Impact of multiple factors on the incidence of developmental dysplasia of the hip: risk assessment tool

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Research Article

Keywords: Developmental Dysplasia of the Hip, Newborn Infant Health, Neonatal Screening, Risk Assessment

Posted Date: January 6th, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1037297/v2>

Abstract

Introduction: Developmental dysplasia of the hip (DDH) is one of the most common musculoskeletal conditions in children. Not treated DDH leads to disability, gait abnormalities, limb shortening and chronic pain. Our study aims to determine the impact of multiple risk factors on the occurrence of DDH and develop an interactive risk assessment tool.

Materials and Methods: We conducted a retrospective cohort study in the Outpatient Clinic for Children of University Hospital. The Graf classification system was used for ultrasonographic universal screening. In total, 3102 infants met the eligibility criteria (n =6204 hip joints).

Results: The incidence of DDH was 4.45%. In multivariate analysis, risk factors for DDH were weight (OR = 2.17 (1.41-3.32)), week of delivery (OR = 1.18 (1.00-1.37)), gender (OR = 8.16 (4.86-13.71)), breech delivery presentation (OR = 5.92 (3.37-10.40)), symptoms of DDH (25.28 (8.77-72.83)) and positive family history in siblings (5.74 (2.68-12.31)). Multivariate logistic regression predictive model was used to construct the interactive risk calculator.

Conclusion: We confirmed well-known DDH risk factors in the studied population. Our results support the recent hypothesis that preterm infants (37 < week) have lower rate of DDH. The DDH risk calculator was built but needs external validation in prospective study before being used in a clinical setting.

Level of Evidence: Retrospective cohort study: Level III

Introduction

Background

Developmental dysplasia of the hip (DDH) is one of the most common musculoskeletal disorders in children. DDH is an abnormal growth of the hip joint and surrounding tissues. It refers to a heterogeneous spectrum of abnormalities that range from mild acetabular defect to subluxation or complete dislocation of the femoral head. There is no universal definition of DDH, and the term is imprecisely described in the literature [1]. Undetected and not treated DDH can lead to severe disability, gait abnormalities, limb

shortening, reduced range of motion in affected joints and chronic pain. Still, it is the leading cause of osteoarthritis and the main indication for total hip replacement in young adults [2]. The pathogenesis of DDH is still unclear. However, the literature identifies several risk factors, such as female sex, left side, breech position, family history of DDH, and first-born births [3]. The other studied risk factors are oligohydramnios, macrosomia, multiple pregnancy (MuP), hyperlaxity, torticollis, clubfoot, and metatarsus varus. Recently, vitamin D level alterations in DDH patients were demonstrated [4, 5]. Many genes, loci, and polymorphisms are also being investigated in DDH, but the evidence is limited [6, 7].

The diagnosis of DDH in newborns is based on clinical and ultrasound examination. The most commonly used ultrasound methods are *Grafs*, *Harckes* and Terjesen's [8]. Radiographs are useful only from the 3rd – 4th month of life and are the preferred method of evaluating and monitoring DDH after 6 months. The physical examination should include the test for leg length discrepancy (Galeazzi test), stability examination (Barlow's and Ortolani tests) and detection of limited abduction. Universal clinical screening of newborns is recommended by The American Academy of Pediatrics (AAP), the Orthopaedic Society of North America (POSNA), American Academy of Orthopaedic Surgeons (AAOS), and Canadian DDH Task Force [9]. However, even in experienced hands, physical examination findings in DDH can be subtle [10]. Dogruel et al. reported limited physical examination specificity (13.68%) compared to ultrasound findings (Graf). Most ultrasonography-diagnosed dysplastic hips were normal in clinical examination (71.63%) [11].

Currently, there are two primary approaches to DDH ultrasound screening – universal and selective. Ultrasound as a universal screening method for early diagnosis was introduced in several European countries such as Austria (1991), Switzerland (1995), Germany (1996) and the Czech Republic [12]. As the first among Asian countries, Mongolia (2017) recently launched universal ultrasound screening [13]. Implementing ultrasound-based universal screening led to a significant reduction of hip surgery due to DDH in children [14]. A second screening plan established in the United States and England is based on newborn clinical examination. Selective ultrasonography screening is recommended only in infants with positive findings on physical examination. According to the AAP, selective ultrasound could also be useful in children with risk factors such as breech presentation, positive family history, hip instability, or history of lower extremity swaddling [9, 15]. Two randomised trials on universal vs. selective screening were conducted; however, the results were inconclusive, and the need for universal screening is still under debate [16, 17]. According to national arthroplasty registers, selective screening has not reduced the number of procedures performed due to early-onset OA in patients with DDH [18]. The first ultrasound is usually recommended before 6 weeks of life in universal screening countries. It is recommended in the first week of life in cases with risk factors or positive physical examination [8]. There is no official universal screening program or guidelines for the DDH screening and control visits timeframes in Poland. However, ultrasound examination is done in most children. The frequency of DDH depends on ethnicity,

race, age of the population studied, diagnostic criteria, and screening method (physical examination, plain radiographs, ultrasound technique). The incidence of DDH can range from 0.1% in Africans to 7.6% in Native Americans [19]. The current incidence of DDH and risk factors on the first visit in 6 weeks of life in Poland's outpatient clinics remains unknown. What is more, little is known about the cumulative effect of the beforementioned risk factors on DDH incidence in the population.

Objectives

This study aimed to determine the incidence of DDH in newborns in Poland with the Graf method during the first visit to an outpatient clinic. We also wanted to assess potential risk factors for DDH in the studied population. Our study presents a multivariate regression model for DDH and a dedicated interactive risk calculator. In the discussion section, we confront the study results with other findings in the field of DDH.

Methods

The study design is a retrospective cohort study. The study setting was the Outpatient Clinic for Children of Orthopaedics and Traumatology Department of Medical University of Warsaw, Poland. The data was collected for all patients who attended the Outpatient Clinic for the universal ultrasonographic hip infant screening from January 2013 to December 2018. The study size was determined from the study type and included all who met eligibility criteria for participation. The screening method used in every patient was the Graf classification system (I-IV). Certified medical assistants performed the data collection in paper and electronic form. The physical examination included the hip-oriented orthopedic examination and general examination of the newborns. The consent for accessing and retrieving the medical data from the Outpatient Clinic archive was obtained from the head of the Orthopaedics and Traumatology Department of the Medical University of Warsaw, Poland (PM). The Institutional Review Board of the Medical University of Warsaw approved the study protocol on 10 June 2019 (AKBE/227/2019). For this report, we used STROBE Statement for observational studies.

Participants

The examined eligibility included all patients who attended the Outpatient Clinic for the ultrasonographic hip infant screening from January 2013 to December 2018. The newborns who attended the first visit for hip ultrasound in another secondary facility were excluded from the study. The population represents all socioeconomic groups, but the ethnicity is relatively homogenous.

Variables

According to Graf's classification, the diagnostic criteria of DDH were Graf type IIa (-), IIb, IIc, D, III, and IV images. Type II hips were monitored (IIa (+)) and treated only in the absence of signs of sufficient maturation (IIa (-) or IIb) [18]. In our clinic first ultrasound examination is recommended at 6 weeks of life. In case of a positive physical examination upon birth or risk factors, ultrasound is recommended upon first weeks of life. The second control visit is also recommended for healthy children at 12 weeks. The record of the orthopedic examination of the hips included maximum abduction angle value for each hip joint, Ortolani test, Barlow test and Galeazzi test. The asymmetry of abduction was defined as the difference of 20° or more. Articular noises in physical examination such as "clicks", or "creaks" were not classified as pathological findings [18]. The record included the name, national identification code, age, and visit date. The information on potential risk factors such as female sex, abnormal presentation, high birth weight, term of birth, MuP, mode of delivery, diabetes, positive family history and coexisting medical conditions in children were also collected.

Data sources

The physical examination was conducted by an experienced orthopedic surgeon (PW, PG, WW, RW and GT) who also performed the ultrasound and the α and β angles measurements. Ultrasound device operating with a 7-10 MHz linear transducer and holding cradle was used. The diagnostic criteria of DDH were according to Graf's classification [20]. The analysis included the first control visit in the clinic in type Ia, type Ib Graf hips. In patients with IIa (+) upon the first visit, the analysis included the subsequent visits to assess if the treatment was implemented in patients with insufficient hip maturation on next visits.

Bias

Our study is limited to children who do not have obvious dislocations diagnosed upon birth. This group of newborns is usually directed to dedicated centers specialized in children's orthopedic surgery. This fact can modify the study results and possibly lower the DDH rate in our cohort - especially Graf type III and IV with hip instability in physical examination. It is also worth mentioning that the accuracy of the examination, especially regarding specificity, is closely related to the examiner's skills. Graf method must

be performed in strict compliance with the author's instructions. Only certified orthopedic surgeons performed the ultrasound examination (PW, PG, WW, RW and GT) [18].

Quantitative variables

We decided to set a cutoff value for limited hip abduction as the difference of 20^0 or more between both hips. We do not analyze the bilateral limitation of abduction. According to Jari et al., bilateral limitation of hip abduction is not a useful indicator of DDH; however unilateral limitation of 20^0 or more abduction is a specific and sensitive sign of DDH [21].

We adopted the American College of Obstetricians and Gynecologists (ACOG) definition for fetal macrosomia as birthweight over 4.000 g irrespective of gestational age [22]. Preterm delivery was defined as birth before 37 weeks of gestation. We used the ACOG definition of post-term pregnancy. It is defined as a pregnancy extended to or beyond 42 weeks [23].

Statistical methods

To summarize the characteristics of the studied groups, for continuous variables, the median was used together with the lower and upper quartile (Q1-Q3) for continuous variables with a distribution other than the normal. The normality of the distribution was verified with the Shapiro-Wilk test at the significance level $p < 0.05$. The analysis of differences between groups for nominal variables was carried out with the use of 2x2 tables, the significance of which was verified by Chi2, Chi2 with Yates correction or Fisher exact test was used, as appropriate. The results were reported with p-Value. A univariate logistic regression model was performed to verify the predictors significant for the analysis. A multivariate logistic regression was used to further evaluate the predictors and their interactions, building a model using the backward stepwise method with the predictor cutoff point at $p < 0.1$. Odds ratio (OR) with 95% confidence intervals (95% CI) was calculated for each predictor. The diagnostic value of the model was assessed by analyzing the area under the curve (AUC) of the ROC curve with its 95% confidence interval. Sensitivity and specificity were also calculated for the diagnostic test. Statistical significance for the analyzes was set at $p < 0.05$. We used the Statistica 13.3 analytics software by TIBCO. The conditional probability calculator for multivariate logistic regression was calculated from the logistic regression formula. Variables for the presence of the factor were coded as 1 – the presence of the risk factor DDH, 0 – lack of the risk factor DDH. Gender was coded as 1 – Women, 0 – Men. The weight in the model was determined by kilograms. The calculator was created using Excel Microsoft Office 2021.

Results

Participants

Among 4891 infants who underwent hip ultrasonography in the Outpatient Clinic from 01 January 2013 to 31 December 2018, examined for eligibility 3102 met the criteria (n = 6204 hips). Ten initially screened infants excluded from the study were continuing care started in an external facility. Subsequently, we excluded cases with any missing information regarding investigated risk factors.

Outcome & descriptive data

Females constituted 49.7 % of participants while males 50.3 %. The median time of delivery was 39.00 with Q1-Q3 being 38.00-40.00 and the median birth weight was 3.40 (3.09-3.73). The first visit mean time from birth was 7.98 weeks (median 8 weeks minimum 1 week maximum 31 weeks). The number of participants with available data for each variable is shown in table 1.

Main results

The incidence of DDH in the studied group that needed treatment was 4.45%. Bilateral DDH occurred in 60 out of 138 DDH cases (43.48 %). The distribution of Graf hip types is presented in table 2. The treatment methods used are listed in table 3. The category boundaries for continuous variables are discussed in the methods section. Statistical significance was obtained for the factors: female gender ($p<0.001$) breech position ($p<0.001$), cesarean section ($p=0.035$) positive family history of DDH in at least one parent ($p=0.027$) positive family history of DDH in at least one sibling ($p<0.001$), DDH symptoms ($p<0.001$) and preterm delivery <37 week ($p=0.003$). In our study, 97.11 % of DDH patients had at least one confirmed risk factor (female gender, cesarean section, breech position, family history of DDH). Only 4 patients were free from any significant risk factors (2.89 %)

Logistic regression model

Out of 15 variables, only 9 were statistically significant in the univariate model for the classification of DDH occurrence. The model classified as statistically significant predictors of DDH: female sex, cesarean delivery, breech position during delivery, delivery below 37 weeks, positive history of DDH in parents and siblings, and the occurrence of DDH symptoms (Table 4). However, it should be noted that delivery <37 weeks of gestation is a protective factor (OR = 0.18 (0.04-0.72)). In addition, continuous variables such as weight and week of delivery also, according to the model, statistically significantly increase the chance of DDH (weight: OR = 1.69 (1.22-2.34), week of delivery: OR = 1.22 (1.08-1.38)). In the multivariate model (Table 5), only the variables such as weight, week of delivery, female gender, breech position, symptoms and a positive history of sibling dysplasia statistically significantly influenced the chance of developing DDH. The Hosmer-Lemeshow goodness of fit for the logistic regression test was $p < 0.0001$, indicating a poor model fit to the data. The area under the ROC curve (Figure 1) for the created predictive model was AUC-0.81 with a 95% confidence interval of 0.77-0.85, a sensitivity of 76.09% and a specificity of 72.27%.

A multivariate model was used to construct the DDH risk calculator – supplementary file 1. Conditional probability and OR of DDH can be obtained from the tool by selecting “yes” or “no” for binominal variables (female gender, breech presentation, symptoms, positive family history – siblings) and giving the exact value for continuous measures (weight, week of delivery).

Discussion

Key results

The overall aim of the study was to assess the incidence of DDH in the Polish population and investigate whether the risk factors described in the literature for DDH are also reflected in this group of patients. The occurrence of DDH during the first screening visit is high (4,57%). Our work confirmed the already known risk factors of DDH (table 1). We also discuss some other risk factors that have appeared in the literature. We constructed the DDH risk calculator, which can be used as a clinical decision tool in the future but needs external validation in a prospective study.

Interpretation

In Poland, before implementing ultrasonography, the DDH rate was relatively high 6.80% and the dislocation was reported in 1.06% of the population [24]. It can be speculated that the high DDH rate was due to different diagnosis methods at the time, and only suspected infants had undergone the diagnostic process. Using the ultrasound screening, DDH was diagnosed in 5.60% of the newborns in the first week

of life (Łódź, Poland) [25]. In our study, the occurrence of DDH in the university hospital in the capital city (Warsaw, Poland) during the first screening visit was lower – 4.57% than in the beforementioned study. This difference is probably due to the hip maturation curve and visit timing 1 week vs. median of 8 weeks. The DDH diagnosis can depend on the timing of the examination and the method used. As a child grows older, the hip joint matures, which can be observed with both ultrasound (α angle) and radiographs (Acetabular Index, Acetabular Depth Ratio) [20, 26].

Our work confirmed some of the already known risk factors such as female gender, breech position, cesarean section, and positive family history of DDH. However, according to the literature, there was not even one risk factor in up to 73 - 95 % of DDH cases. Also, most children with risk factors do not develop DDH, and the disease can be observed only in 1 - 10% of cases [27-30]. In contrast to these results in our study, 97.11 % of DDH had at least one statistically significant risk factor.

The female gender is considered one of the most important risk factors of DDH [27, 31]. This strong relationship was also confirmed in our study 8.16 ((4.86-13.71) (OR). This phenomenon is still under investigation, and the mechanism of this connection remains unclear. Various theories explain it - the most common is the gender-dependent influence of hormones, particularly relaxin, on hip joint development. Relaxin is a polypeptide hormone produced by the corpus luteum, endometrium, decidua, and placenta [32]. It has an inhibitory effect on uterine muscle contractions and relaxes the pubic symphysis during labor. The role of relaxin, present in the blood serum, ultimately stimulates collagen turnover by increasing the secretion of matrix metalloproteinases (MMPs), collagenase and a plasminogen activator [27]. Yamasato et al. confirmed a higher expression of relaxin receptors in the placenta of the female fetus [33]. Another study by Dragooet et al. revealed that the female sex is also associated with higher relaxin receptor expression in the anterior cruciate ligament [34]. The recent reports from Ayanoguet et al. confirm the association of DDH and the number of relaxin receptors in the ligament of the femoral head. However, the study does not report the difference in receptor expression depending on infant gender [35]. Although the function of relaxin is already known, there is no evidence that this mechanism of hip joint laxity is exclusively responsible for the higher frequency of DDH in females. What is more, some studies have demonstrated opposite results – lower level of the hormone in umbilical blood and higher risk of DDH [36] Given the above, some researchers have theorized that other maternal factors, such as poorer preparation of a mother's delivery canal, may also play a role, but this does not fully explain the significant prevalence of DDH in females [37].

There is also a whole group of so-called mechanical factors, in which there is pressure on the hip joint during pregnancy by the uterus walls or by the delivery canal tract at birth. One of the mentioned factors is the abnormal position and presentation of the fetus. Many authors have already described breech

positioning as a risk factor. Andersen et al. advocated that neonates in a breech-presenting position in the fetal state have exerted a significant stretching force on the hip joint capsule, thus causing hip instability [38]. According to Dezateux et al. complete breech vaginal delivery (3% of all births) links with a 17-fold increased risk of DDH (OR = 17.15; CI 95 % 2.79 - 22.99), while breech presentation resolved by Caesarean section relates to ten times increased risk (OR = 10.03; CI 95 % 8.58 -11.72) [31]. These findings were confirmed in metanalysis (35,139 infants) by Panagiotopoulou et al. [39]. Therefore, breech positioning is probably an important risk factor of DDH during pregnancy and birth when significant forces are applied to the hip joint [40]. Our results appear to be consistent with the existing literature. We recorded 173 (5,6 %) babies in the breech position, of whom 21 developed DDH (OR = 5.92 (3.37 – 10.40)).

All authors describe abnormalities on physical examination as a risk factor - which was also unquestionably demonstrated in our study. We considered the following as abnormalities: positive Ortolani/Barlow test and/or hip joint abduction asymmetry 20 degrees or more and abduction of the joint less than 45 degrees, which is consistent with the available evidence. Some patients do not present any abnormalities on clinical examination, but an ultrasound reveals DDH. In our study abnormalities on physical examination predisposed to DDH odds of 29.48 (10.81 – 80.41).

Available scientific knowledge indicates that positive family history is one of the most important risk factors of DDH [27]. According to the consensus of the Committee on Quality Improvement, Subcommittee on Developmental Dysplasia of the Hip, a risk of DDH was defined as 6% in cases of healthy parents and recognized DDH in siblings, 12% in cases of confirmed DDH of the mother/father and 36% in cases where DDH was recognized in one parent and a brother/sister. The correlation was also confirmed in our findings [41]. Authors state that higher risk can also be observed if the disease was recognized in a first-degree cousin of the child. In those cases, the risk is specified at a level of 1.7% [28]. Until recently, it was believed that individual genes are responsible for malfunctions in the physiology of connective tissue or proteins of the joint capsule. A hypothesis of a two-gene system in DDH inheritance has also arisen in literature. However, new, more progressive methods for studying molecular biology have led to further findings. We are now familiar with more than a dozen DDH-associated genes and their locations. For Caucasians, these include IL-6 and TGF- β 1 genes mutations, for Asian populations: COL3A1, DKK1, HOXB9, HOXB9, HOXD9, WISP3. Non-location-specific genes mutations were also found: COL1A1, CX3CR1, GDF-5 and PAPP2. At present, research is managing to identify individual genes in specific populations - unfortunately, at this time, we do not know the individual genes that may be involved in DDH for the world population [42]. At present, researchers are attempting to determine the exact mechanisms by which these genes may be involved in the development of DDH. No differences in a higher frequency of DDH were found in genetic disorders like Ehlers-Danlos or Marfan's syndrome [43].

Some studies investigate the mode of delivery as potential risk factor of DDH, but the results are inconclusive. In metanalysis, by L. Ortiz-Neira et al. two studies indicated that vaginal delivery could be a risk factor of DDH, and one study suggested the opposite. The results of the fourth study were inconclusive. The metanalysis of the beforementioned studies resulted in non-significant influence [44]. In our study, a cesarean section in univariate analysis was associated with the chance of developing DDH in a child (OR - 1.44 (1.02-2.02)). However, when the factor was introduced into the multivariate model, where the development of DDH was influenced by several factors simultaneously, the cesarean section was no longer significant and was rejected from the model. Cesarean section is related to a very high rate of breech position (5,29 %; n = 164), which is a significant risk factor of DDH itself. The mode of delivery is most likely not a risk factor.

We also examined MuP as a potential risk factor in our publication. Although the results of our study do not indicate a direct correlation, there is some evidence in the literature that the relationship could be significant for the female gender. According to Dezateux et al., special attention should be paid to MuP, especially when the children's gender is female; congenital joint hypermobility was observed in 70% of those cases [31].

Some authors consider the presence of congenital diseases as one of the DDH risk factors. Congenital Muscular Torticollis (CMT) can be associated with an increased risk of DDH to a level of 17%. Significant differences in correlations were also observed by gender - a fivefold increase of hip joint dysplasia was observed in male newborns with coexisting CMT compared to female newborns with CMT [27]. Some publications indicate congenital foot deformities: as a possible risk factor for DDH. It has been shown that talipes calcaneovalgus or metatarsus adductus may be associated with an elevated risk (at the level of 4-6% and 4%, respectively). However, no connection between Talipes Equinovarus (TEV) and DDH was revealed in available data [28]. This relationship was not confirmed among our patient group.

In our study preterm delivery (37 < week) decreased odds of DDH (OR =0.18 (0.04-0.72)) but only in univariate model. The theory explaining this phenomenon is shorter exposure to maternal hormones and lack of mechanical problems with intrauterine leg movement. Similar results were obtained in the study by Lange et al. [45] and data from the Swedish Medical Birth Register [46].

The literature indicates that most ultrasonography-diagnosed dysplastic hips are normal in clinical examination (71.63%) [11]. Only 9 out of 129 patients treated for DDH had a positive physical examination in our study. Probably due to strict criteria of 20° of abduction angle difference vs.

contralateral side and characteristics of the cohort – first clinical screening with physical examination upon birth. Neonates with positive Ortolani and Barlow signs are directed directly to dedicated wards after the birth.

Other risk factors, sometimes raised in scientific discussions, appear to be statistically insignificant in most studies. We examined some of them (i.e., Apgar Score <10, oligohydramnios, fetal macrosomia, parity, post-term pregnancy). Our results are consistent with the worldwide results (included in supplementary table 1.).

Sahin F et al. highlighted that the negative predictive value of DDH risk factors combined with physical examination is high and calculation of patient's risk could be used as a decision tool for ultrasound screening [47]. Similarly, Woodacre et al. proposed to modify the UK screening program by calculating risk for each child [48]. Roposch et al. proposed the first DDH risk calculator based on analysis of selectively screened patients in the British population. Female gender, family history, physical examination and birthweight were considered. The model demonstrated excellent discrimination and calibration of observed and predicted risk [49]. Our model was built based on universal ultrasound screening and includes risk factors from a multivariate model.

Limitations

The study is retrospective influencing the data collection quality and increasing the missing value rate. Furthermore, the results do not reflect the situation for the entire country. Thus, additional well-designed multicenter prospective studies on this subject are required.

Generalisability

- The study results indicate that the DDH rate in Poland is high.
- There is an urgent need to establish an official guideline for DDH infant screening in Poland.
- The cumulative effect of well-known risk factors can be assessed with a DDH risk calculator.
- The proposed calculator could be used as a decision tool for screening in the future.

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Tables

Table 1. Risk factors of developmental dysplasia of the hip (DDH)

Variable	DDH		χ^2
	Yes	No	
Gender			
Female	120 (3.87%)	1421 (45.81%)	<0.001
Male	18 (3.87%)	1543 (49.74%)	
Cesarean section			
Yes	68 (2.19%)	1194 (38.49%)	0.035
No	70 (2.26%)	1170 (57.06%)	
Delivery presentation - Breech			
Yes	21 (0.68%)	152 (4.90%)	<0.001
No	117 (3.77%)	2812 (90.65%)	
Delivery < 37 week			
Yes	2 (0.06%)	228 (7.35%)	0.003
No	136 (4.38%)	2736 (88.20%)	
Positive family history of DDH - parents			
Yes	17 (0.55%)	215 (6.93%)	0.027
No	121 (3.90%)	2749 (88.62%)	
Positive family history of DDH - siblings			
Yes	10 (0.32%)	42 (1.35%)	<0.001
No	128 (4.13%)	2922 (94.20%)	
Symptoms			
Yes	9 (0.29%)	7 (0.23%)	<0.001
No	129 (4.16%)	2957 (95.33%)	

χ^2 - the significance of p for χ^2

Table 2. Hip type, according to Graf in study participants

Hip type according to Graf		Right hip	Left hip
Type I	A	1297 (41.815)	1326 (42.75%)
	B	1645 (53.03%)	1640 (52.87%)
Type II	A	123 (3.97%)	96 (3.09%)
	B	6 (0.19%)	6 (0.19%)
	C	19 (0.61%)	23 (0.74%)
Type III		11 (0.35%)	11 (0.35%)
Type IV		1 (0.03%)	-

Table 3. Treatment modality used in study participants with DDH

Treatment method	Number of patients (%)
Treatment not necessary	2964 (95.55%)
Tübinger orthosis	100 (3.22%)
Padded abduction diapers	32 (1.03%)
Frejka pillow	2 (0.06%)
Koszla abduction brace	2 (0.06%)
Pavlik Harness	1 (0.03%)
Parents refused treatment	1 (0.03%)

Table 4. Univariate logistic regression to evaluate DDH predictors

Variable	Effect level	Effect	p	OR (95% CI)
Weight [kg]		0.52	0.002	1.69 (1.22 - 2.34)
Week of delivery		0.20	0.001	1.22 (1.08 - 1.38)
Gender	F/M	1.98	<0.001	7.24 (4.39 - 11.95)
Cesarean section	Yes/No	0.36	0.037	1.44 (1.02 - 2.02)
Multiple pregnancy	Yes/No	-0.78	0.279	0.46 (0.11 - 1.88)
Macrosomia > 4000 g	Yes/No	0.21	0.421	1.24 (0.74 - 2.09)
Delivery presentation - Breech	Yes/No	1.20	<0.001	3.32 (2.03 - 5.43)
Delivery ≥ 42 week	Yes/No	0.81	0.066	2.24 (0.95 - 5.28)
Delivery < 37 week	Yes/No	-1.73	0.015	0.18 (0.04 - 0.72)
First childbirth	Yes/No	-0.11	0.525	0.89 (0.63 - 1.26)
APGAR score < 10	Yes/No	-0.03	0.920	0.97 (0.57 - 1.66)
Positive family history of DDH - parents	Yes/No	0.59	0.029	1.80 (1.06 - 3.04)
Positive family history of DDH - siblings	Yes/No	1.69	<0.001	5.44 (2.67 - 11.08)
Oligohydramnios	Yes/No	-0.15	0.881	0.86 (0.12 - 6.38)
Symptoms	Yes/No	3.38	<0.001	29.48 (10.81 - 80.41)

p - significance; OR (95% CI) - Odds Ratio with 95% confidence interval

Table 5. Multivariate logistic regression model to predict the incidence of DDH in children

Variable	Effect level	β	p	OR (95% CI)
β_0		-13,892	<0.0001	
Weight [kg]		0.772	0.0004	2.17 (1.41-3.32)
Week of delivery		0.162	0.0381	1.18 (1.00-1.37)
Gender	F/M	2,099	<0.0001	8.16 (4.86-13.71)
Delivery presentation - Breech	Yes/No	1,778	<0.0001	5.92 (3.37-10.40)
Symptoms	Yes/No	3,229	<0.0001	25.28 (8.77-72.83)
Positive family history of DDH - siblings	Yes/No	1,747	0.0001	5.74 (2.68-12.31)

p – significance; OR (95% CI) – Odds Ratio with 95% confidence interval

Declarations

Funding

The research was funded by the Medical University of Warsaw own funds.

Acknowledgments

Paweł Gidziński (PG), Witold Witkowski (WW), Rafał Wiśniewski (RW) and Grzegorz Tomaszewski (GT) who performed ultrasound in the Outpatient Clinic.

Competing Interests Statement

We report no conflict of interest.

Data availability statement

The datasets analysed during the current study are available from the corresponding author on reasonable request.

Author contributions

Conceived and designed the analysis – ŁP, PŁ, KP

Collected the data – KR, AJ, PK, IT, PW

Contributed data or analysis tools – ŁP, KP

Performed the analysis – ŁP, KP

Wrote the manuscript - ŁP, AS, KP

All authors reviewed the manuscript

Figures

Figure 1

ROC curve for multivariate logistic regression predictive model (Statistica 13.3)

Supplementary Files

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