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Diagnostic Accuracy of Clinical Examination, Ultrasonography, and Radiography for Developmental Dysplasia of the Hip in Infants: A Prospective Diagnostic-Accuracy Cohort Study

Salah Abdulkareem Ibrahim[1*], Nadir Abdullah Garjees[1], Mohammed Ismael Ibrahim[2], Delshad Abdallah Mohamed[2], Jutyar Abdi Hasan[3], Kholoud Hashem Salloum[4]

[1]Pediatric Department, College of Medicine, University of Duhok, Duhok Governorate, 1006, Iraq
[2]Pediatric and Psychiatric Nursing Department, College of Nursing, University of Duhok, Duhok Governorate, 1006, Iraq
[3]Kurdistan Higher Council of Medical Specialties (Radiology), Heevi Pediatrics Teaching Hospital, V224+37C, Duhok, Duhok Governorate, Iraq
[4]Pediatric Nursing, College of Nursing, University of Warith Al-Anbiyaa, Holy Karbala / Baghdad - Karbala, Iraq

**Corresponding Author's Email: salah.ibrahim@uod.ac*

ABSTRACT

Background: Developmental Dysplasia of the Hip (DDH) requires early recognition and appropriate age imaging to reduce delayed diagnosis and the need for more complex treatment. Nurses contribute to risk recognition, caregiver education, referral coordination, and follow-up, although nursing outcomes were not evaluated in this diagnostic study. **Objectives:** To compare the diagnostic performance of clinical examination, ultrasonography, and radiography for DDH in at-risk infants using a common composite reference standard. **Methods:** This prospective diagnostic-accuracy cohort study included 416 infants aged from birth to 12 months who had at least one stated risk factor for DDH. Participants underwent standardized clinical examination, Graf-method ultrasonography, and age-appropriate anteroposterior pelvic radiography. Final DDH classification was based on follow-up radiography at approximately 6 months of age and pediatric orthopedic adjudication. Sensitivity, specificity, Positive Predictive Value (PPV), and Negative Predictive Value (NPV), with 95% Confidence Intervals (CIs), were reported for each index test. **Results:** Ultrasonography had a reported sensitivity of 71.0% (95% CI, 65.5%-76.0%) and a specificity of 69.0% (95% CI, 60.7%-76.3%). Clinical examination had a sensitivity of 54.0% (95% CI, 48.2%-59.7%) and specificity of 64.0% (95% CI, 55.5%-71.7%), whereas radiography had a sensitivity of 71.0% (95% CI, 65.5%-76.0%) and specificity of 39.0% (95% CI, 31.1%-47.5%). **Conclusion:** Ultrasonography provided the most favorable reported balance of sensitivity and specificity in this selected high-risk cohort, while clinical examination remained an important first-line assessment and radiography provided age-dependent structural information. The findings support a coordinated, age-appropriate diagnostic pathway rather than reliance on a single modality. For nursing practice, the results emphasize standardized risk documentation, timely communication with pediatric and radiology teams, caregiver education, and closed-loop follow-up; however, direct nursing competencies, interventions, and outcomes should be evaluated in future studies.

Keywords: Clinical Examination; Developmental Dysplasia of the Hip; Diagnostic Accuracy; Infant; Nursing Practice; Radiography; Ultrasonography

INTRODUCTION

Developmental Dysplasia of the Hip (DDH) encompasses a continuum of abnormalities involving acetabular development, hip instability, subluxation, and dislocation. Because clinical manifestations change with age, delayed recognition can permit persistent dysplasia and increase the likelihood of complex treatment and long-term functional consequences. Early diagnosis is therefore central to preserving normal hip development and enabling timely, predominantly non-operative management when clinically appropriate (St George *et al*., 2020; Nicholson *et al*., 2023).

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The diagnostic pathway is age-dependent. Clinical examination provides an immediate bedside assessment, but its performance varies with infant age, disease severity, and examiner experience. The Barlow and Ortolani maneuvers are most useful in early infancy, whereas restricted abduction and leg-length asymmetry become more informative as the infant grows (O'Beirne *et al*., 2019; Tan *et al*., 2023). Ultrasonography visualizes the predominantly cartilaginous hip and permits static and dynamic assessment without ionizing radiation, while anteroposterior pelvic radiography becomes increasingly informative as ossification progresses (Karnik *et al*., 2021; Nicholson *et al*., 2023).

No single screening strategy has been adopted universally. European programs vary in the timing and use of clinical examination, selective ultrasonography, and universal ultrasonography, and recent systematic reviews have shown continuing uncertainty regarding the optimal balance among late-case detection, treatment rates, resource use, and cost (Cheok *et al*., 2023; Laborie *et al*., 2023). This variability supports evaluation of integrated, locally feasible pathways in which each modality is used at the developmental stage for which it is most informative (Krysta *et al*., 2024).

The nursing perspective is clinically relevant because nurses frequently encounter infants and caregivers during postnatal care, immunization services, home visits, and well-child follow-up. Within the local scope of practice and institutional policy, nursing responsibilities may include documenting DDH risk factors, observing asymmetry or restricted movement, escalating abnormal findings, preparing infants and caregivers for imaging, tracking referrals, communicating results across disciplines, and reinforcing follow-up plans. Evidence indicates that nurse-performed physical assessment alone may have limited sensitivity; accordingly, nursing practice should emphasize validated competencies, clear escalation criteria, and completion of indicated imaging rather than independent diagnostic labeling (Smart *et al*., 2024a, 2024b). Caregiver education regarding hip-safe positioning and the importance of attending follow-up appointments is also a relevant patient-safety function (Vaidya *et al*., 2021; Yoshioka-Maeda *et al*., 2023).

The Iraqi studies cited in this manuscript have examined selected components of DDH detection, including limited hip abduction, the Barlow and Ortolani maneuvers, nurses' knowledge, and risk-focused imaging pathways (Al-Saeedy & Redah, 2022; Ahmed & Alanee, 2023). However, comparative diagnostic-accuracy evidence integrating clinical examination, ultrasonography, and radiography within a common pathway and against a defined final classification remains limited. Clarifying the relative performance of these methods may support standardized multidisciplinary protocols and more consistent nursing referral and follow-up processes (Akber *et al*., 2024; Hassan *et al*., 2025).

Study Significance and Nursing Relevance

This study addressed a practical diagnostic problem in a selected high-risk infant population. Its findings may inform age-appropriate imaging workflows, multidisciplinary communication, and evidence-based nursing protocols for risk recognition, caregiver education, and referral completion. The study did not measure nursing knowledge, nursing interventions, caregiver outcomes, or workflow indicators; consequently, its nursing relevance is interpretive and practice-oriented rather than evidence of a direct nursing effect.

Aim of the Study

The primary aim was to compare the sensitivity, specificity, PPV and NPV of clinical examination, ultrasonography, and radiography for detecting DDH in infancy against the same composite reference standard. Secondary aims were to describe the distribution of diagnostic findings, examine the association between infant sex and reported hip involvement, and assess inter-rater agreement for radiographic interpretation.

Pre-specified Hypothesis

An integrated, age-appropriate diagnostic pathway was hypothesized to be more sensitive than clinical examination alone while maintaining acceptable specificity when all index tests were evaluated against the same reference standard and follow-up time point.

METHODOLOGY

Study Design

A prospective, single-center diagnostic-accuracy cohort design was used. The study was conducted over 12 months and was reported with reference to the Standards for Reporting Diagnostic Accuracy Studies (STARD 2015) (Bossuyt *et al*., 2015).

Study Setting

The study was conducted at a specialized children's hospital in Iraq.

Participants

The study enrolled 416 infants from birth to 12 months of age who were referred or identified as having at least one stated risk factor for DDH. Both hips were examined, yielding 832 hip assessments. The infant was treated as the reported primary unit for the descriptive and diagnostic-accuracy results.

Sample Size

The final sample comprised 416 infants.

Sampling Technique

A total consecutive sampling technique was used. Every eligible infant presenting during the recruitment period was considered for enrollment until the study period ended.

Eligibility Criteria

Eligibility was assessed at the time of presentation using the criteria below.

Inclusion Criteria

Infants are from birth to 12 months of age. Presence of at least one stated DDH risk factor: breech presentation, a family history of DDH, or oligohydramnios. Written informed consent provided by a parent or legal guardian.

Exclusion Criteria

Neuromuscular disorders, affecting hip stability or development. Skeletal dysplasia. Previous hip surgery.

Data Collection

Data were collected at each scheduled visit using a study record that included demographic characteristics, stated DDH risk factors, clinical examination findings, ultrasonographic classifications, radiographic findings, and the final DDH classification. Data were entered into a secure electronic database.

Imaging Protocol

Clinical Examination

Experienced pediatricians performed a standardized clinical examination of both hips. Hip stability was assessed with the Barlow and Ortolani maneuvers, and each hip was categorized as stable, unstable, or dislocated. Infants were re-examined at approximately 6 weeks.

Ultrasonography

Ultrasonography was performed after approximately 6 weeks of age by certified radiologists using the Graf method, with static and dynamic assessments of both hips. Hips were classified as Graf type I, II, III, or IV according to acetabular morphology and femoral-head coverage.

Radiography

Anteroposterior pelvic radiographs were obtained when infants were older than 4 months and were repeated or obtained at approximately 6-month visit when clinically indicated. Two radiologists independently evaluated femoral-head position, acetabular development, the acetabular index, and continuity of Shenton's line.

Outcome Measures

The primary outcomes were the sensitivity, specificity, PPV, and NPV of clinical examination, ultrasonography, and radiography for DDH. The reference classification was a composite of follow-up pelvic radiography at approximately 6 months and pediatric orthopedic adjudication. Secondary outcomes were the frequencies of positive and negative results for each method, the reported laterality of hip involvement, the association between infant sex and hip involvement, and inter-rater agreement for radiographic assessment.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, NY, USA, released in 2020). Categorical variables were summarized as frequencies and percentages. The diagnostic performance of clinical examination, ultrasonography, and radiography was expressed as sensitivity, specificity, PPV, and NPV, with 95% confidence intervals calculated using the Wilson score method. Associations between categorical variables were examined using Pearson's chi-square test. One-way analysis of variance (ANOVA) was performed as a supplementary analysis to compare the mean coded diagnostic-test results across the final DDH classification groups. Inter-rater agreement between radiologists was assessed using Cohen's kappa coefficient. All statistical tests were two-tailed, and a p value < 0.05 was considered statistically significant.

Ethical Considerations

The study protocol was approved by the Ethics Committee of the College of Nursing at Warith Al-Anbiyaa University, Iraq, with reference number 366 on 12th October 2024.

RESULTS

Participant Characteristics

Table 1: Demographic Characteristics of the Enrolled Infants

Characteristic	Category	n	Percentage (%)
Gender	Male	135	32.5
	Female	281	67.5

Note. N = 416 infants; n = number of infants. Percentages were calculated using the total sample as the denominator

Among the 416 enrolled infants, 281 (67.5%) were female and 135 (32.5%) were male (Table 1).

Diagnostic Findings

Table 2: Distribution of Final DDH Classification, Diagnostic-Test Findings, and Hip Involvement among the Enrolled Infants

Measure	Category	n	Percentage (%)
Final DDH Classification	Positive	284	68.3
	Negative	132	31.7
Clinical Examination	Positive	201	48.3
	Negative	215	51.7
Ultrasonography	Positive	335	80.5
	Negative	81	19.5
Radiography	Positive	283	68.0
	Negative	133	32.0
Hip Involvement	Right	112	26.9
	Left	155	37.3
	Bilateral	149	35.8

Note: DDH: Developmental Dysplasia of the Hip; N: Total Sample; n: Number of Infants.

Percentages were calculated using N = 416 as the denominator of the 416 infants, 284 (68.3%) were classified as DDH-positive and 132 (31.7%) as DDH-negative. Clinical examination was positive in 201 infants (48.3%) and negative in 215 (51.7%). Ultrasonography was positive in 335 infants (80.5%) and negative in 81 (19.5%), while radiography was positive in 283 (68.0%) and negative in 133 (32.0%). Hip involvement was right-sided in 112 infants (26.9%), left-sided in 155 (37.3%), and bilateral in 149 (35.8%) (Table 2).

Diagnostic Accuracy

Table 3: Diagnostic Accuracy of Clinical Examination for Detecting DDH

Diagnostic Measure	Estimate (%)	95% CI (%)
Sensitivity	54.0	48.2-59.7
Specificity	64.0	55.5-71.7
Positive Predictive Value (PPV)	76.0	69.6-81.4
Negative Predictive Value (NPV)	39.0	32.7-45.7

Negative Predictive Value (NPV)39.032.7-45.7Note: CI: Confidence Interval; DDH: Developmental Dysplasia of the Hip

Estimates and 95% CIs are presented as percentages. Confidence intervals were calculated using the Wilson score method. Clinical examination had a sensitivity of 54.0% (95% CI: 48.2%-59.7%) and a specificity of 64.0% (95% CI: 55.5%-71.7%). The PPV was 76.0% (95% CI: 69.6%-81.4%), and the NPV was 39.0% (95% CI: 32.7%-45.7%) (Table 3).

Table 4: Diagnostic Accuracy of Ultrasonography for Detecting DDH

Diagnostic Measure	Estimate (%)	95% CI (%)
Sensitivity	71.0	65.5-76.0
Specificity	69.0	60.7-76.3
Positive Predictive Value (PPV)	83.0	78.6-86.6
Negative Predictive Value (NPV)	76.0	65.7-84.0

Note: CI: Confidence Interval; DDH: Developmental Dysplasia of the Hip

Estimates and 95% CIs are presented as percentages. Confidence intervals were calculated using the Wilson score method. Ultrasonography had a sensitivity of 71.0% (95% CI: 65.5%-76.0%) and a specificity of 69.0% (95% CI: 60.7%-76.3%). The PPV was 83.0% (95% CI: 78.6%-86.6%), and the NPV was 76.0% (95% CI: 65.7%-84.0%) (Table 4).

Table 5: Diagnostic Accuracy of Radiography for Detecting DDH

Diagnostic Measure	Estimate (%)	95% CI (%)
Sensitivity	71.0	65.5-76.0
Specificity	39.0	31.1-47.5
Positive Predictive Value (PPV)	71.0	65.5-76.0
Negative Predictive Value (NPV)	39.0	31.1-47.5

Note: CI: Confidence Interval

Estimates and 95% CIs are presented as percentages. Confidence intervals were calculated using the Wilson score method. Radiography had a sensitivity of 71.0% (95% CI: 65.5%-76.0%) and a specificity of 39.0% (95% CI: 31.1%-47.5%). The PPV was 71.0% (95% CI: 65.5%-76.0%), and the NPV was 39.0% (95% CI: 31.1%-47.5%) (Table 5).

Additional Statistical Analyses

Table 6: One-Way ANOVA of Binary Diagnostic-Test Results by Final DDH Group

Diagnostic Test	Source	SS	*df*	MS	F	*p*-value
Clinical Examination	Between groups	3.124	1	3.124	12.836	0.0001
	Within groups	100.758	414	0.243		
	Total	103.882	415			
Ultrasonography	Between groups	7.330	1	7.330	52.417	0.0001
	Within groups	57.898	414	0.140		
	Total	65.228	415			
Radiography	Between groups	1.065	1	1.065	4.933	0.027
	Within groups	89.413	414	0.216		
	Total	90.478	415			

ANOVA: Analysis of Variance; DDH: Developmental Dysplasia of the Hip; df: Degrees of Freedom; F: F Statistic; MS: Mean Square; SS: Sum of Squares

The analysis was reported as a comparison of mean binary diagnostic-test coding across final DDH groups. All tests were two-sided; $p < 0.05$ was considered statistically significant. The one-way ANOVA showed statistically significant between-group differences for clinical examination ($F = 12.836$, $p = 0.0001$), ultrasonography ($F = 52.417$, $p = 0.0001$), and radiography ($F = 4.933$, $p = 0.027$) (Table 6).

Table 7: Association between Gender and Hip Involvement

Variables Compared	*p*-value
Gender and Hip Involvement	0.001

Note: The specific statistical test, test statistic, degrees of freedom, and effect-size estimate were not reported in the source manuscript. A two-sided p < 0.05 was considered statistically significant

A statistically significant association was reported between gender and hip involvement ($p = 0.001$; Table 7). Inter-rater agreement between the two radiologists was reported as Cohen's $\kappa = 0.80$.

DISCUSSION

This prospective study compared three components of an age-dependent DDH screening pathway in a selected high-risk cohort of 416 infants. Ultrasonography showed the most favorable reported balance of sensitivity and specificity (71% and 69%, respectively). Clinical examination showed lower sensitivity (54%) and moderate specificity (64%), whereas radiography showed the same reported sensitivity as ultrasonography (71%) but substantially lower specificity (39%). The results support a pathway that incorporates clinical assessment and imaging at developmentally appropriate ages rather than reliance on a single screening test at a single time point. Because the complete underlying 2 × 2 tables, the analytic unit, and the decision rule for the reference standard were not available in the reporting file, the confidence intervals should be verified against the original SPSS output before final publication. The reported sensitivity for clinical examination (54%) is consistent with results from other studies indicating that physical assessment alone may miss a considerable number of DDH cases. A recent systematic review and meta-analysis reported a pooled sensitivity of 36% (95% CI, 27% to 47%) for the Ortolani-Barlow tests and 57% (95% CI, 42% to 71%) when combined with limited hip abduction (Chavoshi *et al*., 2022). A small Australian study found that 50.5% (95% CI, 34.5% to 67%) of infant hips were correctly classified as normal or abnormal using child health nurses' physical assessment against handheld ultrasonography (Smart *et al*., 2024b). The specificity of clinical examination in the present study was 64%, which was lower than several published estimates; this difference may reflect variation in study populations, examiner experience, reference standards, and diagnostic thresholds. Thus, a normal clinical examination does not rule out the need for imaging in at-risk infants. Furthermore, even experienced clinicians may obtain false-negative results for the Ortolani and Barlow tests in infants with clinically relevant risk factors for DDH (Tan *et al*., 2023).

Ultrasonography reported sensitivity 71% and specificity 69%, numbers that are significantly lower than those reported for expertly performed, standardized Graf studies. Importantly, a number of factors influence the accuracy of each of these components, including the accurate acquisition of the standard plane, operator training and experience, accurate interpretation of the images, and appropriate classification of a developmentally immature hip. Importantly, there is increasing evidence that screening after the first 4 weeks of life improves specificity and reduces follow-up examinations (Lussier *et al*., 2019). International agreements (O'Beirne *et al*., 2019) and reviews (Karnik *et al*., 2021) on the use of imaging for DDH also highlight the importance of high-quality imaging, acquired in a standardized fashion, with a quality-assured operator. In this study, test performance could not be definitively attributed to ultrasonography alone, as information regarding the device, operator, blinding, and threshold for a positive Graf score was not reported.

Radiography was reported to have a sensitivity of 71% and a specificity of 39%. The specificity of radiography is known to be affected by a number of factors, including the age of the infant, quality of the

radiograph, pelvic positioning, degree of ossification, and the use of an acetabular index as a threshold for abnormality. The use of follow-up radiographs in the final classification of the infant's hips as part of the reference standard, and the fact that these radiographs were taken 4 months after the initial assessment, may have introduced an element of bias in terms of the interpretation of the results for radiography. The results for radiography by age are not presented, and thus it is not known if the results for this test at 4 months of age are comparable to results obtained at or after 6 months of age.

A DDH screening pathway that is integrated and utilizes the skills of multiple health care professionals is thought to be superior to a single method or test. There are, however, many varying models of care and health care systems around the world. Norlén and Faergemann, (2022) evaluated a cohort of infants who were already on a DDH screening and referral pathway and utilized pediatric orthopedic assessment in combination with imaging in accordance with standardized ultrasonography and radiography criteria. Cheok *et al*. (2023) found that universal screening with ultrasonography for DDH decreased the number of late presentations, but this was at the cost of an increase in the number of infants who were placed in abduction bracing as opposed to surgery. Other evidence, however, supports the opposite, that there is no decrease in childhood surgery for DDH when screened with ultrasound as opposed to selective screening (Laborie *et al*., 2023). Evidence regarding the cost-effectiveness of screening for DDH in the neonate also is variable (Harper *et al*., 2021). The value of a structured screening program with complete follow-up is felt to be superior to a screening program where all tests are used at all ages.

It is also important to note that the high percentage of DDH-positive cases in this study is not indicative of the DDH prevalence in the general population. This study was restricted to a group of infants who had risk factors for DDH and were therefore referred to a specialized DDH screening center. As a result, the pre-test probability for DDH was high for all infants in this study, and therefore the PPV and NPV are not generalizable to universal screening of all newborns (Altman & Bland, 1994). In addition, the laterality of DDH-positive cases (i.e., left-sided, right-sided, or bilateral) was reported; however, the laterality denominator was not provided. Therefore, any conclusions regarding the epidemiology of DDH and the association between sex and laterality of DDH-positive cases in this study must be verified.

The findings highlight the importance of nurses not providing false reassurance to families when a physical assessment is within normal limits and the infant is at high risk for developmental dysplasia of the hip (DDH). While a normal clinical screening can provide some reassurance, it is not enough to rule out DDH (Shaw & Segal, 2016; Smart *et al.*, 2024). Rather, the key role of the nurse is to accurately document risk factors, communicate with families, and refer to a pediatrician or orthopedic surgeon when there are any indicators of instability or abnormality, whether suspected or apparent (Shaw & Segal, 2016). The nurse must also ensure that all scheduled and completed imaging is reviewed by the referring pediatrician and that a plan of care is communicated to families. Scoping studies and diagnostic-accuracy research are warranted to clarify the required nursing competencies for the assessment of DDH (Inagaki-Asano *et al.,* 2024; Smart *et al.,* 2024). Recent education studies and implementation evaluations of nurse-led programs of ultrasound screening of newborns and of caregiver education of healthy hip positioning, which support the use of nurse-led programs, highlight the potential for the use of skilled nurses in these new roles (Yoshioka-Maeda *et al.*, 2025, 2026a, 2026b).

Communication with caregivers and their understanding of DDH screening and of hip-safe positioning of their infants is an important nursing function. Studies of health guidance given by community health nurses during the time that an infant is screened for DDH have identified the screening process as significant to the family (Yoshioka-Maeda *et al.*, 2023). In terms of preventing DDH, health evidence indicates that infants should be positioned in hip-safe ways and that certain practices such as extension-adduction positioning of an

infant's hips should be avoided (Pediatric Orthopaedic Society of North America, 2015; Vaidya *et al.*, 2021). The study reported here did not measure these practices or other aspects of nursing that might be evaluated within a study of a DDH screening process. Rather, the implications of the findings for the development of a process of care are identified.

While results cannot indicate specific practices or recommendations, the findings support a standardized, age-appropriate, structured, and comprehensive DDH pathway where all assessments are completed by health care professionals best suited for the given test, with screening or assessment performed by and documented by the same individual each time. That is, a completed nursing assessment does not substitute for the pediatric or radiologic assessment and thus does not clear a child with a documented indication for further assessment for DDH. A checklist that includes assessment for risk indicators (i.e., breech presentation in the third trimester, family history of DDH, oligohydramnios, and previous abnormal findings for hip development) (Shaw & Segal, 2016; Tirta *et al*., 2025) can be used to complete the screening and document findings during well-child visits or postnatal visits. Subsequent assessment for clinical findings or other risk indicators for DDH must be completed and documented and communicated to the responsible clinician, along with scheduled and completed imaging and referrals and documented plans and follow-up after imaging and review by the specialist. Follow-up after the screening assessment should also confirm that the results of completed imaging were reviewed by all healthcare professionals who completed the portion of the assessment that relied on the completed imaging and that all others were notified of abnormal results and a plan documented and communicated to the family.

As with any screening test, high-quality follow-up of a screened infant is as important as the test itself (Lowry *et al*., 2005; Shaw & Segal, 2016). Within the imaging process itself, the nurse can clearly establish patient safety and contribute to quality of care through several steps. These would include: 1) Clear documentation of the reason for the test (diagnostic indication) as well as the age of the infant at the time of the test; 2) Preparat

Limitations

This study has several limitations. The study was conducted at one specialized DDH center. The results of this study therefore cannot be applied to universal newborn screening in different populations. Another limitation is that the sample-size calculation was not mentioned, the flow of participants was not reported, and the numbers of infants for which the different index tests and reference-standard tests were performed were not given. The ages of the infants studied ranged from birth to 12 months of age, and therefore, test performance at different ages was not reported. The meaning of 6 months of follow-up is also not clearly stated.

The thresholds for positive findings for clinical examination, Graf ultrasonography, radiography, and the final assessment by the clinical teams were unspecified. It was also unclear whether assessors for the index tests and the reference standard were blinded to information that could potentially introduce bias. A major concern is that follow-up radiographs included in the reference standard may have introduced incorporation bias into the assessment of radiographic accuracy. Additional concerns include operator-dependent factors, image quality, and test timing. The manuscript did not include complete 2 × 2 contingency tables for each index test. Therefore, the 95% confidence intervals were calculated from the reported point estimates and the relevant denominators and should be verified against the original SPSS output before final publication.

Future Scope

Future studies must incorporate a multicenter design with a focus on assessing the diagnostic accuracy of

various tests to identify DDH, using an independent and explicit reference standard, with blind interpretation. Reporting should include a complete 2x2 contingency table for each test, and statistical analysis should account for the paired nature of the hips when analyses at the hip level are conducted. Test performance should be reported for specific age groups and risk groups and by the different disciplines that perform ultrasound, as well as by level of experience of the ultrasound operator and by image quality. Economic studies must account for the costs of repeat imaging, late diagnosis, and treatment, as well as the burden of care on families and health care providers for children with late-diagnosed DDH and those for whom follow-up is lost.

Nursing research focused on DDH should be aimed at evaluating aspects of DDH assessment in nursing practice. In particular, there is a need for more research on competency-based education for nursing in the assessment of DDH and in referral processes for infants with at-risk hips. Studies that evaluate the ability of nurses to recognize risk for DDH and the timeliness of referrals made by nurses would be very beneficial. Additionally, studies that evaluate the tracking of infants with at-risk hips for imaging and review by a pediatric orthopedic surgeon, as well as studies of caregiver knowledge and safe positioning of hips, would identify areas where further development of nursing practice is needed. An important area for future research would be the implementation of a DDH screening program, with particular focus on a comparison of a nurse-coordinated versus a nurse-led model of care. Emerging models of nurse-led screening using ultrasound are promising; however, further research is needed to 1) define and credential nurse practice in this area, 2) ensure that high quality of care is provided, 3) undergo quality assurance activities, and 4) conduct studies in a variety of health care systems (Yoshioka-Maeda *et al*. 2025, 2026).

CONCLUSION

In this particular at-risk population, ultrasonography found the best test characteristics for a screening tool; the clinical examination as a first screening tool has its limited use as a stand-alone tool, and radiography provides age-dependent structural information with poor specificity. Information obtained with a modality for screening can be used to select the best modality for subsequent assessment in relation to the age of the infant; the risk study highlights the importance of the nursing assessment in the early detection of DDH and in the following steps after diagnosis. The study also identifies an area for future research in this regard. As the study did not measure the nursing interventions and their effects, future research should focus on measuring nursing competencies and the process outcomes that are sensitive to the nursing care. of the infant, prior findings in the infant, and for follow-up of previously assessed hips with abnormal or unresolved findings.

CRediT Authorship Contribution Statement

S.A.I: Conceptualization, Methodology, Investigation, Project administration, Supervision, Writing – original draft, Writing – review and editing. N.A.G: Conceptualization, Methodology, Investigation, Supervision, Writing – review and editing. M.I.I: Investigation, Data curation, Writing – original draft, Writing – review and editing. D.A.M: Investigation, Data curation, Validation, Writing – review and editing. J.A.H: Methodology, Investigation, Validation, Visualization, Writing – review and editing. K.H.S: Writing – original draft, Writing – review and editing.

AI Assistance Declaration

AI-assisted language editing was used only to improve readability, grammar, and linguistic clarity. The authors critically reviewed and edited all revisions, verified the scientific accuracy and integrity of the manuscript, and assume full responsibility for the content, interpretations, and conclusions presented.

Conflict of Interest

The authors declare that they have no competing interests related to this study.

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