Birthweight correlates to pubo-femoral distances and α angles in hip ultrasound of newborns at 6 weeks of age: a retrospective cohort study

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Background and purpose — There is inconsistency in the literature regarding the relationship between increased birthweight and risk of developmental dysplasia of the hip (DDH). We aimed to investigate the correlation between birthweight and pubo-femoral distance (PFD), as well as Graf’s α angle in newborns undergoing hip ultrasound examination at 6 weeks of age.

Patients and methods — Basic newborn characteristics and ultrasound measurements were retrospectively collected during a 1-year study period. We excluded multiple births, newborns born at less than 37 gestational weeks, and incomplete information. Simple and multiple linear regression analyses were performed to evaluate the correlation of birthweight and PFD, and, second, birthweight and α angles including a stratified regression analysis investigating the potential effect modification of sex.

Results — 707 newborns (1,414 hips) were included. Mean birthweight was significantly higher for male newborns (P < 0.001). Increased birthweight was positively correlated to PFD values (crude coefficient 0.21, 95% confidence interval [CI] 0.10–0.32) and the correlation was still present after adjusting for sex, family history, and breech presentation (adjusted coefficient 0.18, CI 0.07–0.29). The stratified α angle model for the males was significant for both the crude coefficient (−0.73, CI −1.28 to −0.19) and the adjusted (−0.59, CI −1.15 to −0.03), and also for the females (crude coefficient −1.14, CI −1.98 to −0.31 and adjusted coefficient −1.15, CI −1.99 to −0.31).

Conclusion — We found that increased birthweight positively correlated to PFD, and negatively correlated to α angle, but this was not of clinical significance.

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Patients and methods

Study design

This was a retrospective observational study. Reporting follows the STROBE guidelines for reporting on observational studies [14].

Participants

We included newborns born at Aarhus University Hospital from October 2021 to October 2022 within 37–42 gestational weeks who were referred for follow-up hip ultrasound based on presence of risk factors (breech presentation, family history, multiple births, oligohydramnios, or clubfeet), positive clinical examination, a PFD above 5.1 mm or a combination of these factors. PFD as a referral criterion was introduced as part of the Danish Hip Screening project (DHS) at Aarhus University Hospital. Referred newborns received specialized hip ultrasound, ideally within 6 weeks or 2 weeks if clinical instability was detected upon screening.

From patients’ files we included birthweight, gestational age, sex, age at ultrasound examination, and hip ultrasound measurements. We excluded multiple births as newborns from multiple births are usually lighter, as well as premature newborns born at less than 37 gestational weeks. Newborns with incomplete data, defined as missing information on one or more variables, were also excluded.

Ultrasound examination

Hip ultrasound examination of referred newborns was made by 1 of 3 senior musculoskeletal radiologists experienced in pediatric hip ultrasound. α angles were obtained according to the methods described by Graf [6] (Figure 1a), and PFD measurements, defined as the minimal measurable distance between the medial femoral epiphysis and the ossified pubic bone while applying lateralizing stress to the hip, according to the methods described by Treguiet et al. [8] but with the child in the lateral examination position (Figure 1b). Ultrasound was performed using a high-frequency linear transducer (Canon Aplio i800; Canon Medical Systems, Tokyo, Japan).

Variables

Variables under investigation were sex (male/female), birthweight (gram), breech presentation (yes/no), family history of DDH (yes/no), positive clinical examination (yes/no), oligohydramnios (yes/no), congenital foot deformities (yes/no), referred based on primary PFD > 5.1 mm at first week after birth (yes/no), gestational age (days), and age at examination (days). Ultrasound measurements at 5–6 weeks were α angle (°) and second PFD measurement (mm), which were used for the correlation analysis.

Statistics

For descriptive statistics, continuous variables (birthweight, gestational age, age at examination, α angles, and PFD measurements) were reported as arithmetic mean and standard deviation (SD). For categorical variables (positive clinical examination, breech presentation, family history of DDH, oligohydramnios, congenital foot deformities), the number of observations and the relative percentages were reported. PFD and α-angle measurements from the follow-up hip ultrasound were used for the statistical analysis. As a first step, Pearson’s chi-square test and Fisher’s exact test (the latter when the expected count was < 5) were performed for categorical variables and t-test for the continuous variable to estimate possible differences between female and male newborns.

In a second step, simple linear regression analysis was performed to evaluate the potential association of birthweight (independent variable) and PFD (dependent variable), and, second, the potential association of birthweight (independent variable) and α angle (dependent variable). Multiple regression analysis was performed to evaluate the above-mentioned potential associations adjusted for 3 well-known risk factors (sex, breech presentation, and family history of DDH). As a third step, stratified regression analysis in male and female newborns was performed for birthweight and α angle, due to potential effect modification of sex between these 2 variables. The coefficient results are presented with 95% confidence interval (CI) and scatter plots were created to present the regression analysis results. To account for the bilaterality of data, a sensitivity analysis was performed using mixed-model analysis for all the previously mentioned simple and multiple linear regressions. As the analysis was not significantly different, independence between sides was assumed and the linear regression results are reported for simplicity.

Normal distribution of birthweight, PFD, and α angle measurements were inspected using QQ plots. A P value < 0.05 was considered statistically significant. Statistical analyses were performed using Stata version 17.0 (StataCorp, College Station, TX, USA).

Ethics, registration, data sharing, funding, and disclosures

Written consent for data acquisition (prospectively collected data of PDF and α-angle measurements, as well as retrospec-
Results

Study population

Based on 4,694 newborns born during the 1-year study period, a cohort of 2,375 newborns (51%) participated in the Danish Hip Screening project following consent from their parents. Of these, 820 newborns (34%) were referred for ultrasound (Figure 2). 55 did not attend. Furthermore, 37 were multiple births and 13 had a gestational age < 37 weeks, leaving 707 newborns (1,414 hips) for inclusion in our study with equal distribution of males and females (348; 359). 431 newborns were referred based on their first PFD measurement without any other risk factor. Mean birthweight was significantly higher for male newborns at 3,689 g (SD 475) vs. 3,530 g (SD 439) (P < 0.001), while the total mean age at examination was 37 days (SD 11.9) (Tables 1 and 2). There was no difference between the 2 groups in the PFD measurements (PFD right side P = 0.7, PFD left side P = 0.4). The mean α-angle measurements for both left and right hip were significantly lower for female newborns (P < 0.001). Considering the risk factors, there was no difference between the groups (Table 2).

Birthweight and PFD

Increased birthweight was positively correlated to PFD values (crude coefficient 0.21, CI 0.10–0.32) and this correlation was still present when adjusting for sex, family history, and breech presentation (adjusted coefficient 0.18, CI 0.07–0.29). A regression model and a scatter plot were established according to the following: PFD = 3.27 (mm) + 0.18 (mm) × birthweight (kg) (Figure 3).

Birthweight and α angle

Linear regression analyses showed a significant negative correlation between birthweight and α angles (crude coefficient –0.56, CI –1.06 to –0.07, P = 0.03), which was still present...
Discussion

We aimed to investigate the correlation between birthweight and pubo-femoral distance (PFD), as well as Graf’s α angle in newborns undergoing hip ultrasound examination at 6 weeks of age. We found a positive correlation between increased birthweight and PFD measurements of newborns screened for DDH at 6 weeks of age, regardless of sex. Birthweight was found to be negatively correlated to α angles for both females and males. However, the correlations were too small to be considered clinically significant.

Although several risk factors have been examined in relation to DDH, birthweight still remains a controversial factor. The meta-analysis of De Hundt et al. [2], based on 4 studies [15-18], reported low birthweight (< 2,500 g) as being protective. This finding supported the concept of intrauterine crowding, as DDH may develop in part due to limited space for the fetus inside the uterus. 3 additional studies [11,19-20] have presented high birthweight (> 4 kg) as a risk factor, and Falliner et al. [21] found that children with dysplastic hips had markedly higher birthweight than children with normal hips. The cohort study by Schams et al. [20] suggested low birthweight as a protective factor. Hanratty et al. [12] found no correlation between increased birthweight and risk of DDH.

However, a dichotomous DDH diagnosis as an outcome measurement, while clinically relevant, might not be sensitive enough to show the possible contribution of birthweight, and as a result the use of α-angle measurement or PFD as an outcome seems more suitable for the investigation of birthweight’s effect. The positive correlation of increased birthweight to PFD values found in our study may partly be explained by the fact that the PFD is an absolute distance measurement that increases with the size of the child, similarly to the increase that is seen when the child ages [22]. But as PFD is highly sensitive for DDH [9], increased birthweight may be perceived as an effect modifier on the relationship between PFD and hip dysplasia. These findings may also indicate that a cut-off value for PFD should be assessed on a semi-individual basis, taking the child’s size (i.e., birthweight) into account, in order to decrease false-positive referrals based on PFD measurements.

Orak et al. [13] and Kolb et al. [23] used α-angle measurements as a main outcome. The findings of Kolb et al. seem to be in agreement with our results, as their univariate regression analysis showed a significant negative influence of increased birthweight per 100 grams on the α angle (coefficient –0.071,

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Table 3. Regression analysis indicating the effect of birthweight on PFD and α angle

<table>
<thead>
<tr>
<th>Linear regression for</th>
<th>Coefficient (CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFD and birthweight (per kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude</td>
<td>0.21 (0.09 to 0.32)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Adjusted for sex</td>
<td>0.22 (0.11 to 0.34)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Adjusted for family history</td>
<td>0.18 (0.08 to 0.29)</td>
<td>0.001</td>
</tr>
<tr>
<td>Adjusted for breech presentation</td>
<td>0.20 (0.09 to 0.31)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Adjusted for all above a</td>
<td>0.18 (0.07 to 0.29)</td>
<td>0.002</td>
</tr>
<tr>
<td>α angle and birthweight (per kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude</td>
<td>–0.56 (–1.06 to –0.07)</td>
<td>0.03</td>
</tr>
<tr>
<td>Adjusted for sex</td>
<td>–0.93 (–1.42 to –0.43)</td>
<td>&lt; 0.001</td>
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<tr>
<td>Adjusted for family history</td>
<td>–0.53 (–1.03 to –0.03)</td>
<td>0.04</td>
</tr>
<tr>
<td>Adjusted for breech presentation</td>
<td>–0.57 (–1.07 to –0.07)</td>
<td>0.03</td>
</tr>
<tr>
<td>Adjusted for all above a</td>
<td>–0.88 (–1.38 to –0.38)</td>
<td>0.001</td>
</tr>
<tr>
<td>α angle and birthweight (per kg): male</td>
<td></td>
<td></td>
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<tr>
<td>Crude</td>
<td>–0.73 (–1.28 to –0.19)</td>
<td>0.008</td>
</tr>
<tr>
<td>Adjusted for family history and breech presentation</td>
<td>–0.59 (–1.15 to –0.03)</td>
<td>0.04</td>
</tr>
<tr>
<td>α angle and birthweight (per kg): female</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude</td>
<td>–1.14 (–1.98 to –0.31)</td>
<td>0.007</td>
</tr>
</tbody>
</table>

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a family history, breech presentation, and sex
In addition, premature newborns were defined as newborns with a history of DDH and breech presentation performed by well-trained and experienced senior musculoskeletal radiologists. This prediction model suggests increased birthweight is regarded as a component of the total risk profile of newborns. This suggestion is supported by the existing literature, as well as by the results of our study.

**Strengths**

First, this is the first study that examined the influence of increased birthweight on PFD measurements, as well as on α-angle measurements in hip ultrasounds of newborns screened for DDH at 6 weeks postpartum. Second, we included ultrasound data of a non-selected cohort of newborns with family history of DDH and breech presentation performed by well-trained and experienced senior musculoskeletal radiologists. In contrast, Orak et al. [13] excluded newborns with these risk factors, which makes their population even more selective. In addition, premature newborns were defined as newborns born alive before 37 gestational weeks [25], while Orak et al. [13] included 38–42-week-old newborns and Kolb et al. [23] included both premature and full-term newborns.

**Limitations**

First, the results cannot be generalized because the population consist of screened newborns with risk factors and/or a pathological primary PFD measurement. However, as the PFD measurement was used as a stand-alone referral criterion, 61% of the included newborns had no risk factors for DDH, which makes the present results more generalizable than previous reports from selective screening programs that exclusively included children who had a risk factor for DDH. Second, no interobserver evaluation was performed on ultrasound examinations.

**Conclusions**

Increased birthweight was positively correlated to PFD measurements for both female and male at-risk newborns, and negatively correlated to α-angle measurements in newborns screened for DDH at 6 weeks of age, regardless of sex. The findings seem not to be of clinical significance due to small effect size. Increased birthweight may only be relevant in the context of a multiple-factor risk profile for DDH.

**Study design and conception:** all co-authors. Data acquisition: MBH, MH, NL, and HCH. Data analysis: MT and HCH. Writing: MT. Review: all authors.

**Handling co-editor:** Ilkka Helenius

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