.001.
[a] Logistic regression model was controlled for inter-observer variability and sex.

15-year prospective longitudinal observational study[10] utilizing a similar neonatal clinical DDH screening program found that sensitivity was lower in those screened at 28 days or less (62% vs. 100%, respectively) and specificity was higher for both screening groups [99.8% vs. 90.0% ($\leq$28 days) & 97.3% (>28 days)]. Screening results taken after one month reflect final outcomes more accurately,[12,18] and screening was found to be overly sensitive in the first 6 weeks after birth.[19,20] Previous research from Australia found that there was a two-fold increase in misdiagnosed abnormal hips if the screening occurred within 4 weeks.[13] Variability in earlier screening is thought to be mostly due to interobserver variability, which is more susceptible to vary in earlier screening due to differences in hip maturity.[13,21] Our research supports this finding, as we controlled for examining physicians in our multivariate model without noticeably influencing the final test accuracy. Therefore, it may be beneficial to delay initial screening to coincide with hip maturation and late-developing DDH in order to potentially prevent early misdiagnosis and improve test accuracy.

Delaying initial screening 28 days after birth subsequently required fewer follow-up visits in order to rule out a DDH diagnosis. Although previous protocols have called for early detection of DDH,[22] recent studies provide evidence that earlier hip examination often produced inaccurate measurements due to hip immaturity.[23] Some case outcomes were found to be inconclusive and required sufficient observation time in order to form a conclusive diagnosis.[24,25] However, follow-ups increase the cost of conducting the screening program.[26] Reducing follow-ups could lead to a more efficient and cost-effective screening program. Our study demonstrated that screening after 28 days resulted in improved accuracy and, as a result, led to fewer follow-ups. Increasing screening accuracy can reduce follow-ups, decrease unnecessary pediatric orthopedic referrals, and ease healthcare costs. Previous guidelines support our findings but are based on expert opinions and consensus.[2] This study provides evidence based on data regarding the benefits of performing a hip ultrasound screening after 28 days. Further research could be conducted to determine the cost-savings associated with performing a delayed screening program.

It is important that delayed screenings do not increase the rates of required surgical intervention. In a previous study[17] a cohort of newborns all received a physical evaluation and were randomly assigned to one of three different ultrasound screening criteria groups: no ultrasound screening, selective screening (ultrasound if positive by physical exam), or universal screening (ultrasound regardless of physical exam result). The groups' DDH surgery rates were compared at 4.5 months. Newborns who received only a physical examination did not have a significantly greater surgery rate at 4.5 months than newborns who had received universal or selective ultrasound screening. However, newborns who received only a physical examination displayed a greater requirement for increased screening examinations to reach a conclusive final diagnosis. Based on our findings and the above study[17] we believe that screening later than 28 days after birth does not increase the need for surgery and may be beneficial in reducing the number of visits required to diagnose conclusively. Another concern regarding late screening is follow-up rate.[6] A universal DDH ultrasound screening after 28 days of age could be scheduled alongside the local vaccination program for newborns, which occurs at one month of age. Parents would likely adhere to a requirement to return for a universal DDH screen at this time.

Our study had some limitations. First, the cohort was not representative of the overall population, as we collected data from patients seeking healthcare from six participating clinics. Thus, the findings may not be generalizable to the larger population. Despite this potential bias, our findings are informative because data from a relatively large number of cases were collected. Second, 34 cases were lost to follow-up, and we were unable to determine their final DDH outcome. Cases lost to follow-up, due to lack of compliance with screening protocols, may have led to an underestimation of DDH rates. Additionally, we assumed that negatively screened cases during the initial screening remained negative. However, cases that were screened as negative but were suspected to be late-developing DDH (due to risk factors or physical examination) were asked to return for follow-up, which would have reduced the number of misclassified negative screened cases. Third, the study is observational, and although screenings were observed prospectively, data analysis was performed retrospectively. Further studies could employ a randomized control for newborns screened early vs. later, in order to confirm the findings from our observational study. Finally, due to the lack of complete risk factor data collection, we were unable to include all risk factors as covariates in the final analytical model. This limited our ability to rule out other confounding variables, which may have influenced results.

Our findings provide evidence-based support for hip ultrasound screening performed after 28 days of age. Benefits of delaying screening until after 28 days include a reduced false positive rate, improved accuracy, and a reduced number of required follow-up visits. We recommend establishing a screening age cut-off of 28 days, with follow-ups as required. We hope implementing screenings after 28 days will lessen parental anxiety, reduce the number of ultrasound screenings, facilitate implementation of cost-sensitive screening programs, and reduce burden on pediatric orthopedic surgeons, which will save medical resources.

Conflict of interest

The authors state that they do not have any conflicts of interest.

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References

1. Huang SC, Liu HC, Chen CF, Chen CL, Liu TK. Incidence of congenital dislocation of the hip in Chinese. *J Orthop Surg ROC* 1988;**5**:53—65.
2. Woodacre T, Dhadwal A, Ball T, Edwards C, Cox P. The costs of late detection of developmental dysplasia of the hip. *J Child Orthop* 2014;**8**:325—32.
3. Mahan ST, Katz JN, Kim YJ. To screen or not to screen? A decision analysis of the utility of screening for developmental dysplasia of the hip. *J Bone Joint Surg Am* 2009;**91**:1705—19.
4. Chang CH, Chiang YT, Lee ZL, Kuo KN. Incidence of surgery in developmental dysplasia of the hip in Taiwan. *J Formos Med Assoc* 2007;**106**:462—6.
5. Dogruel H, Atalar H, Yavuz O, Sayli U. Clinical examination versus ultrasonography in detecting developmental dysplasia of the hip. *Int Orthop* 2008;**32**:415—9.
6. Roovers EA, Boere-Boonekamp MM, Castelein RM, Zielhuis GA, Kerkhoff TH. Effectiveness of ultrasound screening for developmental dysplasia of the hip. *Arch Dis Child Fetal Neonatal Ed* 2005;**90**:F25—30.
7. Graf R. Classification of hip joint dysplasia by means of sonography. *Arch Orthop Trauma Surg* 1984;**102**:248—55.
8. Graf R. *The ultrasound examination of the hip. Congenital dysplasia and dislocation of the hip in children and adults*. Springer; 1987. p. 172—211.
9. Vitale MG, Skaggs DL. Developmental dysplasia of the hip from six months to four years of age. *J Am Acad Orthop Surg* 2001;**9**:401—11.
10. Mace J, Paton RW. Neonatal clinical screening of the hip in the diagnosis of developmental dysplasia of the hip: a 15-year prospective longitudinal observational study. *Bone Joint J* 2015;**97-B**:265—9.
11. Woodacre T, Ball T, Cox P. Epidemiology of developmental dysplasia of the hip within the UK: refining the risk factors. *J Child Orthop* 2016;**10**:633—42.
12. Chen HW, Chang CH, Tsai ST, Liu WJ, Chua C, Chen YY, et al. Natural progression of hip dysplasia in newborns: a reflection of hip ultrasonographic screenings in newborn nurseries. *J Pediatr Orthop B* 2010;**19**:418—23.
13. Rawlings E, Burnett M, Reddan T. An audit of referral timeframes for ultrasound screening of developmental dysplasia of the hip (DDH) in neonates with a normal clinical examination. *Sonography* 2017;**4**:1—7.
14. Scott-Jupp R. Ultrasound hip screening: why bother? *Arch Dis Child* 2013;**98**:985.
15. Thallinger C, Pospischill R, Ganger R, Radler C, Krall C, Grill F. Long-term results of a nationwide general ultrasound screening system for developmental disorders of the hip: the Austrian hip screening program. *J Child Orthop* 2014;**8**:3—10.
16. Woolacott NF, Puhan MA, Steurer J, Kleijnen J. Ultrasonography in screening for developmental dysplasia of the hip in newborns: systematic review. *BMJ* 2005;**330**:1413.
17. Rosendahl K, Markestad T, Lie RT. Ultrasound screening for developmental dysplasia of the hip in the neonate: the effect on treatment rate and prevalence of late cases. *Pediatrics* 1994;**94**:47—52.
18. Bialik V, Bialik GM, Blazer S, Sujov P, Wiener F, Berant M. Developmental dysplasia of the hip: a new approach to incidence. *Pediatrics* 1999;**103**:93—9.
19. Storer SK, Skaggs DL. Developmental dysplasia of the hip. *Am Fam Physician* 2006;**74**:1310—6.
20. Lowry C, Donoghue V, Murphy J. Auditing hip ultrasound screening of infants at increased risk of developmental dysplasia of the hip. *Arch Dis Child* 2005;**90**:579—81.
21. Noordin S, Umer M, Hafeez K, Nawaz H. Developmental dysplasia of the hip. *Orthop Rev (Pavia)* 2010;**2**:e19.
22. Barlow T. Early diagnosis and treatment of congenital dislocation of the hip. *Proc R Soc Med* 1963;**56**:804—6.
23. Gulati V, Eseonu K, Sayani J, Ismail N, Uzoigwe C, Choudhury MZ, et al. Developmental dysplasia of the hip in the newborn: a systematic review. *World J Orthop* 2013;**4**:32—41.
24. Cashman J, Round J, Taylor G, Clarke NM. The natural history of developmental dysplasia of the hip after early supervised treatment in the Pavlik harness. *J Bone Joint Surg Br* 2002;**84**:418—25.
25. Koşar P, Ergun E, Unlübay D, Koşar U. Comparison of morphologic and dynamic US methods in examination of the newborn hip. *Diagn Interv Radiol* 2009;**15**:284—9.
26. Tong SH, Eid MA, Chow W, To MK. Screening for developmental dysplasia of the hip in Hong Kong. *J Orthop Surg (Hong Kong)* 2011;**19**:200—3.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.pedneo.2018.07.008.