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A Follow-up Study of Children with Instability of the Hip Joint at Birth

Clinical and Radiological Investigations with Special Reference to the Anteversion of the femoral neck

BY

KAREL BJØRN CYVÍN

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To My Wife Helga

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INTRODUCTION

Since the pioneer works of Le Damany (1908) and Ortolani (1937) the modern principles of early diagnosis and treatment of congenital dislocation of the hip (CDH) have been gradually adopted in most countries. The earliest reports of the clinical aspects of the disease are from Russia (Marx 1938), USA (Chapple 1935, Hart 1948), Czechoslovakia (Frejka 1941) and Austria (von Haberler 1944). Investigations on CDH in Sweden have been carried on since 1950 (Palmén 1950, 1957, 1961, 1970, von Rosen 1970, Andrén 1960, Palmén & von Rosen 1975). In Norway important contributions to the subject have been made by Walter & Moe (1954), Njå (1962), Medbøe (1961, 1965) and Bjerkreim (1974). To-day newborn babies in most countries are routinely examined by the classical manoeuvre ("signe de ressault") by which instability of the hip joint can be revealed, and infants with dislocated or dislocatable hips are generally treated with an abduction splint.

The results of the early treatment of unstable hips have been the subject of great interest in medical literature. The most optimistic investigators claim that all, or nearly all cases of CDH can be diagnosed in the newborn period and that with correct treatment these children will develop normal hips (Palmén 1961, von Rosen 1970, Fredensborg 1976 a. o.). On the other hand many of the follow-up studies include groups of patients in whom apparently correct therapy has failed (Finlay 1967, James et al. 1970, Mitchell 1972 a. o.). Finally, a minor group of authors have presented rather discouraging results of early therapy (Weissmann 1966, Ackermann 1974, Bjerkreim 1974). None has as yet given a satisfactory explanation for the divergent therapeutic results of early treatment of unstable hips.

Reviewing the extensive literature on the results of early treatment of CDH I was impressed by the following facts: 1. None of the follow-up studies include control groups of children from the same population matched with the patients for sex and age. 2. Few of the clinical and radiological studies present results which allow definite conclusions of possible "minor" abnormalities of the hip joint. Such abnormalities may pass without obvious symptoms during childhood and adolescence, but may well be the cause of development of arthritic changes of the adult hip. Among such abnormalities increased anteversion of the femoral neck represents a major problem. Despite numerous investigations on that topic, the true nature of the condition is still obscure.

The main aims of the following investigation were:

1. A detailed follow-up study of children with unstable hips at birth treated with an abduction splint, in comparison with a control group of presumably healthy children, and a third group of children with unstable hips at birth, but untreated.

2. An evaluation of "minor" pathological findings, with special attention paid to increased anteversion of the femoral neck.

PATIENTS AND METHODS

During the period 1.5.1969–1.5.1971 6509 children (3322 boys and 3187 girls) were born in the two maternity units in Trondheim (E. C. Dahls Stiftelse and the Ob-

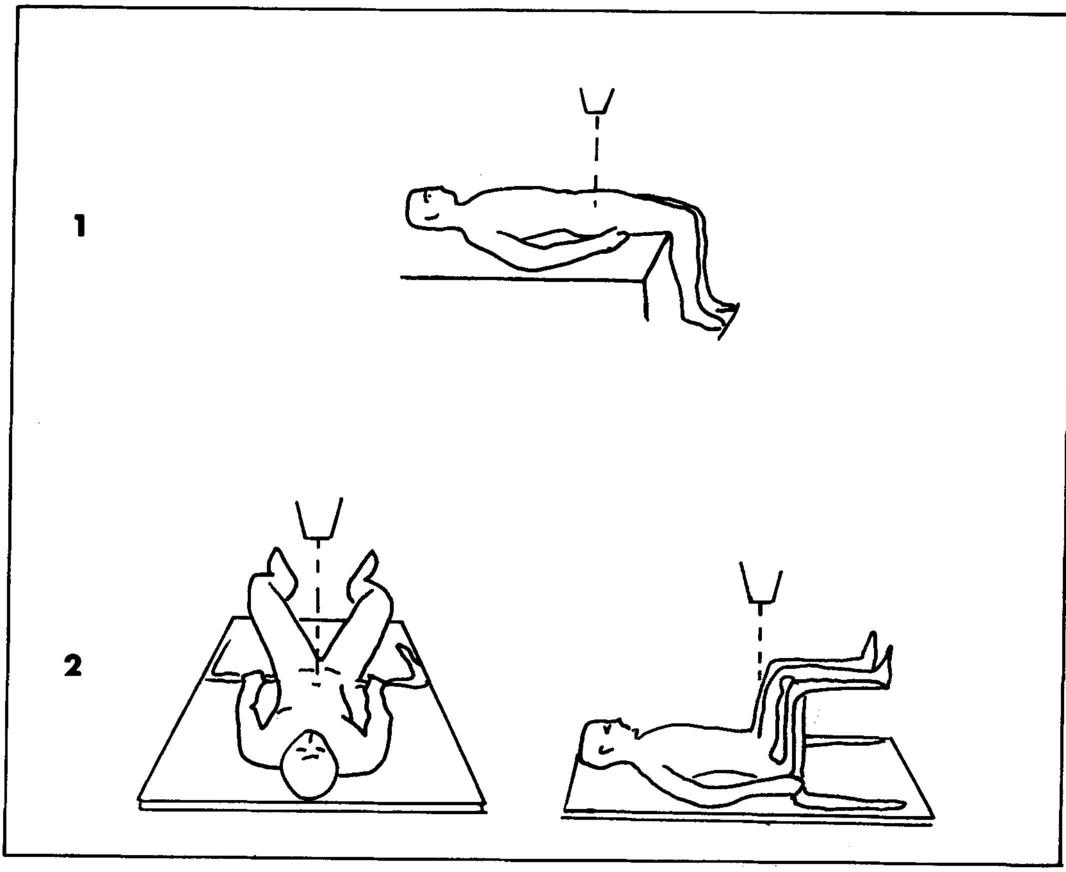


Figure 1. The radiographic examination of the hip joint according to Dunlap and Rippstein. 1. An anterior-posterior view of the pelvis. 2. The position in Müller's apparatus.

stetrical Department of the Regional Hospital of Trondheim.) Most of the mothers came from the city of Trondheim whereas a smaller group came from the neighbouring communities. The newborns were examined at least twice, the first examination being performed on the first or second day of life and the second generally four to six days after birth. About 6000 children were examined by me, the rest by one of the trained consultants of the pediatric department. The hips of the newborns were examined according to Palméns and Barlows modification of the Ortolani test (Palmén 1957, Barlow 1962).

In the course of the two years period instability of the hip joint was found in 146 children, 115 girls and 31 boys. One child with arthrogryposis was excluded from the material. The instability of the hip joint was right-sided only in 38 (26 per cent), left-sided only in 61 (42 per cent) and bilateral in 47 (32 per cent). Breech presentation occurred in 30 children (20.6 per cent).

Table 1. Examination of children with unstable hips at birth and control children with stable hips at the age of four to six years.

Group	No.	Findings at birth	Treatment
A	129	unstable hips	Frejkas pillow
B	100	stable hips	none
C	17	unstable hips	none

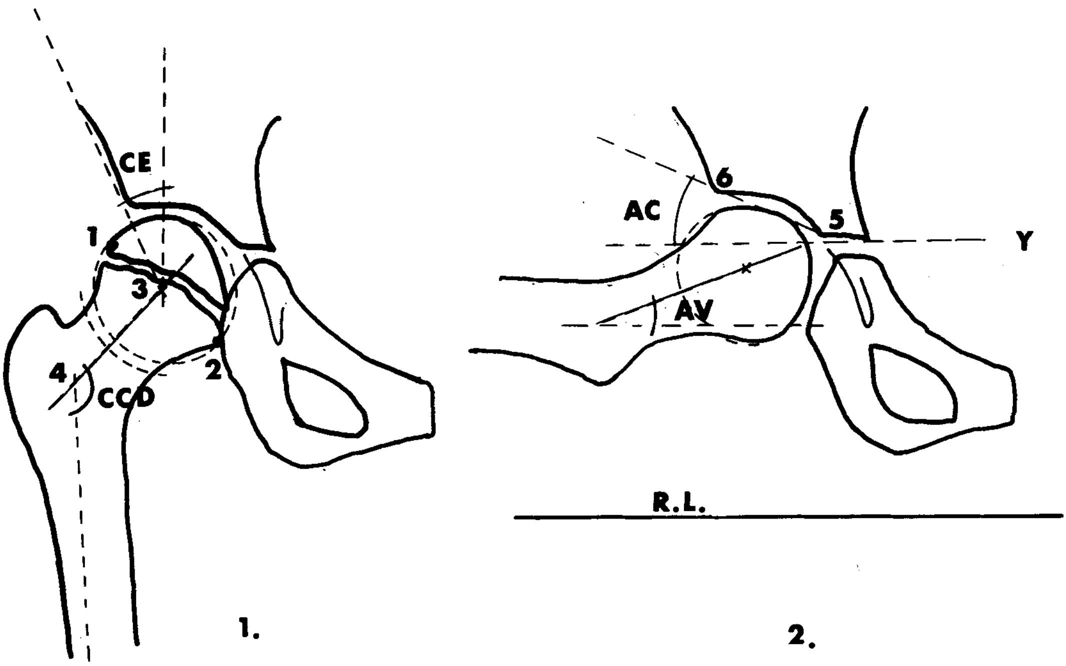


Figure 2. The radiographic measurements of the hip joint. 1. The first X-ray picture: Wibergs angle (CE) and neck-shaft angle (CCD). 2. The second X-ray picture: inclination of the acetabular roof (AC) and torsion (anteversion) of the femoral neck (AV).

All the children with unstable hips were treated in Frejkas cushion splint, usually for three months. The patients were checked by me at three months, six months, and fourteen months of age. They were radiographed on the last two controls. Standardization of the radiological method of these controls was not adequate to make the results suitable for scientific presentation. The aim of these controls was primarily to disclose clearly pathological conditions.

The control group of children consisted of subjects of the same sex and born chronologically next to the children with unstable hips. These children received no treatment.

A clinical and radiological follow-up study was performed at four to six years of age. The follow-up study comprised three groups of children (Table 1).

Group A consisted of 129 children (103 girls and 26 boys) with unstable hips at birth, treated with Frejkas pillow. Of the originally total number, 146, fifteen patients had moved from the town and were unavailable for the examination.

In seven patients of group A (No. 20, 54, 61, 78, 93, 99 and 140 the course of the disease was unfavourable, and these patients needed additional treatment at the Orthopedic department with splinting or plaster cast. In two of them (No. 78 and No. 140) a derotational osteotomy was performed.

Group B consisted of 100 healthy children (80 girls and 20 boys).

Group C comprised 17 children (12 girls and 5 boys) born at the Maternity Hospital of Haukeland Hospital in Bergen. In those infants instability of the hip joint was diagnosed at birth, but all of them had stable joints on the day of discharge from the maternity ward, and no treatment was instituted. The diagnosis was made by an experienced pedi-

Table 2. The range of passive movement of the hip joint at the age of three months in patients with unstable hips at birth.

Range in degrees	Hips 90° flexed: Internal rotation No.	%	External rotation No.	%	Abduction No.	%	Hips extended: Abduction No.	%
< 40			3	3.6				
40–59	11	13.3	46	55.4			17	22.0
60–79	30	36.1	9	10.8			59	76.7
80–90	42	50.6	25	30.1	81	97.6	1	1.3
asymmetrical	0	0.0			2	2.4	0	0.0
Total	83		83		83		77	

Table 3. The range of passive movements of the hip at the age of five to ten months in patients with unstable hips at birth.

Range in degrees	Hips 90° flexed: Internal rotation No.	%	External rotation No.	%	Abduction No.	%	Hips extended: Abduction No.	%
< 40								
40–59	22	23.4	1		2	2.1	1	
60–79	47	50.0	5	5.3	24	25.5	39	45.4
80–90	24	25.5	88	93.6	65	69.1	46	53.5
asymmetrical	1		0		3	3.3	0	
Total	94		94		94		86	

Table 4. The range of passive movement of the hip at the age of twelve to twenty-one months in patients with unstable hips at birth.

Range in degrees	Hips 90° flexed: Internal rotation No.	%	External rotation No.	%	Abduction No.	%	Hips extended: Abduction No.	%
< 40	1							
40–59	14	15.7			3	3.4	2	
60–79	49	55.0	16	18.0	23	25.8	49	55.0
80–90	25	28.0	73	82.0	61	69.0	38	42.7
asymmetrical	0		0		2	2.5	0	
Total	89		89		89		89	

atrician, and he also followed the children in several controls up to the age of eighteen months.

All the clinical examinations of the follow-up study were performed by me. The following data were recorded: 1. Observations made by the parents such as limping, stumbling, asymmetry of the extremities, in-toeing when walking and subjective symptoms of the child such as fatigue or muscular pain in the extremities. 2. Objective examinations: shortening and/or atrophy of the lower extremities, Trendelenburg's sign, observation of the gait, evaluation of the muscular strength and measurements of the range of passive movement. Flexion and abduction were measured in the supine position, extension, internal and external rotation were measured in the prone position. In addition abduction and internal and external rotation were measured in the supine position with hips and knees at right angles. This was mainly performed in order to be able to compare measurements with those of the newborn children who have a marked flexion contracture.

Table 5. The development of walking of children with unstable hips at birth.

Age of walking without support in months	No.	%
9–12	27	37.5
13–15	34	47.2
16–19	11	15.3
Total	72	100.0

The children were radiographed by specially trained assistants, and I participated in most of the examinations. The radiographic examination was performed according to Rippsteins modification of the method of Dunlap (Dunlap et al. 1953, Rippstein 1955). Two exposures were made (Figure 1): 1. An anterior-posterior view of the pelvis and the hips with the patient in the supine position, hips extended, thighs parallel and knees flexed 90° over the edge of the table. 2. The child placed on a simple apparatus constructed by Müller (Müller 1970) which holds the knees and hips flexed at 90° and thighs abducted 20°. The first exposure required 100 mA at 60 kV in 1.2 sec, the second 30 mA at 75 kV in 0.3 sec.

All the measurements of the radiographs (Figure 2) were performed by means of Müllers ischiometer (Müller 1970). On the first x-ray picture I measured the neck-shaft angle (CCD), Wibergs angle (CE) which is the angle between a vertical line through the femoral head and a line from the center of the head to the lateral border of the acetabular roof, and the length and width of the ossified part of the femoral head. The lateral margin of the acetabulum was evaluated and other pathological findings recorded (fragmentation of the epiphysis, ossification defects, subluxations or luxations). On the second picture I measured the anteversion of the femoral neck (AV-angle) and the angle of inclination of the acetabular roof (AC). All measurements were made twice, and the difference between the two values never exceeded 5°, usually it was only 0–2°.

Corrected values of the CCD and AV-angles were computed from the following trigonometric formulas:

(I) $\text{tg}AV = \text{tg}\,AV' \times$
$[\cos(CCD' - 90 - \gamma) - \cos(CCD' - 90)]$
(II) $\cot CCD = \cot CCD' \times \cos AV$

Table 6. Development of the femoral epiphysis of children with unstable hips at birth.

Side of retarded development	Side affected at birth			Total
	right	left	bilateral	
right	9	1	5	15
left		12	2	14
bilateral	1	3	3	7
Total	10	16	10	36

where CCD′ denotes the projected CCD-angle, AV′ the projected AV-angle, CCD the real neck-shaft angle, AV the real angle of anteversion and γ the angle of abduction of the hip (here 20°).

Table 7. Radiological signs of dysplasia in children with unstable hips at birth.

Signs	Age in months 6–12	13–21
Sloping of the acetabular roof or indistinctly marked lateral margin	12	4
Anteversion of the femoral neck	3	3

The collected data were processed in a UNIVAC 1108 at the Computing Centre of the University of Trondheim. The mean values of groups A, B and C were computed. Differences of means were tested by the t-test, and P-values below 0.05 were regarded as statistically significant. When indicated, regression curves and confidence limits were computed. Correlation coefficient > 0.75 was regarded as positive.

RESULTS

1. *The motor development of children with unstable hips at birth*

Of the 146 children with unstable hips at birth 83 were examined at three months of age. Results of the examination are shown in Table 2. In nearly all children the range of passive abduction with hips 90° flexed was 80–90°.

Ninety-four children were examined at the age of five to ten months (Table 3). At this age the group of children with maximal abduction capacity was reduced to nearly 70 per cent.

The results of the clinical examination of 89 children over one year of age are shown in Table 4. 27 children were

Table 8. Symptoms and signs of children with unstable hips at birth (Group A) and healthy children (Group B).

Symptoms and signs	Group A No.	%	Group B No.	%
In-toeing when walking	22	17.0	5	5.0
Stumbling	11	8.5	0	0.0
Fatigue	9	7.0	2	2.0
Muscular pain	5	3.9	2	2.0
Limping	0	0.0	0	0.0
General joint laxity	3		1	
Total no.	129		100	

Table 9. The passive flexion of 490 hip joints at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 99 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

Group	Boys No.	Boys Degrees	Boys S.D.	Girls No.	Girls Degrees	Girls S.D.
A	26	128.46	4.64	103	129.27	7.65
B	20	128.00	8.01	79	127.91	6.49
C	5	129.00	4.18	12	126.67	5.37

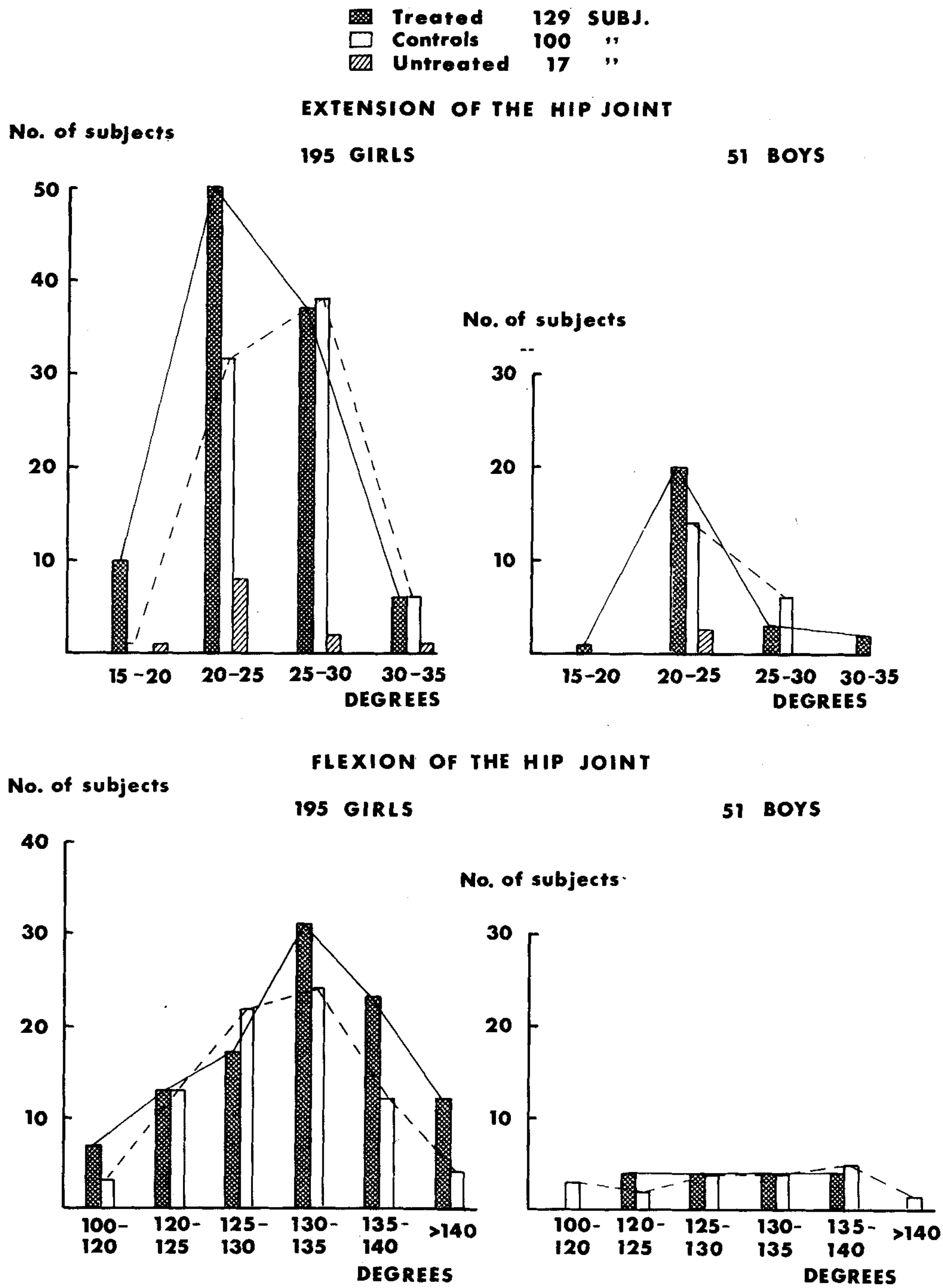


Figure 3. The range of passive extension and passive flexion in 129 children with unstable hips at birth treated with Frejkas pillow, 100 healthy children and 17 children with unstable hips at birth untreated.

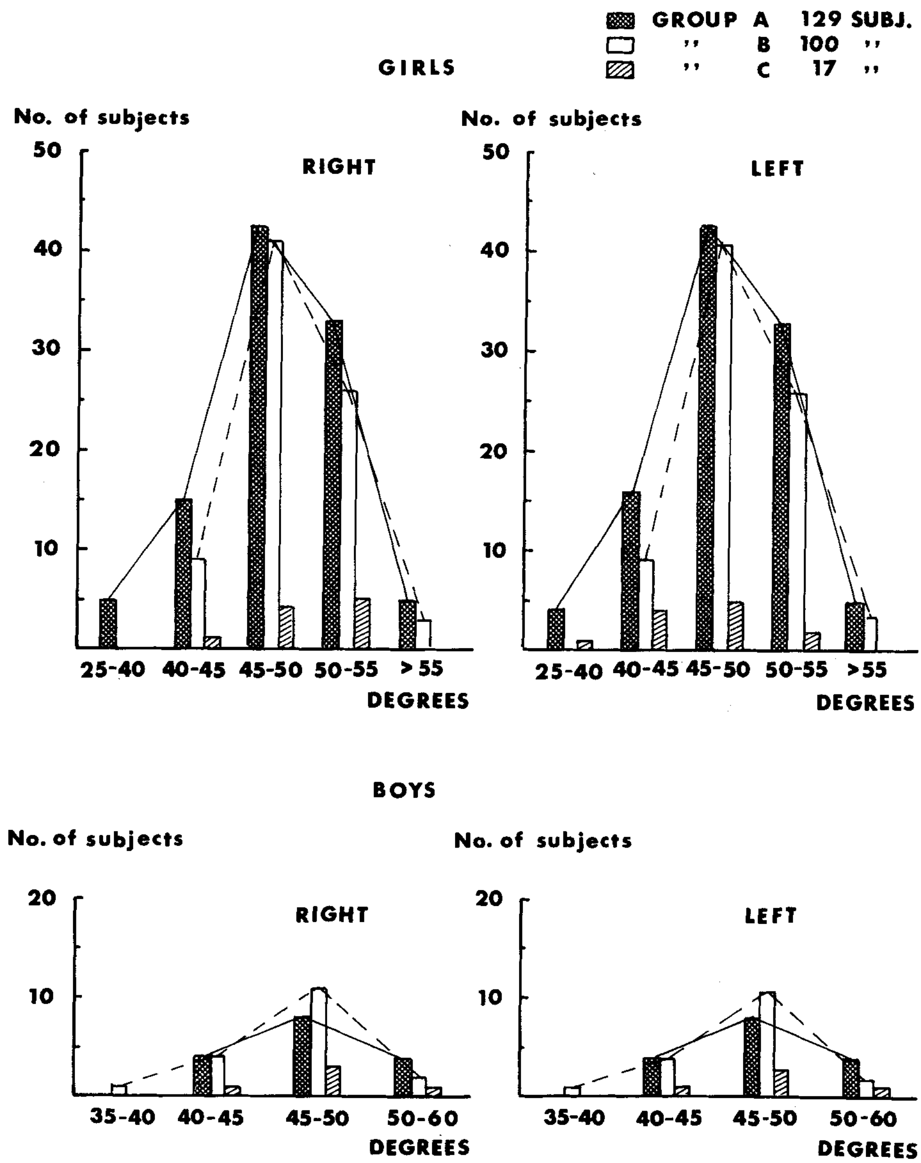


Figure 4. The range of passive abduction with extended hips in 129 children with unstable hips at birth treated with Frejkas pillow, 100 healthy children and 17 children with unstable hips at birth untreated.

examined at the age of 12–14 months, 46 at 15–17 months and 16 at 18–21 months. The maximal abduction capacity was practically unaltered compared with the previous examination.

Table 5 shows the development of walking. As can be seen nearly 50 per cent of the children started to walk without support between 13 and 15 months.

2. *The radiological findings during infancy*

The development of the ossification of the femoral epiphysis in 36 children with

Table 10. The passive extension of 490 hip joints at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 99 healthy children (Group B) and 17 children with unstable hips untreated Group C).

Group	Boys			Girls		
	No.	Degrees	S.D.	No.	Degrees	S.D.
A	26	21.15	3.26	103	21.89	3.71
B	20	21.50	2.35	79	23.10	3.23
C	5	20.00	0.00	12	21.25	3.77

Table 11. The passive abduction of 490 hip joints in extension at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 99 healthy children (Group B) and 17 children with unstable hips at birth untreated (Group C).

Group	Boys			Girls				
					Right hip		Left hip	
	No.	Degrees	S.D.	No.	Degrees	S.D.	Degrees	S.D.
A	26	47.31	4.30	103	45.73	5.30	45.97	4.59
B	20	44.50	3.94	79	46.46	3.59	46.46	3.59
C	5	45.00	3.54	12	43.33	4.44	43.33	4.44

Table 12. The passive adduction of 490 hip joints at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 99 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

Group	Boys			Girls				
					Right hip		Left hip	
	No.	Degrees	S.D.	No.	Degrees	S.D.	Degrees	S.D.
A	26	23.08	6.49	103	22.48	3.63	22.48	3.63
B	20	22.50	2.56	79	22.15	3.07	22.50	2.61
C	5	22.00	2.74	12	22.50	2.61	22.50	2.61

Table 13. The passive abduction of 490 hip joints in 90° flexion at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 99 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

Group	Boys			Girls				
					Right hip		Left hip	
	No.	Degrees	S.D.	No.	Degrees	S.D.	Degrees	S.D.
A	26	53.85	4.54	103	53.45	8.08	53.69	6.89
B	20	54.25	4.06	79	55.38	4.44	55.32	4.48
C	5	54.00	2.24	12	51.25	5.69	51.25	5.69

unstable hips at birth is shown in Table 6. It can be seen that in 67 per cent of the cases retardation of the ossification process appeared on the same side as the instability of the hip joint at birth, whereas in the rest there was no correlation between the retarded ossification and the instability of the hips.

Table 14. The passive internal rotation of 490 hip joints in supine position and 90° flexion of the hips at the age of four to six years in 129 children with unstable hips at birth theated with Frejkas pillow (Group A), 99 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

Group	Boys			Girls				
					Right hip		Left hip	
	No.	Degrees	S.D.	No.	Degrees	S.D.	Degrees	S.D.
A	26	54.42	7.39	103	60.53	10.05	60.87	10.37
B	20	50.50	7.93	79	56.65	7.46	56.56	7.46
C	5	55.00	6.12	12	57.08	7.22	57.08	7.22

Table 15. The passive external rotation of 490 hip joints in supine position and 90° flexion of the hips at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 99 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

Group	Boys			Girls				
					Right hip		Left hip	
	No.	Degrees	S.D.	No.	Degrees	S.D.	Degrees	S.D.
A	26	55.28	6.31	103	56.12	8.54	56.26	8.79
B	20	54.50	3.59	79	54.30	5.23	54.30	5.23
C	5	49.00	4.18	12	55.00	7.69	55.00	7.69

Table 16. The passive internal rotation of 490 hip joints in prone position at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 99 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

Group	Boys			Girls				
					Right hip		Left hip	
	No.	Degrees	S.D.	No.	Degrees	S.D.	Degrees	S.D.
A	26	57.31	8.86	103	64.37	10.02	64.76	10.32
B	20	54.00	7.71	79	58.73	7.82	58.80	7.81
C	5	56.00	6.52	12	61.25	9.56	61.25	9.56

Table 7 shows the frequency of radiological findings described as "dysplasia" by different radiologists.

3. *Results of the clinical examination at 4–6 years of age*

The data regarding the further motor development of the children of group A and group B are based on information from the parents (Table 8). It can be seen that the frequency of abnormalities was higher in group A than in group B. The most frequent observation in both groups was in-toeing when walking. In group A the in-toeing could be seen at clinical examination in 6 children, in group B in two children.

Among the patients of group A six presented symptoms of complicating abnormality or disease. Four of them (No. 31, 71, 777 and 119) are described in detail in "Case Histories". One girl (No. 17) had signs of rheumatoid arthritis with a relative shortening of the right lower extremity of 8 mm. One boy (No. 109) had bilateral pes equinovarus

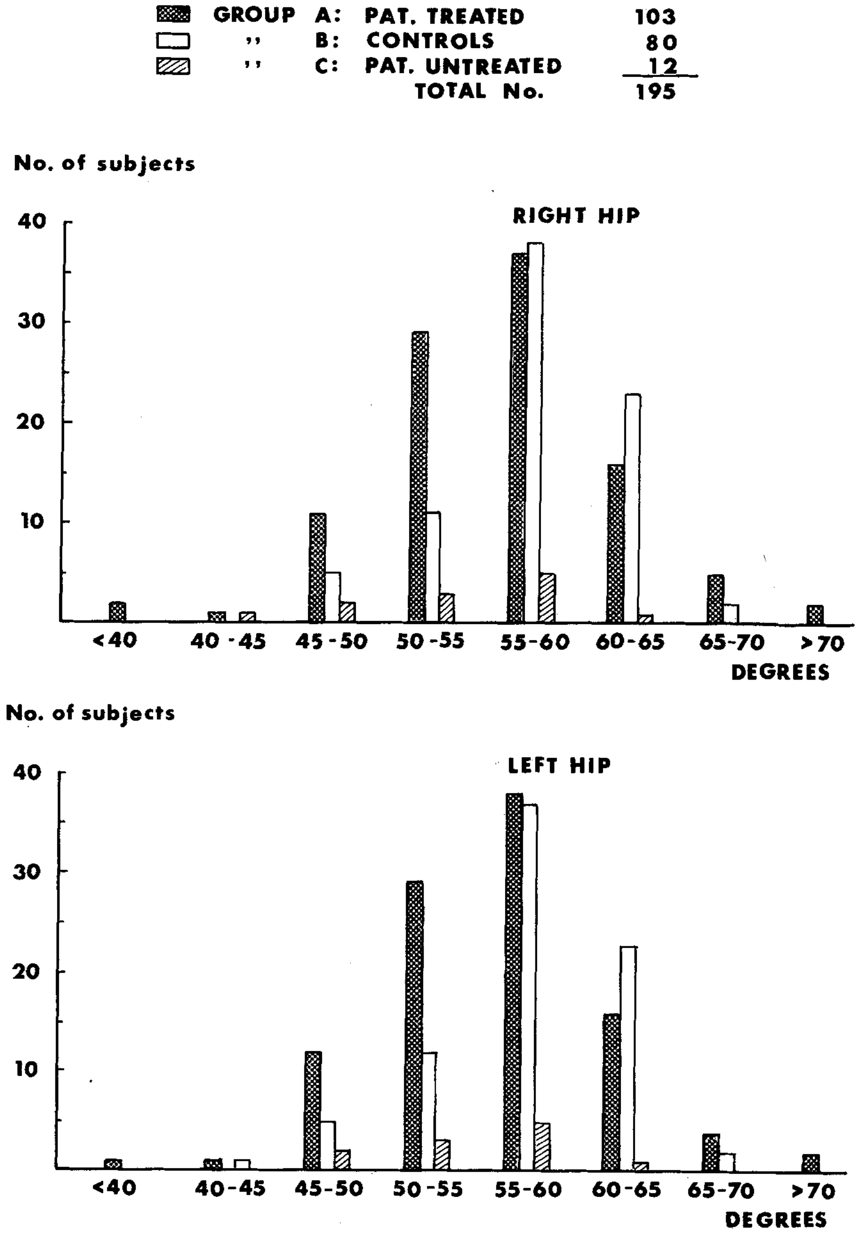


Figure 5. The range of passive abduction with hips 90° flexed in 103 girls with unstable hips at birth treated with Frejkas pillow, 80 healthy girls and 12 girls with unstable hips at birth untreated.

and a head circumference above the upper limit of normal.

Table 9 shows the range of passive flexion, and Table 10 the range of passive extension. There was no statistically significant difference between groups A and B, but the distribution curves of the values showed different patterns in groups A and B (Figure 3).

The range of passive abduction with hips extended is shown in Table 11. The difference between mean values for boys

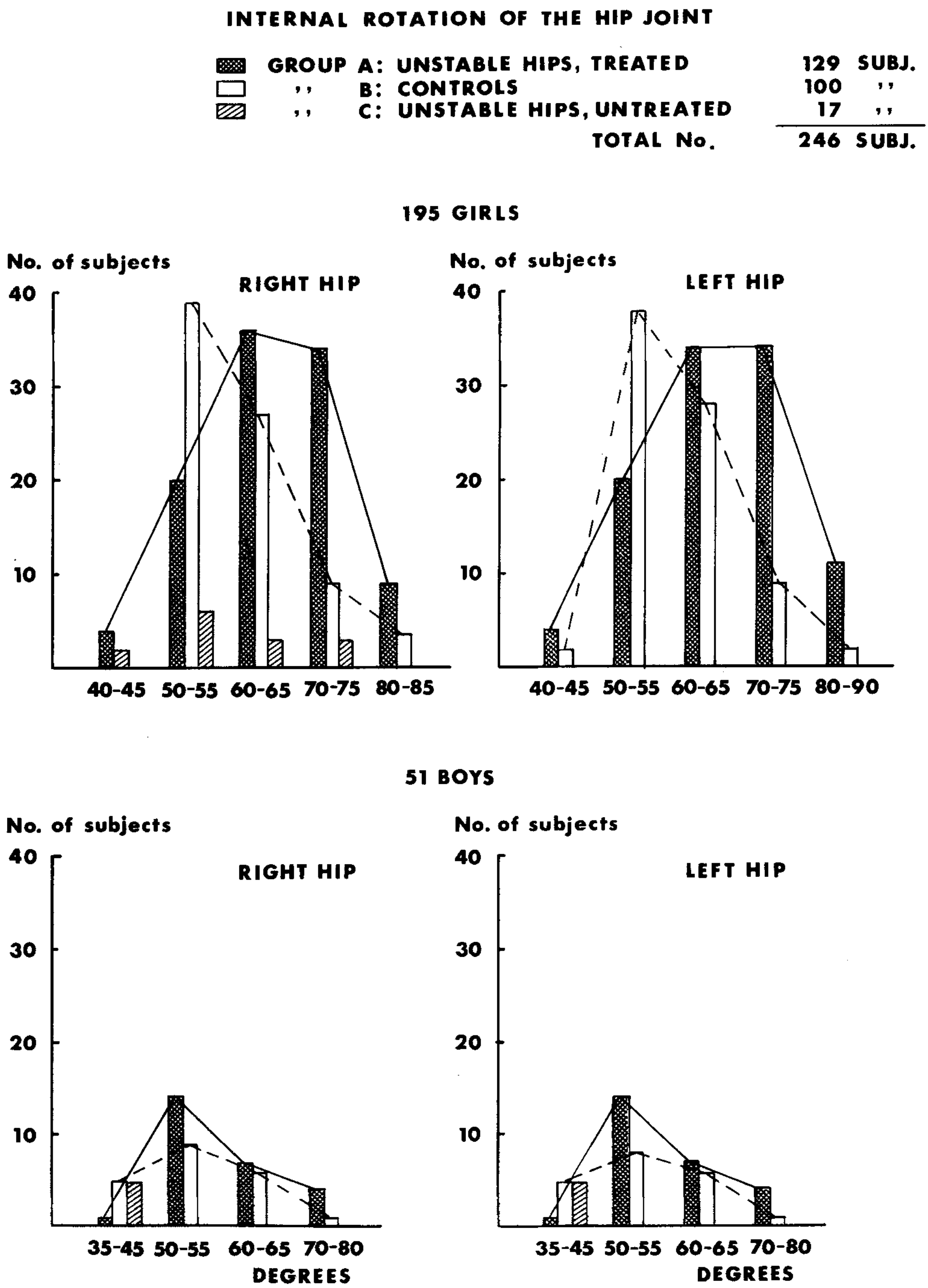


Figure 6. The range of passive internal rotation of the hip in 129 children with unstable hips at birth treated with Frejkas pillow, 100 healthy children and 17 children with unstable hips at birth untreated.

Table 17. The passive external rotation of 490 hip joints in prone position at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 99 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

Group	Boys			Girls				
					Right hip		Left hip	
	No.	Degrees	S.D.	No.	Degrees	S.D.	Degrees	S.D.
A	26	35.96	7.35	103	35.73	11.51	35.39	11.41
B	20	41.00	6.81	79	39.37	5.85	39.37	5.85
C	5	34.00	8.94	12	33.75	5.69	33.75	5.69

Table 18. The acetabular angle (AC-angle) at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 100 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

Group	Boys					Girls				
	No.	Right hip		Left hip		No.	Right hip		Left hip	
		Degrees	S.D.	Degrees	S.D.		Degrees	S.D.	Degrees	S.D.
A	26	15.81	3.49	15.46	3.63	103	15.43	4.55	15.20	3.94
B	20	13.70	3.50	13.80	3.37	80	13.86	3.53	13.86	3.36
C	5	13.40	3.21	13.40	3.21	12	13.83	4.26	13.33	4.52

of group A and boys of group B was statistically significant, and the distribution curves of values showed slightly different patterns (Figure 4).

Table 12 shows the mean values of the range of passive adduction. There was no statistically significant difference between the values of the three groups.

Table 13 gives the mean values of passive abduction with the hips 90° flexed. There is statistically no significant difference between the mean values of group A and group B, but the groups have different patterns of the distribution curves (Figure 5).

Table 14 shows the mean values of the range of internal rotation with the hips 90° flexed. The difference between values for girls from group A and girls from group B is statistically significant.

Table 15 shows the mean values for external rotation in the supine position with the hips 90° flexed. There is no statistically significant difference between groups A and B.

Table 16 shows the range of internal rotation in the prone position. The difference between mean values for girls of group A and girls of group B is statistically significant. The distribution curves of the values for internal rotation show different patterns in group A and group B (Figure 6).

Table 17 shows the range of movements for passive external rotation in the prone position. The difference between values of children from group A and B is statistically significant both for boys and girls. The distribution curves of values for external rotation showed different patterns in group A and group B (Figure 7).

Evaluation of the muscular strength of the lower extremities revealed no gross abnormalities.

None of the subjects of the three groups A, B and C had a positive Trendelenburg sign.

In-toeing when walking was observed in 22 children of group A, representing 0.16 per cent of the total number. In eight of the children the same observa-

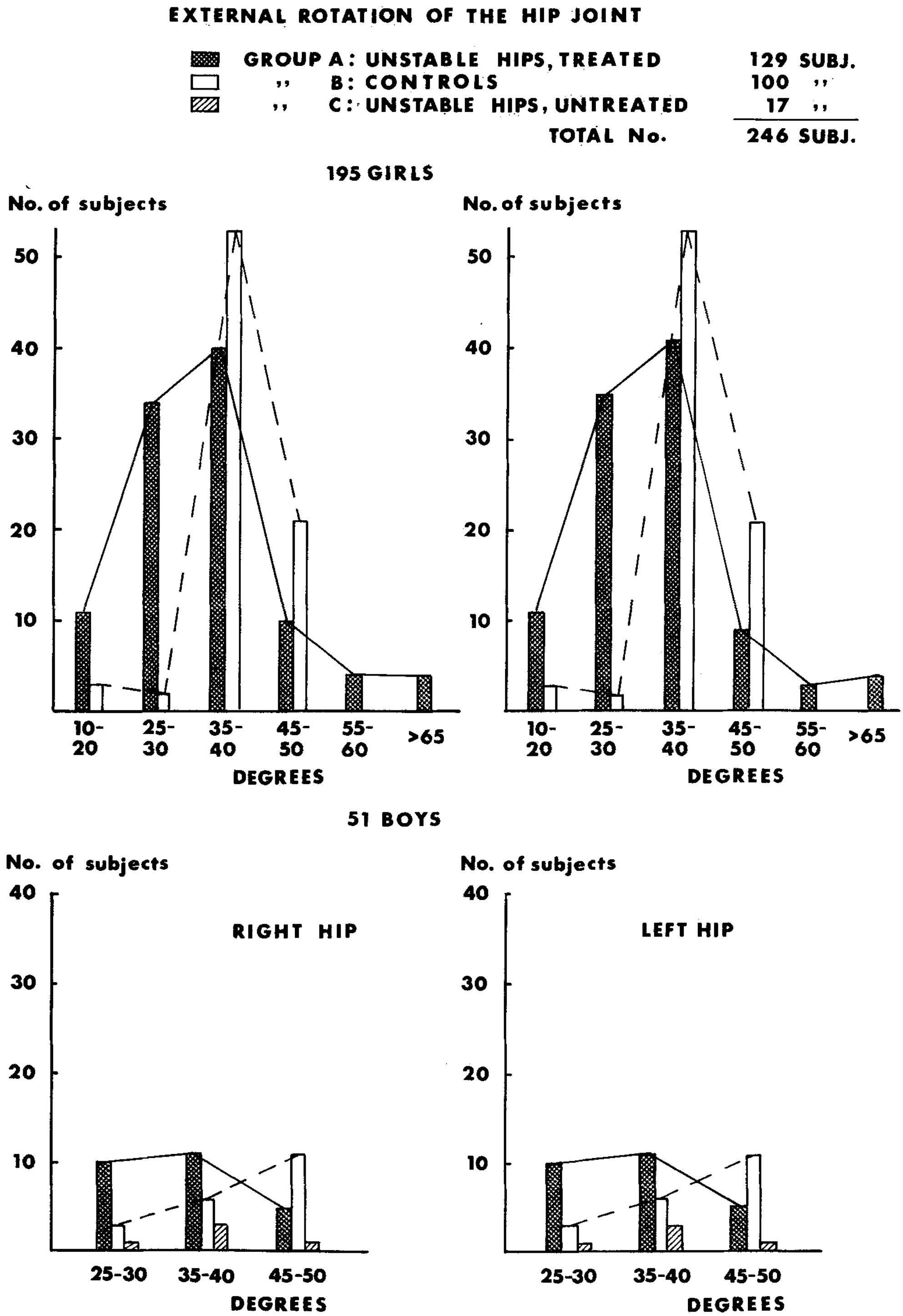


Figure 7. The range of passive external rotation movement of the hip in 129 children with unstable hips at birth treated with Frejkas pillow, 100 healthy children and 17 children with unstable hips at birth untreated.

Table 19. Side difference of the angle of the acetabular roof (AC-angle) at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 100 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

Right side–left side in degrees	Groups A Boys No.	%	A Girls No.	%	B Boys No.	%	B Girls No.	%	C Boys No.	%	C Girls No.	%
— 4			1	1.0								
— 3			4	3.9	1	5.0	3	3.7				
— 2			9	8.7	3	15.0	6	7.5			1	8.3
— 1, 0, + 1	22	84.6	72	69.9	13	65.0	63	78.7	5	100.0	8	66.7
+ 2	4	15.4	11	10.7	2	10.0	5	6.3			3	25.0
+ 3			3	2.9	1	5.0	3	3.7				
> + 3			3	2.9								

Table 20. Wibergs CE-angle at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 100 healthy children (Group B) and 17 children with unstable hips at birth untreated (Group C).

Group	Boys No.	Right hip Degrees	S.D.	Left hip Degrees	S.D.	Girls No.	Right hip Degrees	S.D.	Left hip Degrees	S.D.
A	26	28.92	4.72	30.04	4.83	103	29.51	5.19	30.82	5.21
B	20	31.30	4.50	32.00	4.86	80	31.26	5.15	32.46	5.03
C	5	32.80	2.86	33.80	5.02	12	32.67	4.31	34.00	4.69

Table 21. Side difference of Wibergs CE-angle at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 100 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

Right side–left side in degrees	Groups A Boys No.	%	A Girls No.	%	B Boys No.	%	B Girls No.	%	C Boys No.	%	C Girls No.	%
— 6			3	2.9								
— 5			1	1.0			1	1.2				
— 4	1	3.8	4	3.9			3	3.7				
— 3	5	19.2	17	16.5	2	10.0	13	16.2	1	20.0		
— 2	2	7.7	14	13.6	6	30.0	22	27.5	1	20.0	1	8.3
— 1, 0, + 1	16	61.5	52	50.4	9	45.0	29	36.2	2	40.0	8	66.7
+ 2	2	7.7	8	7.8	2	10.0	8	10.0	1	20.0	3	25.0
+ 3			2	1.9	1	5.0	3	3.7				
+ 4			2	1.9								
+ 5							1	1.2				

tion had been made by the parents. Among the children of group B in-toeing was observed in five, representing 0.04 per cent of the total number. In two of the subjects the same observation had been made by the parents. Among the children of group C in-toeing was recorded by the parents and on clinical

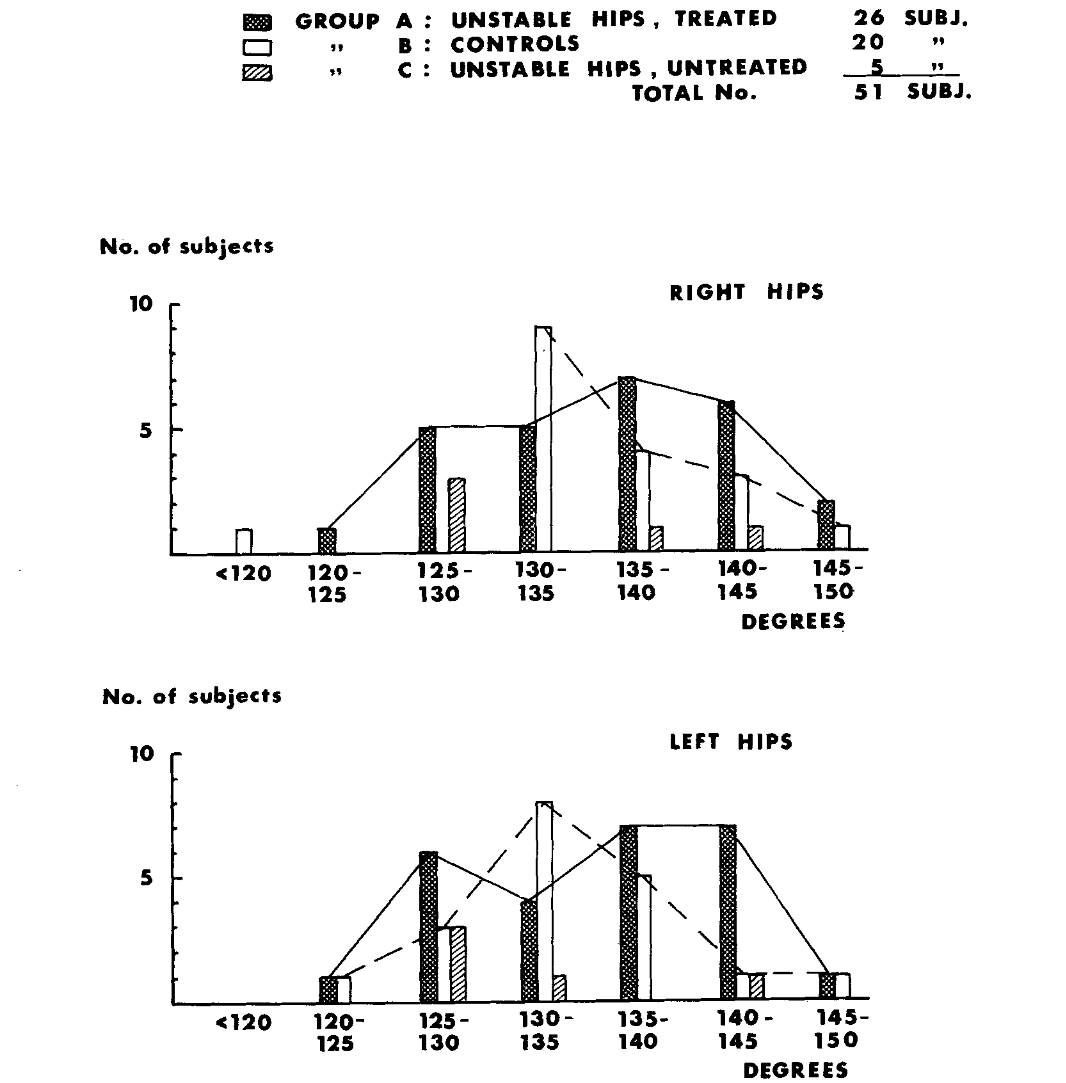


Figure 8. The femoral neck-shaft angle (CCD-angle) in 26 boys with unstable hips at birth treated with Frejkas pillow, 20 healthy boys and 5 boys with unstable hips at birth untreated.

examination in two cases, and in addition in one child slight in-toeing was recorded in the clinical observation only.

4. *Results of radiological examination at the age of 4–6 years*

Table 18 shows the mean values of the AC-angle. The difference between values of group A and group B is statistically significant for girls only.

In Table 19 the values of the AC-angle for the right and left side are compared. 93.9 per cent of the children showed practically no difference between the two sides.

Table 20 shows the mean values of the CE-angle. The mean value for girls of group A was statistically significantly lower than the mean value for girls of group B and girls of group C. There was

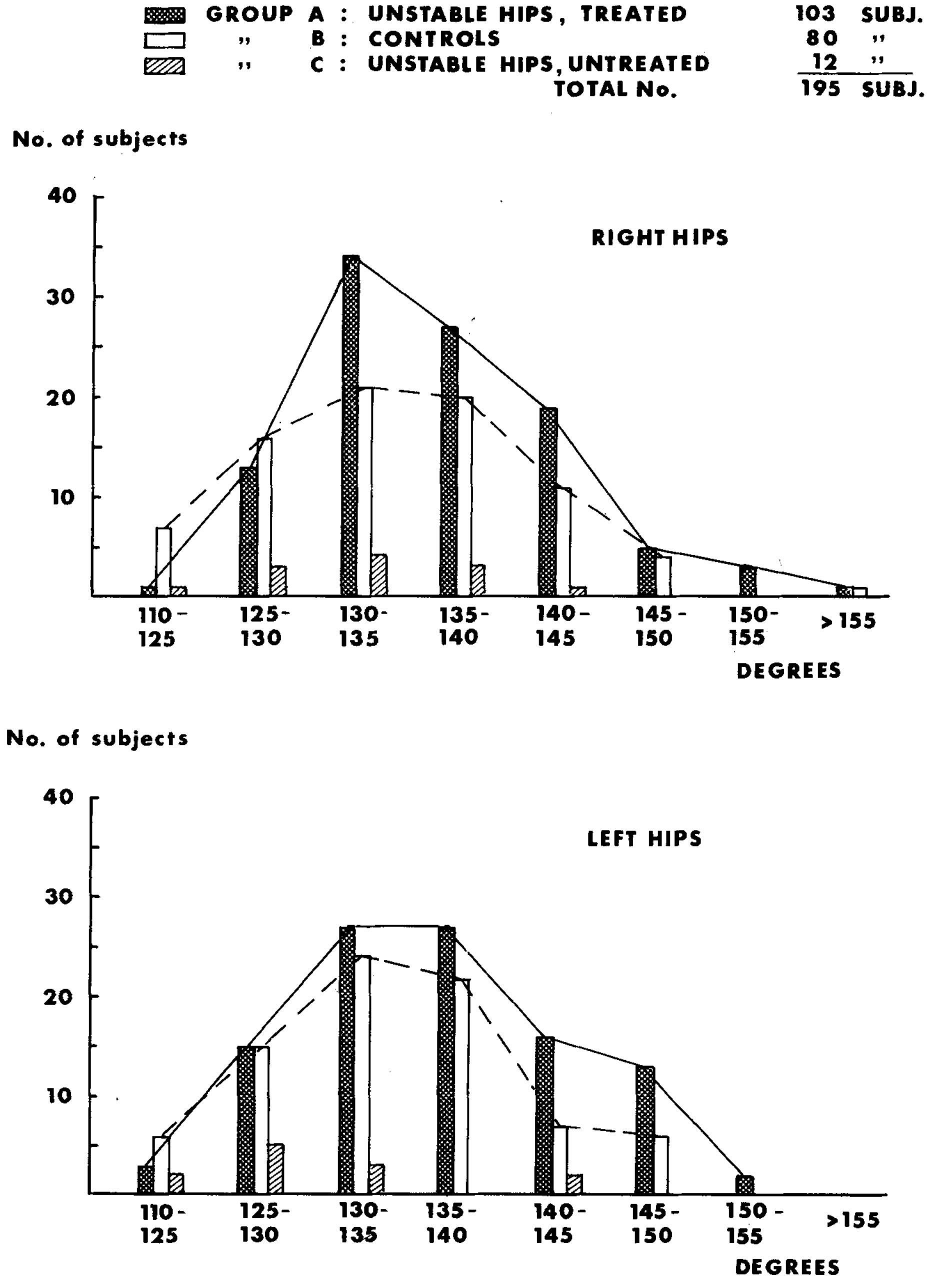


Figure 9. The femoral neck-shaft angle (CCD-angle) in 103 girls with unstable hips at birth, treated with Frejkas pillow, 80 healthy girls and 12 girls with unstable hips at birth.

statistically no significant difference for values of girls from group B and C.

Table 21 compares the measurements of the CE-angle of the right and left side. 81.4 per cent of the children showed minimal differences between the two sides (0–2°).

The mean values of the femoral neck-shaft angle (CCD-angle) are shown in Table 22. The difference between mean

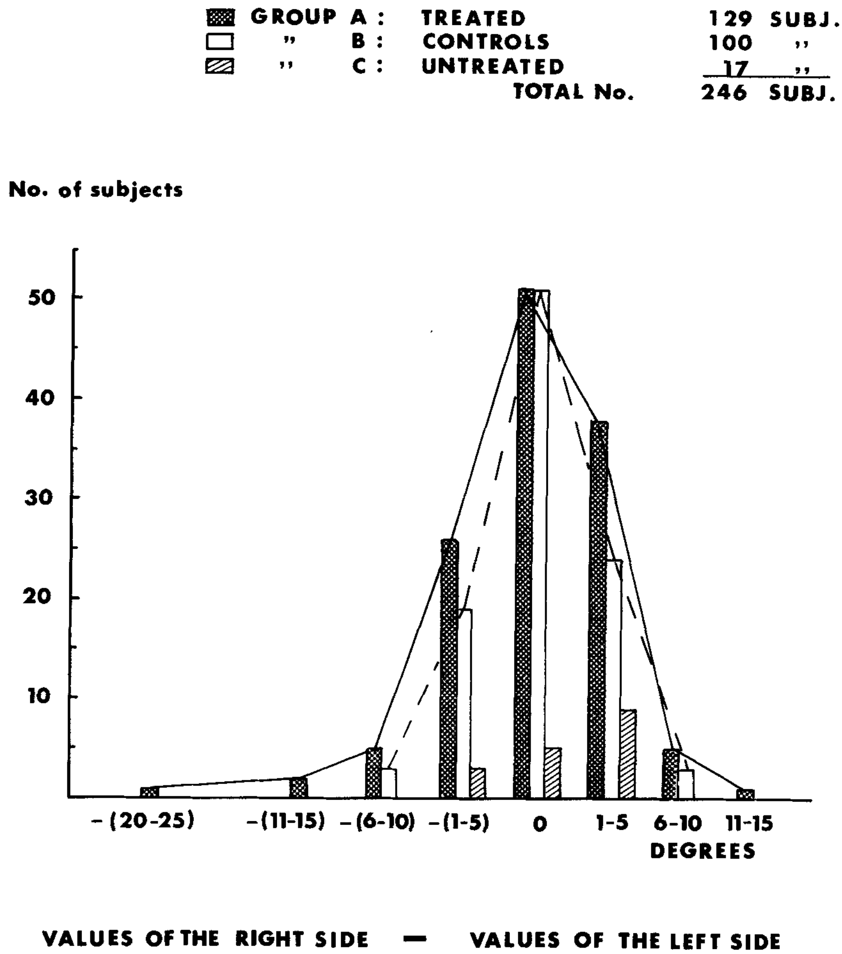


Figure 10. Values of the CCD-angle of the right hip and the left hip in 129 children with unstable hips at birth treated with Frejkas pillow, 100 healthy children and 17 children with unstable hips at birth untreated.

values for girls of group A and group B is statistically significant. The distribution curves for values of boys are illustrated in Figure 8 and the distribution curves for values of girls are shown in Figure 9. It can be seen that there are great individual variations in all three groups. Figure 10 illustrates the results of measurements of the CCD-angle of the right and left side. About 5 per cent of the children showed differences between the two sides greater than 2°.

Table 23 shows the mean values of the angle of anteversion of the femoral neck (AV-angle). The boys of group A showed statistically significantly higher values than the boys of group B. The differences between mean values for girls of group A and group B was statistically highly significant ($P < 0.005$). For both boys and girls there was a statistically significant difference between mean values of group A and group C, but no difference between mean values of groups B and C. Figure 11 illustrates the distribution curves of values of boys, and Figure 12 shows the distribution of values of girls. Figure 13 illustrates the difference be-

Table 22. The femoral neck-shaft angle (CCD-angle) at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 100 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

Group	No.	Boys				No.	Girls			
		Right hip		Left hip			Right hip		Left hip	
		Degrees	S.D.	Degrees	S.D.		Degrees	S.D.	Degrees	S.D.
A	26	135.83	6.60	135.40	6.38	103	136.49	6.25	136.57	6.74
B	20	134.80	6.72	134.60	6.10	80	134.40	6.85	134.34	6.55
C	5	132.01	6.93	131.01	5.90	12	131.90	6.21	130.77	6.61

Table 23. The angle of anteversion (AV-angle) at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 100 healthy children (Group B) and 17 children with unstable hips at birth untreated (Group C).

Group	No.	Boys				No.	Girls			
		Right hip		Left hip			Right hip		Left hip	
		Degrees	S.D.	Degrees	S.D.		Degrees	S.D.	Degrees	S.D.
A	26	35.97	7.67	35.02	7.26	103	38.97	9.51	36.73	10.44
B	20	28.17	6.93	26.93	8.93	80	32.20	8.33	31.27	8.18
C	5	37.21	8.69	36.76	8.91	12	32.98	7.76	31.58	7.24

Table 24. The epiphysis of the femoral head at the age of four to six years in 26 boys with unstable hips at birth treated with Frejkas pillow (Group A), 20 healthy boys (Group B) and 5 boys with unstable hips untreated (Group C).

Group	No.	Right hip				Left hip			
		Length		Width		Length		Width	
		mm	S.D.	mm	S.D.	mm	S.D.	mm	S.D.
A	26	27.00	2.80	13.27	1.54	26.73	2.47	13.12	1.34
B	20	26.80	2.76	13.95	1.57	26.85	2.80	14.00	1.52
C	5	29.60	3.21	14.00	1.41	29.60	3.21	14.00	1.41

Table 25. The epiphysis of the femoral head at the age of four to six years in 103 girls with unstable hips at birth treated with Frejkas pillow (Group A), 80 healthy girls (Group B) and 12 girls with unstable hips untreated (Group C).

Group	No.	Right hip				Left hip			
		Length		Width		Length		Width	
		mm	S.D.	mm	S.D.	mm	S.D.	mm	S.D.
A	103	26.99	3.18	13.15	1.81	26.81	3.03	13.13	1.70
B	80	27.89	2.84	14.05	1.54	27.86	2.86	14.02	1.57
C	12	32.50	5.14	14.67	2.19	32.42	5.18	14.67	2.19

tween values of the AV-angle for the right and the left side. Only 5 per cent of the children showed differences exceeding 2°.

Table 24 shows the length and width of the femoral epiphysis of boys, and Table 25 gives the corresponding values of girls. The slight difference between

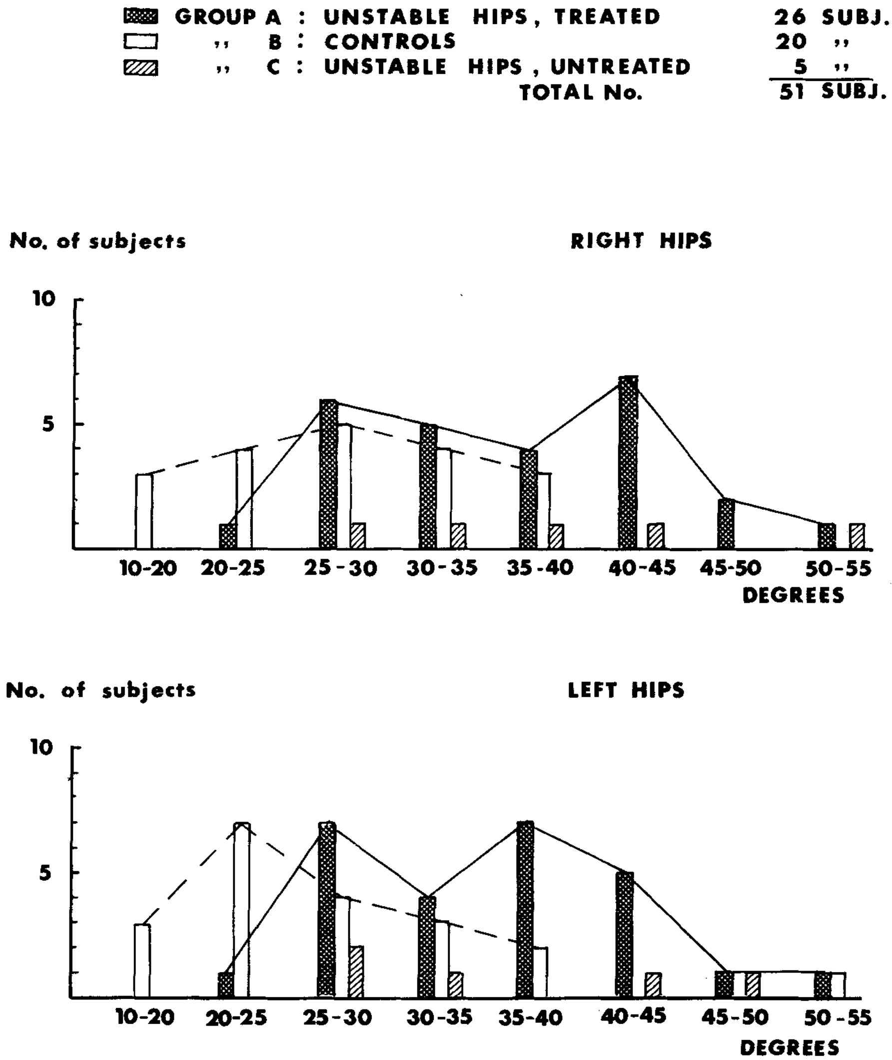


Figure 11. The anteversion angle of the femoral neck (AV-angle) in 26 boys with unstable hips at birth, 20 healthy boys and 5 boys with unstable hips at birth untreated.

Table 26. The area of the epiphysis of the femoral head at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 100 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

Group	No.	Boys				No.	Girls			
		Right hip		Left hip			Right hip		Left hip	
		mm²	S.D.	mm²	S.D.		mm²	S.D.	mm²	S.D.
A	26	1135.44	238.79	1107.77	192.59	103	1124.81	256.84	1116.39	247.59
B	20	1181.71	227.04	1187.84	224.02	80	1239.44	240.63	1236.49	243.77
C	5	1308.16	240.33	1308.16	240.33	12	1526.81	488.27	1523.41	490.39

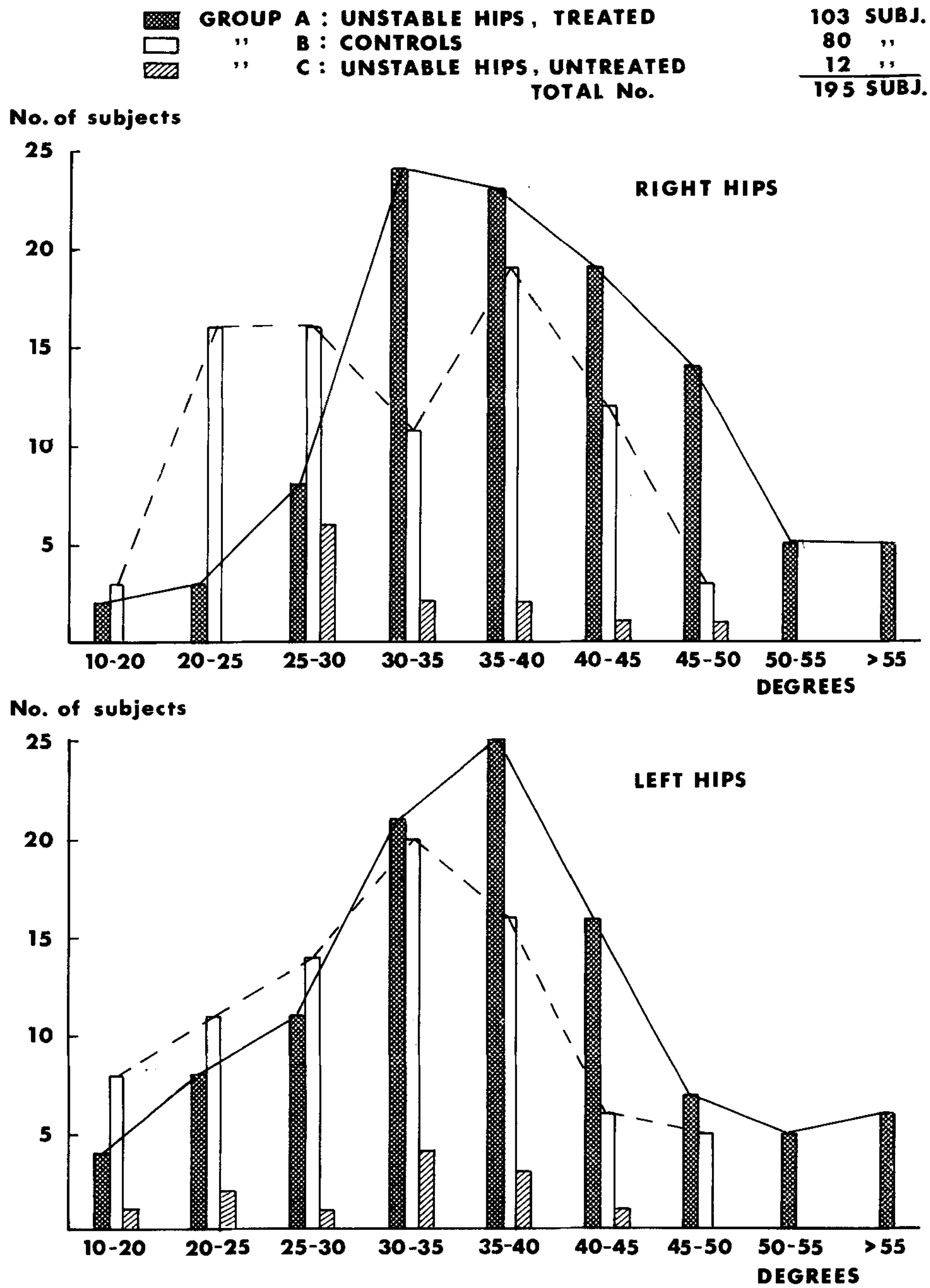


Figure 12. The anteversion angle of the femoral neck (AV-angle) in 103 girls with unstable hips at birth treated with Frejkas pillow, 80 healthy girls and 12 girls with unstable hips at birth untreated.

mean values of the groups A and B is not statistically significant.

Table 26 shows the area of the epiphysis for the different groups. The difference between values for groups A and B is not statistically significant.

The form of the epiphysis expressed by the length/width ratio is shown in Table

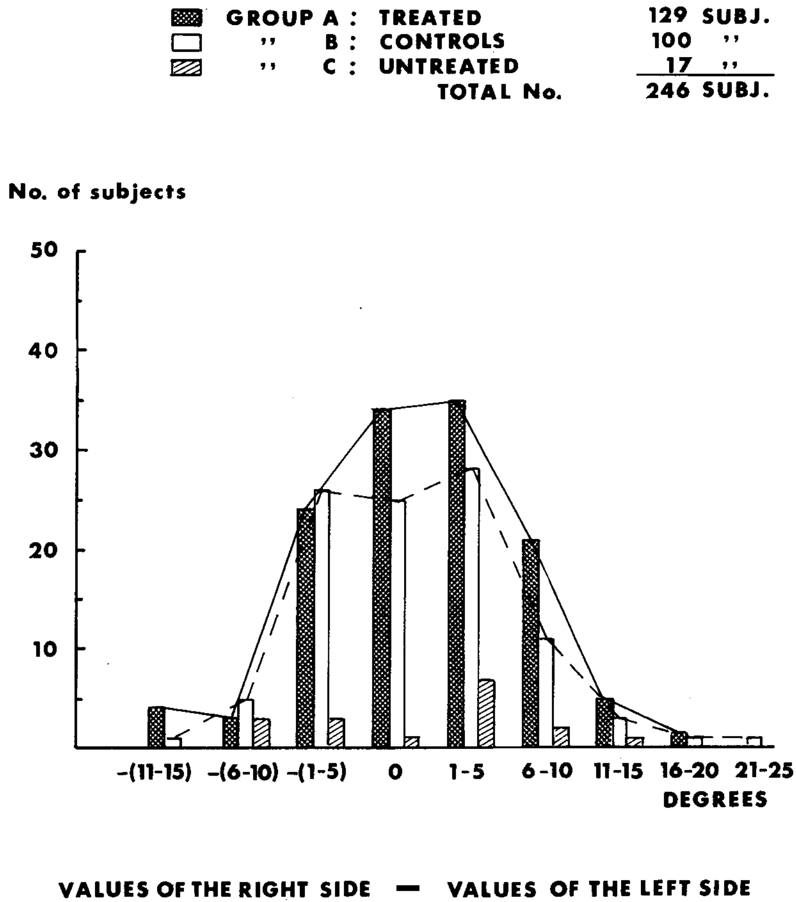


Figure 13. Values of the AV-angle of the right hip and the left hip in 129 children with unstable hips at birth treated with Frejkas pillow, 100 healthy children and 17 children with unstable hips at birth untreated.

Table 27. The length/width ratio of the epiphysis of the femoral head at the age of four to six years in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 100 healthy children (Group B) and 17 children with unstable hips untreated (Group C).

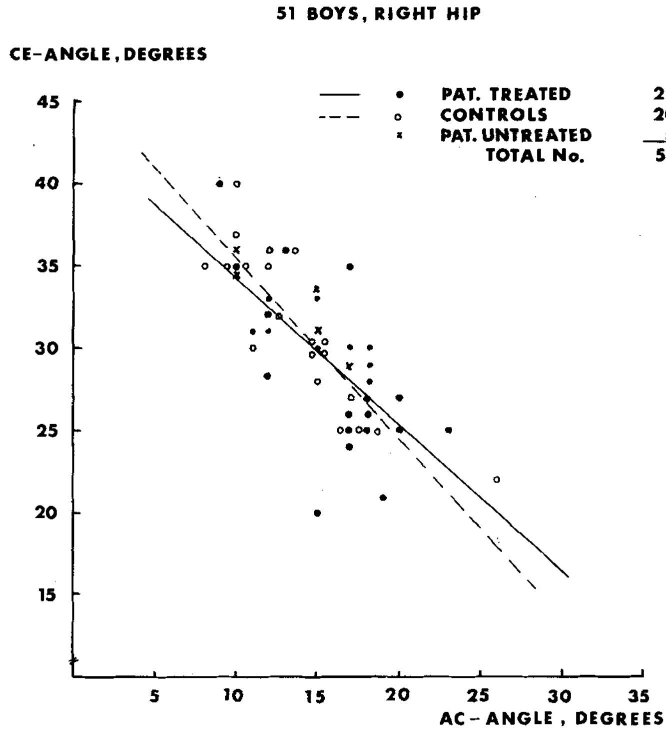
Group	No.	Boys				No.	Girls			
		Right hip		Left hip			Right hip		Left hip	
		L/W	S.D.	L/W	S.D.		L/W	S.D.	L/W	S.D.
A	26	2.04	0.16	2.05	0.17	103	2.08	0.31	2.05	0.20
B	20	1.93	0.19	1.93	0.19	80	1.99	0.19	2.00	0.19
C	5	2.12	0.20	2.12	0.20	12	2.22	0.15	2.21	0.15

27. There is no difference between the groups. The values for children of group C were not computed as they included some relatively older children.

5. *Correlation of the radiological results*

Figure 14 and Figure 15 illustrate the correlation of values of the CE-angle and

Figure 14. The correlation of the CE-angle and AC-angle of the right hip in 26 boys with unstable hips at birth treated with Frejkas pillow, 20 healthy boys and 5 boys with unstable hips at birth untreated.



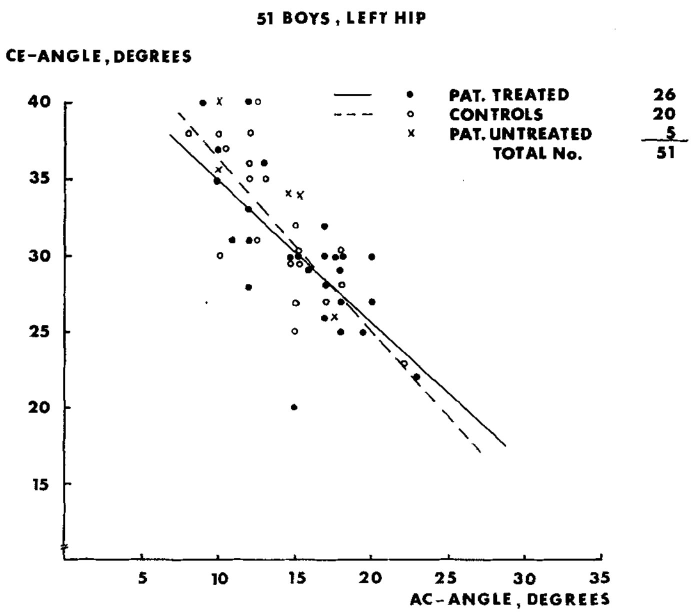


Figure 15. The correlation of the CE-angle and AC angle of the left hip in 26 boys with unstable hips at birth treated with Frejkas pillow, 20 healthy boys and 5 boys with unstable hips untreated.

AC-angle of boys in the right and left hip respectively. The correlation coefficient (cor.coef.) of group A was — 0.66 and that of group B — 0.85. The slight difference between group A and group B is without practical importance.

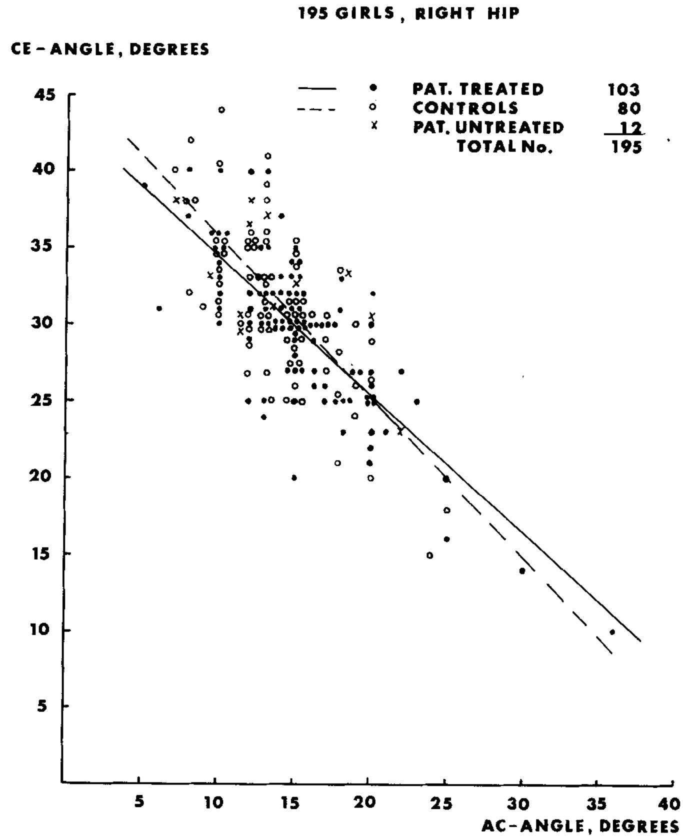


Figure 16. The correlation of the CE-angle and AC-angle of the right hip in 103 girls with unstable hips at birth treated with Frejkas pillow, 80 healthy girls and 12 girls with unstable hips at birth untreated.

Figure 16 and Figure 17 show the correlation between values of the CE-angle and the AC-angle of girls in the right hip and the left hip respectively. The cor.coef. of group A was — 0.72 and that of group B — 0.75. The difference between the two groups is without practical importance.

Figure 18 shows an attempt to find a possible correlation between values of the CE-angle and AV-angle. No correlation could be proved, but the regression lines of values of group A and values of group B were different.

No correlation could be found between the retarded ossification of the femoral head and increased anteversion of the femoral neck.

No correlation could be found between values of the AV-angle and the CCD-angle (cor.coef. 0.27).

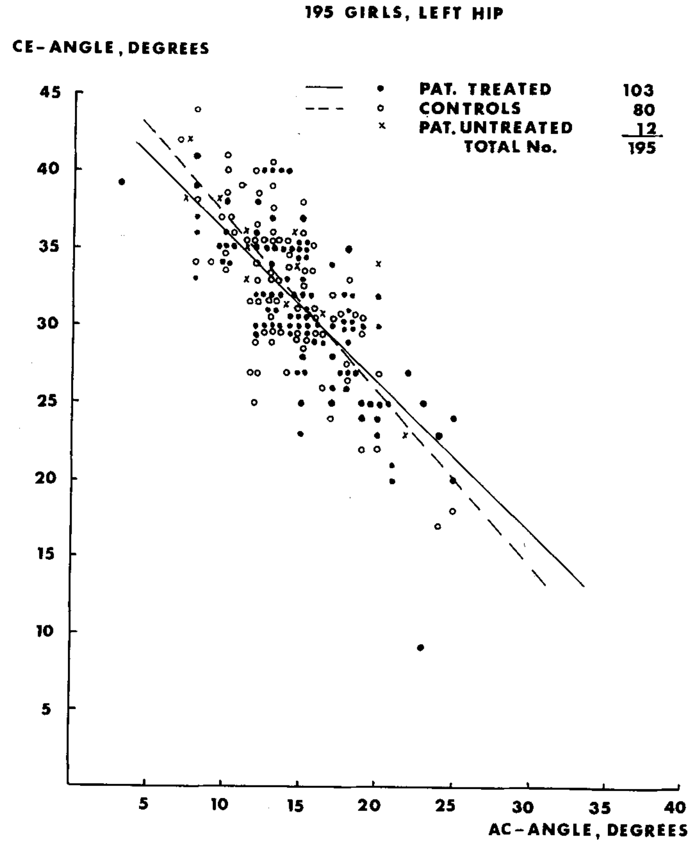
6. *Correlation of some clinical and radiological findings*

Figure 19 illustrates the correlation between the passive internal rotation movement and the values of the AV-angle. The correlation was very poor (cor.coef. 0.52). For the sake of simplicity only the figures for the left hip of the girls in the prone position are shown, but the same results were obtained for the rest of the material.

Figure 20 shows the values of the AV-angle of boys related to the age of the subjects. There is no correlation for values in group A (cor.coef. of the right hip 0.027 and the left hip 0.035). In group B the corresponding figures for the cor. coef. are — 0.41 and — 0.397, and in group C — 0.61 and — 0.397.

Figure 21 and Figure 22 illustrate the

Figure 17. The correlation of the CE-angle and AC-angle of the left hip in 103 girls with unstable hips at birth, 80 healthy girls and 12 girls with unstable hips at birth untreated.



correlation between values of the AV-angle of girls and the age of the subjects. In group A the cor.coef. was 0.07 for the right hip and 0.08 for the left. In group B the corresponding values were — 0.41 and — 0.20. The small number of values for group C yielded cor.coef. of — 0.14 and — 0.35 for the right and left side respectively.

Table 28 shows the correlation between the length and width of the epiphysis and the age of the subjects. The girls of both group A and group B showed a definite correlation, whereas no correlation was found in boys. In group C there was a positive correlation for all groups of values, except for the width of the epiphysis of boys.

No correlation was found between the values of the CE-angle and CCD-angle and the age of the subjects.

As can be seen from the Table 29 there is no relation between the age when the children started to walk without support and the values of the AV-angle. Those results are based upon informations from the parents of 72 children of group A.

Table 30 shows the average values of the AV-angle of 11 children of group A who showed a gradual increase of passive internal rotation during the first year of life. The average value for boys was 37.8° for the right hip and 34.6° for the left hip. The corresponding values for girls were 45.8° and 39.5°. The latter values are near the upper normal level.

In Table 31 is shown the correlation between the height/weight ratio of the children and the values of the AV-, CCD- and CE-angles. Individuals with height/weight ratio below the 50th percentile have statistically significantly higher

Table 28. Length and width of the epiphysis of the femoral head correlated with age in 129 children with unstable hips at birth treated with Frejkas pillow (Group A), 100 healthy children (Group B) and 17 children with unstable hips at birth untreated (Group C).

Group	No.	Sex	Length (L) Width (W)	Right (R) Left (L)	Slope of regression line	Correlation	Significance
A	26	M	L	R	0.12150	0.24522	0.11364
			L	L	0.10016	0.22871	0.13055
			W	R	0.05140	0.18891	0.17769
			W	L	0.00217	0.00917	0.48228
A	103	F	L	R	0.22102	0.47252	0.00001
			L	L	0.22109	0.49599	0.00001
			W	R	0.08108	0.30541	0.00085
			W	L	0.08110	0.32537	0.00040
B	20	M	L	R	0.21934	0.42291	0.03160
			L	L	0.21360	0.40717	0.21360
			W	R	0.08911	0.30214	0.09771
			W	L	0.08151	0.28550	0.11120
B	80	F	L	R	0.23455	0.56400	0.00001
			L	L	0.23631	0.56493	0.00001
			W	R	0.07292	0.32318	0.00173
			W	L	0.07414	0.32168	0.00181
C	5	M	L	R	0.25399	0.96993	0.00312
			L	L	0.25399	0.96993	0.00312
			W	R	0.04494	0.38945	0.25849
			W	L	0.04494	0.38945	0.25849
C	12	F	L	R	0.28836	0.92930	0.00001
			L	L	0.29043	0.92973	0.00001
			W	R	0.12110	0.01738	0.00001
			W	L	0.12110	0.91738	0.00001

values of the AV-angle than those with a ratio above the 50th percentile. The values for the CCD- and CE-angles showed no significant difference between the two groups.

CASE HISTORIES

The following case histories illustrate some of the characteristic findings for the different categories of patients.

1. *Patient no. 39 Da. 101269. Male.*

No known cases of CDH in the family. Vertex presentation. Positive dislocation test in the left hip on the first day of life, negative on the fourth day. Frejkas pillow used for three months. At that age normal clinical findings.

Six months old: internal rotation 70°, external rotation 90°, abduction 90°. X-ray: "possibly indistinctly marked lateral margin of the left acetabulum".

Eighteen months: internal rotation 50°, external rotation 80°, abduction 80°. X-ray: normal findings.

Six years of age: flexion 135°, extension 20°, abduction 50°, internal rotation 50°, external rotation 45°. Hips 90° flexed: abduction 55°, internal rotation 50°, external rotation 45°. X-ray: femoral epiphysis 29 × 14 mm, AC-angle 12°, CE-angle 28°, CCD-angle 140°, AV-angle 26° (Figure 23).

Figure 18. The correlation of the CE-angle and AV-angle of the right hip in 103 girls with unstable hips at birth treated with Frejkas pillow, 80 healthy girls and 12 girls with unstable hips at birth untreated.

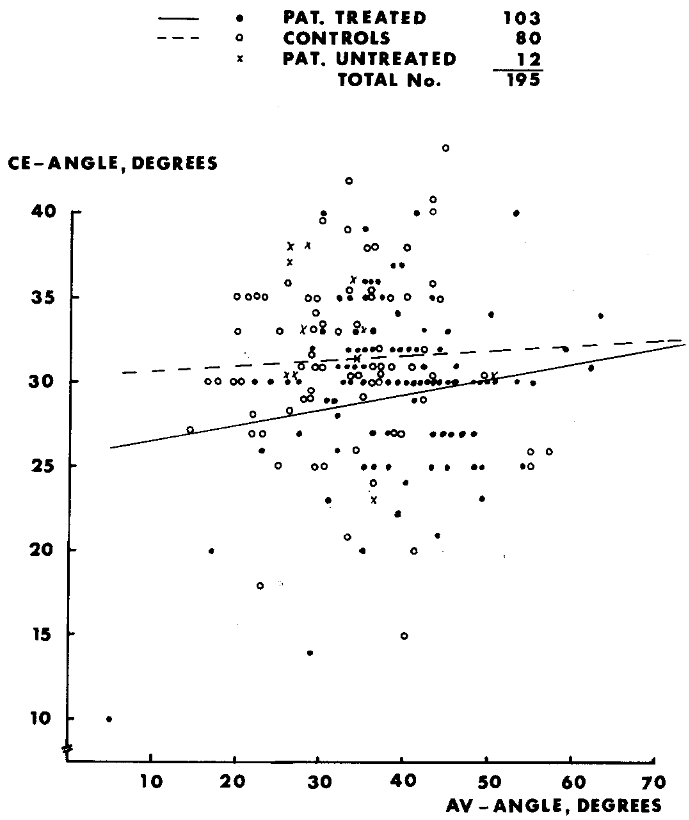


Table 29. The AV-angle in relation to the development of walking in children with unstable hips at birth.

Age of walking without support in months	AV-angle in degrees (left hip)				
	20–29	30–39	40–49	50–59	59
9–12	6	9	9	3	0
13–15	8	18	4	3	1
16–19	4	2	4	1	0

Conclusion: normal clinical and radiological findings.

2. *Patient no. 1 Au 040569. Female.*

No cases of CDH in the family. Breech presentation. The birth induced by oxytocin. Positive dislocation test in the left hip on the second day of life. Treated with Frejkas cushion splint for three months. At that age normal clinical findings.

Walked without support 14 months old.

Sixteen months of age: internal rotation 90°, external rotation 90°, abduction 80°. X-ray picture normal.

Six years old: flexion 135°, extension 20°, abduction 40°, internal rotation 75°, external rotation 10°. Hips 90° flexed:

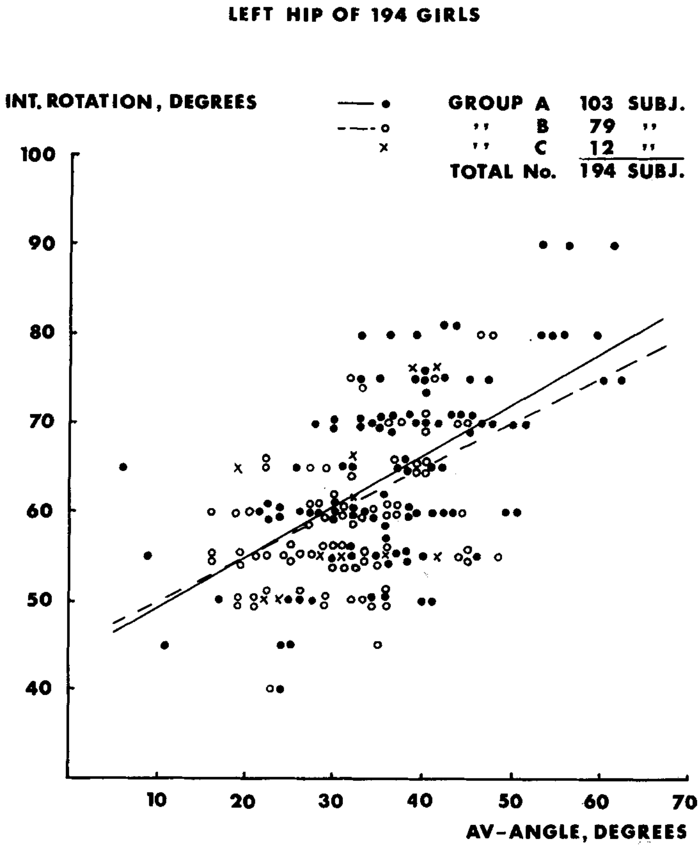


Figure 19. The correlation between the passive internal rotation and the AV-angle of the left hip in 103 girls with unstable hips at birth treated with Frejkas pillow, 79 healthy girls and 12 girls with unstable hips at birth untreated.

Table 30. The AV-angle at four to six years in relation to the increasing passive internal rotation during infancy. Observations in 11 children with unstable hips at birth.

No.	Sex	AV-angle in degrees			Mean
		Right hip	Mean	Left hip	
1	M	40		40	
2	M	43		35	
3	M	41	37.8	39	34.6
4	M	39	(boys)	33	(boys)
5	M	26		26	
6	F	44		37	
7	F	36		36	
8	F	50	45.8	50	39.5
9	F	45	(girls)	40	(girls)
10	F	39		32	
11	F	43		42	

internal rotation 75°, external rotation 10°, abduction 50°. X-ray: femoral epiphysis 32 × 12 mm, AC-angle 10°, CE-angle 34°, CCD-angle right side: 138°, left side 140°, AV-angle right side 63°, left side 62° (Figure 24).

Figure 20. The values of the AV-angle related to the age of 26 boys with unstable hips at birth treated with Frejkas pillow, 20 healthy boys and 5 boys with unstable hips at birth untreated.

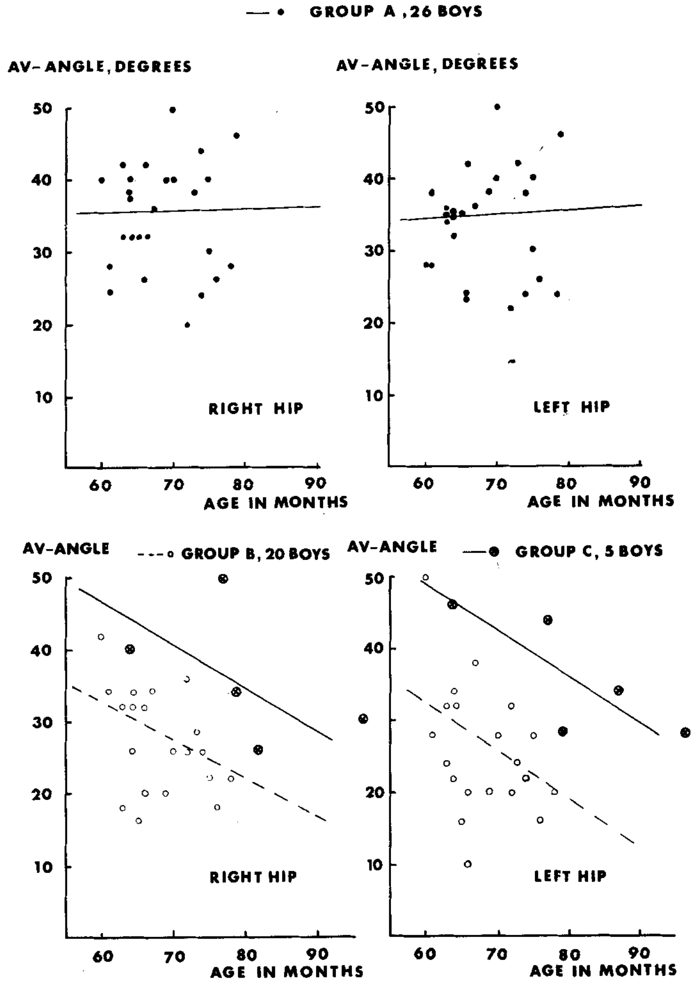


Table 31. The relation between the height/weight ratio of 123 children and the AV-, CCD- and CE-angle.

Height/Weight ratio	AV-angle		CCD-angle		CE-angle	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
≦ 50 percentiles	37.20	9.74	135.47	6.43	30.32	4.82
> 50 percentiles	32.68	8.56	135.97	5.80	30.44	5.43

Conclusion: increased range of passive internal rotation. Increased anteversion of the femoral neck.

3. *Patient no. 138 Hu 050170. Male.*

No cases of CDH in the family. Vertex presentation. Birth weight 2830 g. Dysmature appearance. Positive dislocation test in both hips on the second day, negative on the eight day. Treated with Frejkas pillow.

Three months old: internal rotation 60°, external rotation 80°, abduction right side 80°, left side 60°. Treatment with Frejkas pillow continued to five months.

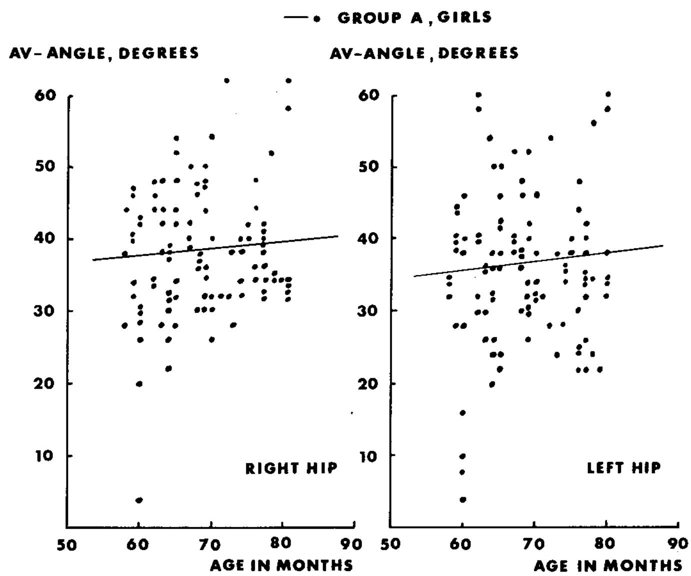


Figure 21. The values of the AV-angle related to the age of 103 girls with unstable hips at birth treated with Frejkas pillow.

Nine months: internal rotation 40°, external rotation 80°, abduction 60°. X-ray: negative.

Five years old: flexion 135°, extension 20°, abduction 40°, internal rotation 60°, external rotation 45°. Hips 90° flexed: internal and external rotation 60°, abduction 45°. X-ray: femoral epiphysis right side 26 × 11 mm, left side 24 × 12 mm, AC-angle 17°, CE-angle right side 24°, left side 28°, CCD-angle right side 134°, left side 138°, AV-angle right side 25°, left side 38° (Figure 25).

Conclusion: asymmetrical development of the hip joint. Relative increase of the anteversion of the femoral neck of the left side. Normal clinical findings.

4. *Patient no. 77 Ne 230271. Female.*

No known hip anomalies in the family. Vertex presentation. Positive dislocation test in the left hip on the first day of life, negative on the fourth day. Treated with Frejkas pillow for three months, did not come to follow-up afterwards.

Five years old:

Position:		Movement:	right hip	left hip
supine	hips 0°	flexion	135°	135°
		abduction	45°	45°
		adduction	20°	20°
	hips 90° flexed	abduction	55°	55°
		internal rotation	55°	65°
		external rotation	60°	60°
prone		extension	25°	25°
		internal rotation	60°	70°
		external rotation	55°	40°
X-ray findings: (Figure 26)		femoral epiphysis	29 × 14 mm	29 × 14 mm
		AC-angle	12°	12°
		CE-angle	29°	29°
		CCD-angle	144°	141°
		AV-angle	31°	38°

Conclusion: asymmetrical development of the hip joint both on clinical and radiological examination.

5. *Patient no. 119 Mau 140970. Female.*

No cases of CDH in the family. Breech presentation, forceps delivery. Birth weight 2620 g. Dysmature appearance. Positive dislocation test in the right hip on the first day of life, negative on the third day. Treated with Frejkas pillow for three months. Did not come to follow-up afterwards.

Five years old:

Position:		Movement:	right hip	left hip
supine	hips 0°	flexion	120°	120°
		abduction	25°	35°
		adduction	20°	20°
	hips 90° flexed	abduction	15°	30°
		internal rotation	65°	50°
		external rotation	45°	45°
prone		extension	25°	25°
		internal rotation	70°	70°
		external rotation	20°	30°
X-ray findings: (Figure 27)		femoral epiphysis	24 × 11 mm	24 × 11 mm
		AC-angle	15°	10°
		CE-angle	30°	35°
		CCD-angle	143°	141°
		AV-angle	53°	44°

Conclusion: restricted movements and increased internal rotation of the right hip. Increased anteversion of the right femoral neck.

6. *Patient no. 31 So 281069. Female.*

No hip anomalies in the family. Vertex presentation, birth induced by oxytocin. A positive dislocation test on the second day of life, negative on the fourth day. Treated with Frejkas pillow for three months, at that stage normal clinical findings.

Eight months: internal rotation 80°, external rotation 90°, abduction 90°. Walked without support 15 months old.

Seventeen months: internal rotation 45°, external rotation 90°, abduction 80°. Shortly afterwards the mother observed that the child did not move her left arm normally, and slight spasticity of the left leg was noticed. Treated with physiotherapy.

Five and a half years old: flexion 115°, extension 20°, abduction 50°, adduction 15°, internal rotation 60°, external rotation 50°. Hips 90° flexed: abduction 50°, internal rotation 35°, external rotation 70°.

X-ray findings (Figure 28):

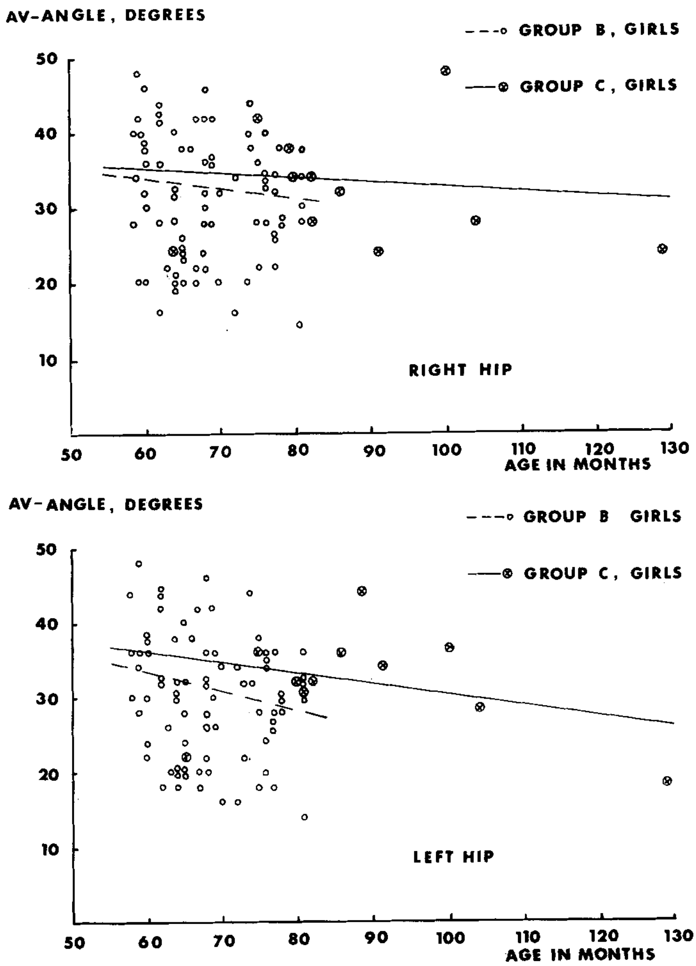
	right hip	left hip
Femoral epiphysis	32 ×16 mm	32 × 14 mm
AC-angle	15°	21°
CE-angle	20°	20°
CCD-angle	140°	147°
AV-angle	17°	23°

Conclusion: cerebral palsy. Left-sided hemiparesis. Relatively increased anteversion of the left femoral neck.

7. *Patient no. 71 Ne 241270. Female.*

No hip abnormalities in the family. Breech presentation, forceps delivery. Erythroblastosis foetalis. Fourteen hours

Figure 22. The values of the AV-angle related to the age of 80 healthy girls and 12 girls with unstable hips at birth untreated.



after birth an exchange transfusion was performed because of hyperbilirubinaemia. Positive dislocation test in the right hip on the first day of life, negative on the fourth day. Treated with Frejkas cushion splint for three months.

Three months old: internal and external rotation 45°, abduction 90°. The child showed a marked retardation of neuromuscular development and was hypotonic.

Eight months: internal rotation 40°, external rotation 80°, abduction 70°. X-ray picture was normal.

Five years: length 105 cm (10 perc.) Weight 13 kg (below 2.5 perc.) General spasticity. Flexion of the hips: 115°, extension 15°, abduction 40°, adduction 30°, internal rotation 90°, external rotation 60°. Hips 90° flexed: abduction 45°, internal rotation 80°, external rotation 70°. X-ray: femoral epiphysis 17 × 10 mm, AC-angle 25°, CE-angle right side 16°, left side 24°, CCD-angle right side 151°, left side 154°, AV-angle right side 67°, left side 61° (Figure 29).

Conclusion: cerebral palsy. Bilateral increase of the anteversion of the femoral neck.

8. *Patient no. 777 Gu 240970. Female.*

Positive dislocation in the right hip on the second day of life, negative on the fifth day. No treatment instituted.

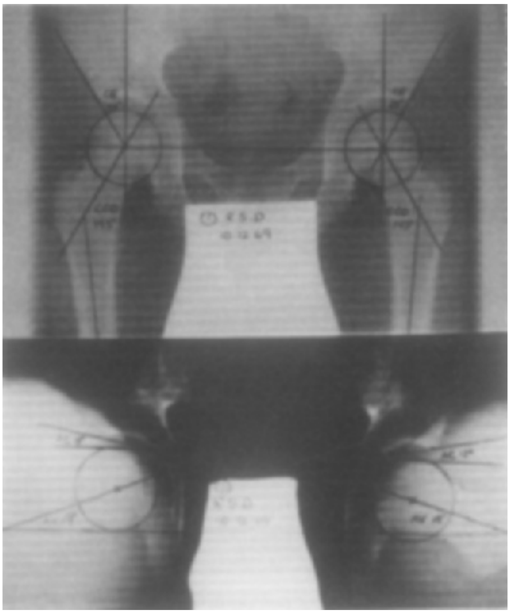


Figure 23. Radiological examination of a six years old boy with a positive dislocation test in the left hip at birth. R.: Normal findings.

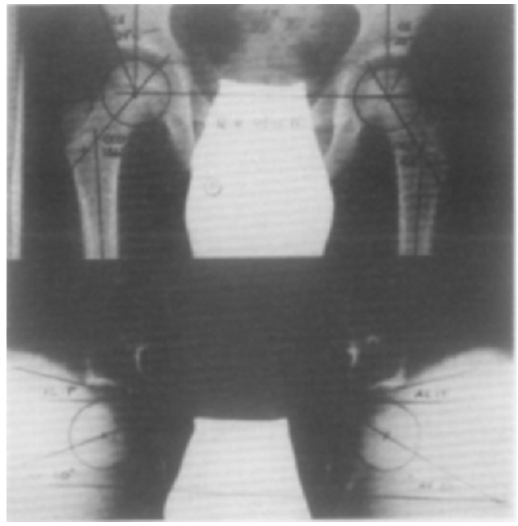


Figure 25. Radiological examination of a five years old boy with a positive dislocation test in both hips at birth. R.: Asymmetrical development of the hip joint. AV-angle on the right side 25°, on the left side 38°.

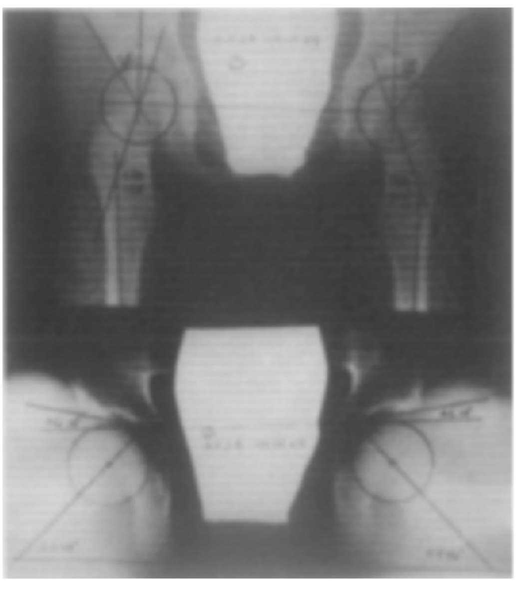


Figure 24. Radiological examination of a six years old girl with a positive dislocation test in the left hip at birth. R.: Increased anteversion of the femoral neck. AV-angle on the right side 63°, on the left side 62°.

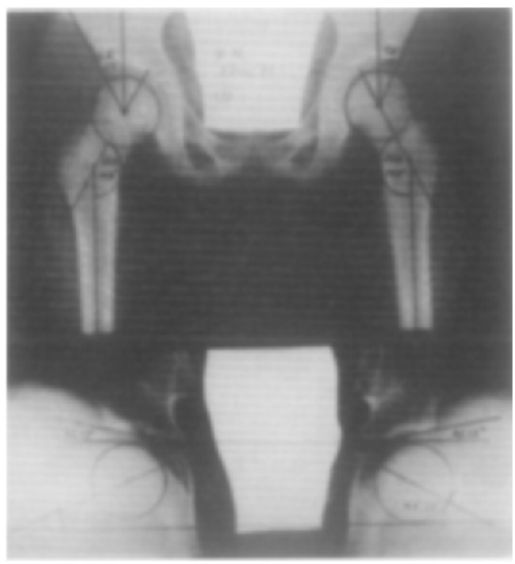


Figure 26. Radiological examination of a five years old girl with a positive dislocation test in the left hip at birth. R.: Asymmetrical development of the hip, AV-angle on the right side 31°, on the left side 38°.

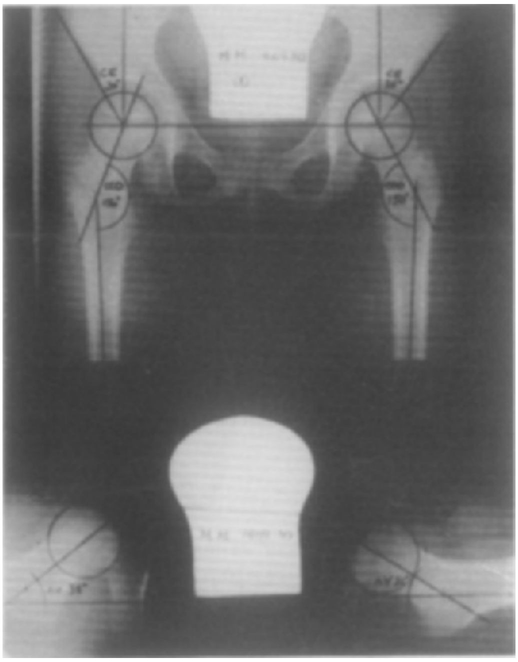


Figure 27. Radiological examination of a five years old girl with a positive dislocation test in the right hip at birth. R.: Increased anteversion of the femoral neck of the right hip (AV-angle 53°). AV-angle on the left side 44°.

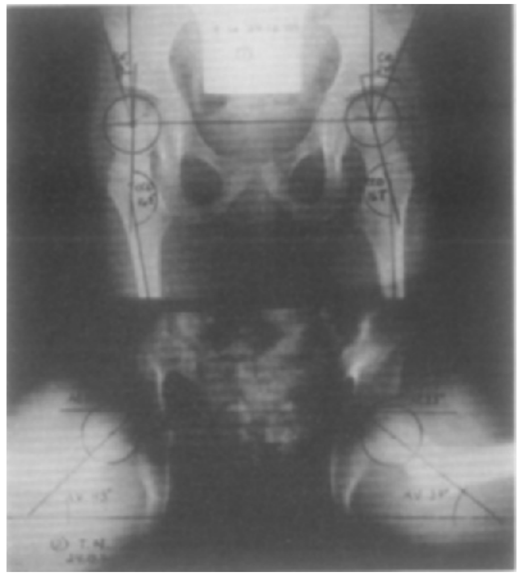


Figure 29. Radiological examination of a five years old girl with a positive dislocation test in the right hip at birth. R.: Cerebral palsy. General spasticity. Bilateral increase of the anteversion of the femoral neck. AV-angle: right 67°, left 61°.

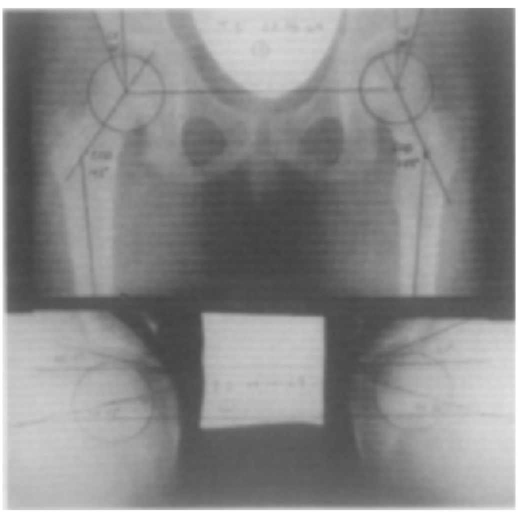


Figure 28. Radiological examination of a five years old girl with a positive dislocation test in both hips at birth. R.: Cerebral palsy. Hemiparesis sin. Asymmetrical development of the hips. AV-angle on the right side 17°, on the left side 23°.

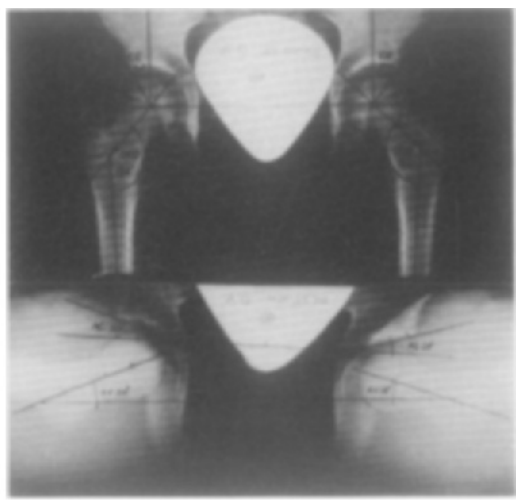


Figure 30. Radiological examination of a six years old girl with a positive dislocation test in the right hip at birth, left untreated. R.: Normal findings.

Clinical and radiological controls at two, six and eighteen months of age revealed nothing pathological. Walked without support 11 months old.

Six years old: flexion 125°, extension 20°, abduction 50°, adduction 20°, internal rotation 50°, external rotation 35°. Hips 90° flexed: abduction 60°, internal rotation 55°, external rotation 60°. X-ray: femoral epiphysis 25 × 12 mm, AC-angle 20°, CE-angle right side 30°, left side 34°, CCD-angle right side 135°, left side 130°, AV-angle right side 26°, left side 22° (Figure 30).

Conclusion: clinically and radiologically normal findings.

DISCUSSION

1. *Patients and methods*

The Trondheim area offers good conditions for the investigation of the problems of congenital dislocation of the hip. All children are delivered in two maternity clinics, and examination of the newborn are performed by few, experienced pediatricians. All cases of the "late-diagnosis" dislocation of the hip are referred to the orthopaedic department of the Regional Hospital.

The frequency of unstable hips in the present material was 22.4 $^0/_{00}$. Apart from data reported by Harlem (1961) and Ramstad (1964) the incidence in Trondheim is the highest reported in Norway (Kåss 1961, Medbø 1961, Torp 1961, Njå 1962, Bjerkreim 1974, Høyer 1975). Among the widely differing results published from different countries it is not difficult to find incidence of unstable hips similar to ours (James & Sevasticoglou 1970, Fredensborg 1976). Apart from the fact that incidence of unstable hips of the newborn in Trondheim has shown a tendency to decrease during recent years (from 20 to 15 $^0/_{00}$) the findings have been remarkably stable, and there is reason to believe that the figure of 22 $^0/_{00}$ represents the true incidence of unstable hips of newborn in the region.

In the examination of the newborn I used both the abduction test and the subluxation provocation test (Palmén 1957, Barlow 1962). I did not try to classify unstable hips into "dislocated" and "dislocatable" (Finlay et al. 1967, Barlow 1962, Rosenblum et al. 1972, Siffert et al. 1972, Komprda 1974), as I had a strong impression that it depended largely on the position of the legs, whether I found the hips in or out of joint at the time of examination. "Atypical clicks"of the hip joint were not recorded as they seem to be without clinical significance (Sommer 1971).

The sex distribution, side affected, and the incidence of breech presentation are in accordance with the results of other neonatal series (Palmén 1961, Hirsch & Scheller 1970, Lauritzen 1971, Huttová et al. 1972, Ritter 1973, Bjerkreim 1974, Ackermann et al. 1974, Artz et al. 1975).

One of the main problems of the present investigation was to find a suitable group of control children. Being aware of the sex and racial variations of the incidence of CDH (Getz 1955), geographical distribution (Bjerkreim 1974), seasonal fluctuations (Record & Edwards 1958, Nagura 1955, Pap 1956, Uibe 1959, Chen et al. 1970, Andrén & Palmén 1963) and possible other factors in the pathogenesis of neonatal CDH, I tried to find a control group within the population of Trondheim.

I sent an inquiry to all the parents of the children of the same sex born chronologically next to the children with unstable hips. All those children had been examined by me at birth. They had stable hips and received no treatment. One cannot be sure that the group represents completely "normal" material. In a few cases the parents reported of hip abnormalities in the family. The control group differed from the patient group with respect to birth order of the child in the family. In the patient group (A) 75 children (58 per cent) were first-born, whereas in the control group (B) 39 children (39 per cent) wer first-born. The control group and the patient group were not matched for possible differences in social class distribution. One boy originally in the control group revealed serious abnormalities of the hip joint, probably due to Calvé-Legg-Perthes disease. This child was excluded from the series. Another girl with a probable developmental anomaly of the lower extremities was also excluded.

Nearly 70 per cent of the parents of the control children responded to the inquiry. Among the remainder the majority had moved from the town and some refused the examination. One cannot exclude the possibility that among the 30 per cent children not examined there might be so many pathological findings that the differences between groups A and B might be minimized. It is not very likely, however, as parents generally are aware of even small abnormalities of their childrens development. In addition, most of the children are regularly examined at welfare clinics, and examination of the hip is included in the routine examination at most centres.

Fifteen patients with unstable hips at birth were not examined because they had moved from the town. It is impossible to say how additional results from examination of this group might have influenced the final results. However, with the present results in view, one can not exclude the possibility that differences between group A and B might be even greater.

Of the 146 children with unstable hips at birth eleven received prolonged treatment wiht a plaster cast. Seven of them were examined by me. As one of the purposes of the present investigation was to study the effect of various factors upon the development of the hip joint, it seemed correct to include these patients in the series. In the final analyses mean values with and without these patients were compared, and there was no differences of the results.

The follow-up study was performed at four to six years of age. This age group was considered suitable for investigation on the following grounds: 1. Most children at this age cooperate fairly well and thus permit detailed measurements at both the clinical and radiological examination. 2. The development of the hip joint has progressed to such a degree that comparison between different groups of children is possible. 3. Practical therapeutic problems often arise in the preschool period, so it might be desirable to complete treatment (especially surgical procedures) before the school age.

Before embarking on radiological examination of the children of the control group it was necessary to evaluate the risks of x-ray studies on healthy individuals (Grossmann 1969, Devik 1971, Frik 1972, Schmidt 1974). Having reviewed the relevant data on the method used in the present investigation, I could not find any contraindications to the examination.

The radiographic method of Dunlap (Dunlap et al. 1953) modified by Rippstein (1955) has the advantage that only two exposures are necessary. The described method has been tested by several investigators (Rippstein 1955, Gross 1972), and the conclusion is that it is sufficiently accurate for scientific purposes.

The formula used for the correction of the pojected values of the CCD-angle and AV-angle has been the subject of much discussion. Obviously the formula given by Müller (1970) is incorrect (Sudman 1976, Rusten 1976), and the formula used in the present study gives correct values. Elsasser (1973) holds that the formula is not precise enough for high values of the AV- and CCD-angles, and that the results may vary by as much as 5 degrees. He uses somewhat different projections and his definition of the AV-angle differs from that used in the present study (Gibson 1967, Müller 1970).

The vast literature on the radiological descriptions of the hip gives a strong impression that many variations of both normal and pathological appearances of the joint still remain unexplained. Thus, there is no unanimous definition of the concept "dysplasia".

Various descriptions of the acetabulum include the sloping of the acetabular roof (Hilgenreiner 1925, Idelberger & Frank 1952, Caffey et al. 1956, Root 1967, Kalenov 1970, Busse et al. 1972), areas of sclerosis (Garavaglia 1970) and the thickness of the bottom of the acetabulum (Schindlmaisser & Kotz 1972). Different measurements have led to a number of concepts, such as the "Z-line" (Zsernaviczky 1974), "acetabular-head-quotient" (Sun Do Hong 1969), "Zentrierungs-deficit" (Hoffmann-Daimler 1974), "Wibergs angle" (Wiberg 1939). Felländer et al. (1970) points out that it is important to distinguish between late ossification of the acetabular roof with a small or absent lateral margin of the roof and ossification defects as signs of real dysplasia. Keller (1975) lists the following important radiological signs of real dysplasia: "wedge segments", delayed ossification of the acetabular roof, "tailliation" of the acetabular edge, double contour of the acetabulum, subchondral sclerosis and steep acetabular roof. Among the "non-osseous signs" Garavaglia (1970) describes the "arcuate line" and the "triangular area" as early signs of dysplasia. The upper end of the femur has been described by Hadziselimovic & Secerov (1968) and Skrypczak (1971) among others.

Many of the radiological findings can only be demonstrated on specially exposed films, and some of the results are difficult to interpret. I found the measurements of the present study relatively simple and the results of the measurements suitable for statistical analysis.

2. *Results*

The study of children with unstable hips at birth has shown several deviations from the normal motor development. During infancy the following trends were noticed:

At three months of age practically all children had an abduction angle of 80–90 degrees. The frequency of maximal abduction was reduced to 69 per cent during the second half year of life, and remained practically unaltered thereafter.

A small group of children (11 patients) showed a gradual increase of passive internal rotation from 40–50 degrees to 80–90 degrees, whereas the remainder showed either unaltered or reduced capacity for internal rotation.

The number of children with external rotation of 80–90 degrees increased from 30.1 per cent at the age of three months to 93.6 per cent during the second half year of life and then decreased to 69.1 per cent after one year of age.

On the basis of investigations made by Harris et al. (1960), Haas et al. (1973) and Coon et al. (1975) the normal internal rotation of the hip is 62 ± 12.9 degrees at birth, 26 ± 3.4 degrees at three months and 21 ± 4.3 degrees at six months. The external rotation is 89.1 ± 14.3 degrees at birth, 45 ± 4.5 degrees at three months and 46 ± 4.8 degrees at six months. The normal abduction seems to be 80–90 degrees in the newborn and 60–70 degrees at the age of 1–9 months.

As will be discussed later one cannot exclude the possibility that the deviating motor development of children with unstable hips at birth has important influence on the development of the hip joint.

It is noteworthy that minor abnormalities of the function of the lower extremities (in-toeing when walking, stumbling and complaints of fatigue) appeared more frequently in the patient group than in the control group.

On the basis of the present investigation the following values seem to represent useful guidelines for evaluation of mobility at the age of four to six years: flexion 130 ± 15 degrees, extension 20 ± 5 degrees, abduction 45 ± 10 degrees, adduction 25 ± 5 degrees, internal rotation in boys 50 ± 15 degrees and in girls 55 ± 15 degrees, external rotation 55 ± 10 degrees.

Clinical examination at the age of four to six years showed several definite differences between the groups A and B. The girls of group A showed on average a pronounced increase of internal rotation and a decrease of external rotation of the hip as compared with girls of group B. In conjunction with the radiological findings this is an expression of the increased anteversion of the femoral neck. However, the poor correlation between the clinical and radiological findings (Figure 19) would indicate great caution in the evaluation of increased anteversion of the femoral neck on the basis of clinical examinations only.

The boys of group A had on average an increased range of passive abduction movement compared with the boys of group B. No satisfactory explanation for this tendency could be found. In view of the fact that the boys of group A had a decreased range of external rotation, but the same range of internal rotation as boys of group B, it is unlikely that the increased abduction ability should depend on increased laxity of the joint. Moreover, one would have expected to find the same tendency in the group of girls.

It may be justified to conclude that on average *about 20 per cent of the girls and 10 per cent of the boys of group A showed abnormal function of the hip joint.*

The results of the present study seem to indicate that the following values might be used as practical guidelines for the evaluation of x-ray pictures of five to six years old children: AC-angle 14 ± 8 degrees, CE-angle 31 ± 10 degrees, CCD-angle 135 ± 12 degrees, AV-angle in boys 28 ± 18 degrees, in girls 32 ± 16 degrees. In the absence of comparable studies one cannot be sure that these values apply to other populations.

There are few reports of the normal values of the AC-angle and CE-angle at the age of four to six years. Meyer & Schreiber (1964) give values similar to those of the present study, whereas Tönnis & Brunken (1968), Tönnis (1969) and Tönnis & Trede (1970) give somewhat higher values. The CE-values of Wiberg (1939) and Severin (1941) are similar to ours.

The close correlation between values of the AC-angle and the CE-angle demonstrated in the present study would indicate that it is sufficient to measure only one of the parameters, preferably the CE-angle which is easier to mate.

The results of the radiological study would indicate that *nearly 30 per cent of the girls and 10 per cent of the boys of group A present clearly pathological values of the angles measured* (2 S.D. or above the mean values).

The results of the present investigation contrast with the normal or nearly normal results of most of the previously reported follow-up investigations (Medbø 1961, Palmén 1961, Barlow 1962, Gregersen 1969, von Rosen 1970, James & Sevastikoglou 1970, Crézé 1970, Pešek & Ambler 1972, Fredensborg 1976).

Bjerkreim has stressed the important fact that even in children where the clinical course has apparently been satisfactory one may find deviation from normal clinical and radiological findings (Bjerkreim 1974). In his large series 24.4 per cent of the children treated with an abduction splint presented abnormal signs. Of those, 12 per cent had increased anteversion of the femoral neck and 12.4 per cent signs of "dysplasia". As Bjerkreim had no control group and did not examine systematically all children treated, some have questioned the reliability of his results (Fredensborg 1976). The results of the present investigation are in agreement with Bjerkreims findings, the frequency of increased anteversion of the femoral neck being even higher.

The variable results of the different follow-up studies published may be due to one or several of the following factors:

1. Different definitions of the concepts "dysplasia", "preluxation", "instability of the hip", "anteversion of the femoral neck" a. o. (Finlay 1967, Komprda 1974).

2. Lack of standardised diagnostic procedures. The diagnosis of instability of the hip in the newborn period is to some extent subjective. Diagnosis may be missed for such reasons as inexperience, difficult examination (crying child, large baby), dislocated irreducible hips or hips with the potential tendency to dislocate later (Ramstad 1964, Sommer 1971, Uher 1972, Mitchell 1972, Moore 1972). On routine clinical examination of older children minor deviations from the normal may easily be missed. Lack of standardised radiological examinations and "normal" values of different age groups make it difficult to compare results from different departments.

3. "Congenital dislocation of the hip" probably comprises different etiological and pathogenetical entities (Carter & Wilkinson 1964, Wynne-Davies 1970, Wilkinson 1972, Stohr 1972). The genetic background may vary for different populations. The classification of "neonatal CDH" and "late-diagnosis CDH" which seems widely accepted to-day may be rather arbitrary. The "late-diagnosis" CDH includes at least three categories of children: a) those who are insufficiently or not examined at birth, b) newborn with stable hips with a potential to dislocate later and c) dislocated, irreducible hips. Some investigators would also include patients with unstable hips at birth who are inadequately or not treated.

Apart from the fact that instability of the hip joint at birth may lead in a small proportion of children to luxation, subluxation or dysplasia at a later stage, the true connection between the instability of the hip and late pathological states is unclear.

4. Different long-term results of early treatment of unstable hips may depend on different therapeutic regimes (Allen 1962, Felländer et al. 1970, Lauritzen 1071, Emneus 1971, Ilfeld et al. 1972).

3. *The anteversion of the femoral neck*

Family studies of the structure of the hip do not permit any conclusions concerning a possible genetic influence upon the anteversion of the femoral neck (Carter & Williams 1964, Rott 1968, Wynne-Davies 1970, Czeizel et al. 1975). Getz (1955) found an increased anteversion of the femoral neck in adult Lapps, but this may be due to environmental influence (Bjerkreim 1974). His values for children of 20.5 ± 10.8 degrees are not matched with control subjects.

The embryonal development of the hip joint has been studied by Watanabe (1974). He found great individual variations of the AV-angle (— 30 to 40 degrees). In contrast to the other structural characteristics of the hip (neck-shaft angle, depth of the acetabulum and the inclination of the acetabular roof) the AV-angle was independent of the age of the foetus. Neither could he find any correlation between the AV-angle and the "dysplastic" hip joint which was demonstrated in 9.1 per cent of the cases.

Wilkinson (1963) states that different types of breech malposition may lead to different development of the shape of the femur. The more common lateral rotation breech malposition with flexion of the knees produces femoral retroversion whereas the medial rotation breech posture leads to femoral anteversion.

In the postnatal development of the hip joint both age-dependent, sexual and individual variations are well documented. The average values of the AV-angle of infants are reported to be 30–40 degrees, and there seems to be a steady decrease to values of 5–10 degrees in the adult (Dunlap et al. 1953, Shands & Steele 1958, Manlot et al. 1964, Teinturier & Dechembre 1968, Fabry 1973). This age-dependent decrease of values is also observed in children with an initially pathological increased anteversion (Gibson 1967, Schwarzenbach 1971) .Heinrich et al. (1968) found a temporary increase of the femoral neck anteversion from 30–40 degrees at birth to 40–50 degrees at the age of four years, and a decrease thereafter. In the present study the age difference between subjects was relatively small, and the age-dependent tendency could not be convincingly demonstrated. This justifies the computing of the total number of values of groups A, B and C.

The normal values given for the AV-angle of children at the age of four to six years differ considerably in the available reports. The following figures illustrate some of the diverging results: 20 degrees (Shands & Steele 1958), 22 degrees (Dunlap et al. 1953), 26.7±7.4 degrees (Fabry 1973), 20–30 degrees (Rogers 1934), 23–40 degrees (Teinturier 1968), 30–50 degrees (Heinrich et al. 1968). Different techniques of examination may explain the different results, but the influence of different populations cannot be excluded. The present findings of 27.5 ± 8 degrees in boys and 31.5 ± 8 degrees in girls are practically the same as those of Fabry. However, he gives no difference between boys and girls.

The present study also demonstrated a correlation between the anteversion of the femoral neck and the build of the child. Slender children on average have higher values of the AV-angle compared with those of the more "athletic" type. This suggests a possible influence of the muscular activity upon the degree of anteversion.

If the muscular influence upon the bony structures is exerted through balanced muscle tone, one would not expect to find any correlation between the age of walking start and the values of the AV-angle. This assumption was in accordance with the findings of the present study.

As early as 1934 Rogers pointed out that various pathological conditions may cause an increase of the anteversion of the femoral neck. Among the conditions listed in his report are: fractures, poliomyelitis, osteomyelitis, and congenital dislocation of the hip.

Cahuzac et al. (1974) have shown that cerebral palsy has a valgelizing effect on the femur, and demonstrated that inactivity accentuated this effect.

Fabry et al. (1973) demonstrated increased anteversion of the femoral neck in coxa plana.

In the present investigation the highest values for the AV-angles (right 67 degrees, left 61 degrees) were found in a girl with cerebral palsy (Pat. no. 71). Another girl (no. 31) with a hemiparesis showed increased anteversion of the femoral neck on the same side. A girl with polyarthritis (no. 17) showed high values of the AV-angle (43 degrees).

The association between increased anteversion of the femoral neck and congenital dislocation of the hip has been accepted for several years (Alvik 1962, Gibson 1967, Dabadie 1971, Fabry 1973, Bjerkreim 1974). In most cases of CDH increased anteversion could also be demonstrated on the "unaffected" side (Dunlap et al. 1953, Shands & Steele 1958, Fabry 1973). The published data seldom give information about the type of congenital dislocation treated, but probably most of the patients are of the so-called late-diagnosis type treated with a plaster cast or by operation. It has not been possible to find any controlled examination of the AV-angle of children with unstable hips at birth. The present investigation demonstrates that the problem of increased anteversion of the femoral neck exists also in this group of patients.

The development of the hip in children of the present series who received prolonged treatment is of special interest. Of the eleven patients treated with plaster cast four eventually underwent derotational osteotomy. Even if those children were not examined by the same method as used in the present study, one must assume that they had considerably increased anteversion of the femoral neck. Two patients were checked in the orthopaedic department and had normal findings. The remaining five patients are included in the present follow-up study. Three of them had values of the AV-angle 1–2 S.D. above the mean value and two had normal values except for a difference between the right and left sides of 5 and 7 degrees respectively. Thus over 50 per cent of the patients who received prolonged treatment showed increased anteversion of the femoral neck.

The relation between increased anteversion of the femoral neck and CDH has been explained by different opposing theories. Alvik (1962) regarded the increased anteversion as one of the manifestations of CDH, possibly genetically determined. Others have regarded the increased anteversion as a secondary phenomenon, possibly due to muscular inactivity or special therapeutic procedures (Fettweis 1971, Papadopulos 1971, Sommerville 1974). Different theories of pathogenesis for the latter hypothesis have been proposed. Fettweis (1971) holds the view that muscular imbalance produces uneven pressure upon the epiphysis and leads to uneven development of the growth of the skeleton. Papadopulos (1971) advocates the theory of relative hypertrophy of muscles affecting the rotation movement of the hip.

If the sloping acetabular roof with an indistinctly marked lateral margin and a small epiphysis of the femoral head are characteristics of the dysplastic hip (Bjerkreim 1974), it may be noted that no correlation was found between increased anteversion of the femoral neck and dysplastic changes in the present investigation.

One of the most important questions is whether abduction splinting may have an untoward influence upon the normal development of the hip joint.

As early as 1961 Palmén reported two cases with fragmentation of the femoral head after the ordinary splinting therapy. Later similar observations have been made by others (Dabadie 1971). The potential danger of avascular necrosis after abduction splinting has recently been stressed by Mears (1974), but strongly opposed by Fredensborg (1976). Siffert et al. (1972) warn against the extreme "frog" position which produces abnormal pressure on the anterior part of the acetabulum and results in failure of normal development. Bjerkreim (1974) states that "it is not likely that the pillow treatment is harmful to the hip joint". In any case, it is justified to conclude that avascular necrosis of the femoral head represents a relatively rare complication. However, I have not been able to find any controlled investigation of possible other adverse effects of the splinting therapy.

The first months of life represent an extremely important period of the child's motor development, and it would be surprising if the relative inactivity of the lower extremities in the maximally abducted position should not produce a muscular imbalance with secondary changes in the bony structures. Three muscles are important for both abduction and internal rotation of the hip, namely gluteus medius, gluteus minimus and the tensor fasciae latea. Partial atrophy and shortening of special muscle groups may finally lead to inward rotation of the femur, and the effect may be more marked in individuals with less developed muscles (slender subjects, patients with muscular atrophies of various origin a. o.).

The possible harmful effect of abduction therapy might be verified by splinting healthy children with stable hips at birth. Such a project is however unacceptable on ethical grounds. Another approach to the problem is a systematic follow-up study of children with unstable hips at birth which are left untreated. The group of children examined in the present investigation is too small to allow any definite conclusions, but one gains a strong impression that abduction splinting represents at least one of the pathogenetic factors for the increased anteversion of the femoral neck.

The beneficial effect of splinting against luxation, subluxation and serious dysplastic changes of the hip is undisputable, in spite of the fact that some cases are "missed" at birth and a certain number do not respond to apparently correct therapy. However, in regions where instability of the hip joint appears relatively frequently (Trondheim 22.4 per thousand) the present therapeutic regime possibly leads to pathological development of the hip in 2–4 children per thousand liveborn. This number is too high and indicates the necessity of finding more selective criteria of therapy of the newborn.

The results of the present investigation have shown an asymmetrical development of the hip joint in a well-defined group of children. Differences of the AV-angle between the right and left hip exceeding 10° were found in 28 per cent in group A and 23 per cent in group B. On average the values for the right side were higher than those for the left. No certain explanation for these findings can be presented, but the clue to the problem may well be found in the well-known habitual oblique position assumed by many infants. Palmén (1976) has found the habitual oblique position to be the cause of one-sided limited abduction of the hip in about two per cent of infants.

Discussion of the indications for derotational osteotomy in cases with increased anteversion of the femoral neck is outside the scope of this project. In view of the present investigation one would tend to advocate a more "dynamic" view of the therapy, and at least in some patients consider physiotherapy as a possible alternative to operative treatment (Scholder 1967).

SUMMARY

Among 6509 newborn instability of the hip joint was found in 146 (22.4 per thousand liveborns). All of them were treated with Frejkas cusion splint, usually for three months. Eleven patients required additional treatment with a plaster cast, and in four a derotational osteotomy was performed.

During infancy the children showed several deviations from the normal motor development, the most important being an increased abduction and an increased external rotation capacity of the hip joint. A small group of infants showed a gradual increase of the passive internal rotation from 40–50 degrees to 80–90 degrees.

In 129 patients a detailed clinical and radiological follow-up study was performed at the age of four to six years, and the results were compared with those of 100 healthy children and 17 children with unstable hips at birth left untreated.

Clinical examination at the age of four to six years showed that about 20 per cent of the girls and about 10 per cent of the boys with unstable hips treated with abduction had abnormal function of the hip. The most important findings were

increased internal rotation and decreased external rotation in girls and increased abduction in boys.

Radiological examination of the treated group of affected children showed pathological values of the angles measured in 30 per cent of the girls and in 10 per cent of the boys. In girls pathological mean values were demonstrated for all angles measured (AC, CE, CCD and AV), whereas the boys displayed pathological values of the AV-angle only.

The mean angle values of the untreated children with unstable hips at birth showed no significant deviation from the values of the control group.

A positive correlation was demonstrated between the values of the AC-angle and the CE-angle, but no correlation could be demonstrated between the AVangle and the other angles.

Slender children showed significantly higher values for the AV-angle than children with a low height/weight ratio.

Seven of eleven children who received prolonged treatment with a plaster cast showed pronounced anteversion of the femoral neck. Increased anteversion of the femoral neck was also demonstrated in three patients with concomitant muscular abnormalities.

It is suggested that increased anteversion of the femoral neck is a secondary phenomenon in CDH, possibly because of relative muscular inactivity, and that abduction splintage may be a causative factor.

APPENDIX

Results of the radiological examination of 129 children with unstable hips at birth treated with an abduction splint (group A), 100 healthy children (group B) and 17 children with unstable hips at birth left untreated (group C). The exluded numbers represent subjects not followed up.

GROUP A

Case		AC-angle		CE-angle		CCD-angle		AV-angle	
no.	Name	R	L	R	L	R	L	R	L
1	Au	10	10	34	34	138	140	63	62
2	Sa	20	20	32	32	139	139	59	60
3	Fo	15	15	32	32	133	131	35	40
5	Od	13	13	35	40	133	133	35	35
6	Du	10	10	36	38	135	135	36	35
7	Gj	20	18	25	29	143	143	34	34
8	Pr	18	16	26	29	139	139	47	47
9	Kn	12	12	31	38	131	127	35	24
10	St	18	18	27	27	130	138	29	25
11	Da	12	12	32	36	132	130	35	26
12	Fu	5	8	39	39	143	143	35	35
14	Pe	8	10	40	34	142	140	53	56
15	Br	15	15	25	25	135	135	38	32
16	Un	15	15	27	27	125	126	38	36
17	Ve	13	13	25	30	146	146	43	43
18	Ha	14	14	30	30	133	135	33	36
19	Tø	13	10	32	35	126	126	33	24
20	To	16	18	30	27	130	130	42	42
21	Aa	17	17	30	30	133	122	41	36
22	Ru	10	12	32	32	129	129	35	39
23	Sn	6	3	32	39	136	132	41	26
24	No	21	24	23	23	139	138	49	45
25	Mø	15	15	27	27	134	132	45	50
26	Bu	10	8	36	36	127	128	35	32
27	Fr	12	12	30	30	145	145	24	24
28	Sc	17	17	30	34	140	137	38	25
30	Am	17	17	30	30	129	129	28	28
31	So	15	21	20	20	140	147	17	23
32	Ni	18	18	30	30	143	143	40	40
33	Sk	19	19	27	25	146	148	43	40
35	Hø	12	12	33	33	128	128	30	30
36	Bu	13	13	40	40	132	132	41	41
37	Jo	18	18	25	25	128	131	46	38
38	Kn	8	8	37	37	130	128	39	38
39	Da	12	12	28	28	140	140	26	26
40	Sæ	15	15	32	33	137	135	41	37
41	Sø	10	15	31	28	134	134	34	34
42	Br	13	13	31	31	137	135	33	28
44	Tr	18	18	29	29	137	137	39	43
45	We	14	14	30	30	135	138	40	40
46	El	12	12	40	35	140	143	30	25
47	No	14	8	31	41	131	134	32	29
48	Ha	18	18	31	31	141	146	62	56
49	Pe	20	20	27	27	141	141	41	41
50	Wi	18	18	30	32	145	143	55	47

APPENDIX (continued).

GROUP A

Case no.	Name	AC-angle R	AC-angle L	CE-angle R	CE-angle L	CCD-angle R	CCD-angle L	AV-angle R	AV-angle L
51	Rø	10	8	33	33	137	137	30	35
52	Be	20	20	30	30	130	134	48	38
54	St	14	18	30	30	152	146	50	53
57	Fo	12	10	32	37	132	129	33	27
58	Sk	10	10	35	35	147	146	32	24
59	Fr	20	17	26	28	140	142	30	23
60	Re	14	14	30	30	147	147	35	36
61	Ha	18	18	25	30	128	126	54	38
62	Ri	13	13	24	31	135	137	40	27
63	Je	9	9	40	40	134	133	34	35
64	St	12	12	31	31	143	143	40	40
65	St	15	15	30	30	145	152	48	54
66	Bo	13	13	32	32	151	147	44	37
67	Nj	10	10	35	35	126	127	43	35
69	So	20	20	25	25	135	133	35	30
70	Sæ	15	15	27	32	130	131	36	33
71	Ne	25	25	16	24	151	154	67	61
72	Qu	16	16	29	29	135	135	31	30
73	Sv	15	15	30	34	135	136	22	17
74	Mu	15	15	35	35	137	136	43	46
75	Rø	15	15	20	20	141	140	41	30
77	Ne	12	12	29	29	144	141	31	38
78	Sl	30	23	14	9	134	146	29	6
79	We	18	18	25	30	134	131	33	30
80	La	13	13	30	30	132	143	46	40
81	An	16	16	27	29	147	146	47	41
82	St	16	16	30	30	142	141	41	39
83	Do	15	15	29	35	136	134	41	45
85	Wa	15	15	30	32	132	144	39	32
87	Lo	13	13	36	36	131	131	21	22
88	Sk	18	15	33	31	133	129	34	33
89	Ta	11	11	31	31	142	142	51	51
90	Pa	15	15	31	31	140	135	42	40
92	So	20	20	23	23	139	142	33	36
93	Rø	14	14	30	40	142	145	26	33
94	Es	18	18	23	26	135	134	31	33
95	Ka	12	12	25	25	139	135	49	53
96	Hå	15	13	34	34	126	123	50	43
97	Sl	22	18	27	32	132	126	45	27
98	Da	15	15	33	35	128	124	36	30
99	Ol	25	25	20	20	139	138	35	30
100	Ol	13	13	30	30	135	133	33	34
101	Gr	10	13	40	40	141	140	49	42
102	Pe	23	23	25	22	137	133	41	39
104	Ho	13	13	35	35	137	133	37	32
105	Jo	10	10	36	36	143	143	36	36
106	Af	15	15	33	37	129	129	49	49
107	Jo	15	15	28	30	143	143	32	47
108	Hj	15	15	34	34	133	133	39	39
109	Gr	15	15	30	30	148	148	37	37
110	Ha	15	13	32	37	137	134	39	38
111	Gr	14	14	30	30	133	136	43	41

APPENDIX (continued).

GROUP A

	Case	AC-angle		CE-angle		CCD-angle		AV-angle	
no.	Name	R	L	R	L	R	L	R	L
113	Aa	14	14	33	35	137	137	42	42
114	Kr	20	20	25	30	129	126	44	43
115	Al	17	17	26	26	137	137	26	26
116	Aa	20	20	21	25	136	136	44	43
117	Sj	19	19	21	25	136	138	34	34
118	Tø	18	18	30	35	135	138	50	50
119	Ma	15	10	30	35	143	141	53	44
120	Ma	15	15	31	35	127	129	46	46
121	Ne	18	18	25	30	137	137	33	33
122	Vi	19	19	27	24	135	136	27	22
123	Ro	10	14	35	33	134	134	33	37
124	Ho	18	18	28	30	137	129	39	33
125	Ov	16	18	26	27	131	132	23	25
126	Ås	17	17	26	26	137	139	32	33
127	Iv	15	12	33	40	148	136	40	35
128	Fj	14	14	32	30	141	139	39	51
129	Be	20	20	22	24	134	134	39	39
130	Gj	17	15	25	30	139	141	32	38
131	Ni	14	14	37	35	129	128	39	36
132	Fa	17	17	25	25	141	142	45	30
133	Mj	13	13	32	32	131	133	29	28
134	Vi	10	15	30	23	133	129	45	40
135	Gr	23	23	25	25	139	133	48	59
137	Sa	20	18	27	27	156	148	48	42
138	Hu	17	17	24	28	134	138	25	38
139	Gr	17	17	35	32	124	124	28	28
140	Le	37	21	10	21	120	150	5	9
141	Pe	15	13	30	32	133	134	43	42
142	Ny	17	19	30	30	134	130	27	11
143	Er	20	20	25	25	134	130	36	45
145	Te	17	13	33	35	135	134	45	34
146	Sk	20	22	25	27	132	139	30	35

APPENDIX (continued).

GROUP B

no.	Case Name	AC-angle R	AC-angle L	CE-angle R	CE-angle L	CCD-angle R	CCD-angle L	AV-angle R	AV-angle L
379	Si	20	20	29	27	133	134	35	33
380	Ge	7	7	40	42	129	129	30	30
382	Sa	15	18	27	27	135	136	14	16
383	Su	15	15	25	30	127	126	30	32
385	Be	12	12	27	34	143	138	39	37
388	Næ	17	15	25	25	137	137	23	21
389	Ag	15	12	25	27	136	137	30	29
390	Ca	17	17	27	32	138	139	38	31
391	Th	10	10	33	37	122	124	29	32
393	Gr	10	10	35	35	127	127	28	26
394	Kv	13	13	39	39	123	124	33	29
395	Su	15	12	27	27	131	128	22	19
396	Sk	19	19	24	22	130	131	36	37
399	Rø	9	9	31	34	135	135	27	27
401	Wo	15	15	30	36	130	128	34	22
402	An	8	8	38	38	126	123	36	35
406	Gr	18	17	21	24	141	139	33	33
407	He	20	20	20	22	139	139	41	36
408	My	8	8	35	38	149	147	19	18
409	Me	12	12	35	35	129	133	28	25
411	Ha	10	13	31	31	143	142	36	39
412	Ki	13	13	27	33	131	134	23	29
413	Gj	11	15	30	27	135	133	23	29
414	Sl	15	13	29	32	155	147	29	19
415	Ny	10	12	35	38	145	146	27	23
419	Mi	24	24	15	17	131	130	40	32
420	Mo	20	18	26	26	146	147	45	45
421	Ro	10	10	37	37	134	132	29	25
423	Sø	14	14	35	34	141	137	22	23
424	Lu	12	12	31	35	126	125	41	33
425	Gr	15	15	30	30	129	133	17	16
426	Le	14	13	35	35	134	134	36	36
430	Er	10	10	40	41	124	132	43	36
431	Lu	12	12	36	36	123	124	26	34
432	Ha	25	25	18	18	142	141	23	19
433	Be	12	12	36	31	125	134	32	11
437	Be	15	15	31	28	138	136	38	40
438	Jo	20	16	33	38	141	132	25	34
440	Ja	13	13	30	35	136	136	21	22
441	Ma	15	15	30	30	145	145	36	36
442	Ha	12	12	35	35	136	137	19	25
447	Sv	13	15	41	38	142	138	43	45
448	Ha	13	18	30	30	129	129	43	44
449	Ku	13	13	25	30	135	135	45	45
450	Ha	13	13	35	30	145	148	38	40
451	Ve	10	10	35	38	144	144	33	25
453	Ha	10	12	40	40	131	130	42	51
455	Rø	18	18	33	33	131	133	21	23
456	Ma	12	12	35	38	139	139	36	36
457	Vo	19	14	30	35	138	130	36	28
458	Hå	10	12	44	40	132	131	44	37
460	Fe	10	14	35	27	135	137	22	35

APPENDIX (continued).

GROUP B

no.	Case Name	AC-angle R	AC-angle L	CE-angle R	CE-angle L	CCD-angle R	CCD-angle L	AV-angle R	AV-angle L
462	Wo	17	19	30	30	139	142	50	48
463	Se	8	10	38	40	130	130	36	44
464	Re	15	10	30	30	131	128	27	33
465	Gj	17	15	25	30	140	136	36	22
468	Hå	10	10	32	36	139	140	32	27
470	Ru	15	15	26	30	137	134	34	36
471	Hå	12	12	32	36	132	133	26	29
473	Sk	10	10	35	37	135	135	44	42
474	Wo	13	13	31	29	142	143	37	31
475	Kv	13	13	33	37	124	122	37	37
476	Mo	15	15	34	35	138	139	29	27
479	Bj	13	13	33	33	138	140	32	27
480	St	10	10	35	38	128	129	22	22
481	Me	15	15	33	33	142	139	48	47
482	La	13	13	30	30	135	135	23	22
483	Tr	15	15	30	33	139	138	37	24
485	Ny	8	8	42	44	126	125	33	30
486	Jo	14	14	32	30	138	139	29	33
487	Tø	22	22	26	23	138	136	34	39
488	Ka	13	13	32	32	129	129	21	21
489	Aa	13	13	36	36	134	135	43	44
491	Ha	12	17	35	30	135	135	40	40
492	Ti	15	15	30	30	133	133	21	21
493	Tr	13	13	35	35	134	134	16	16
494	Ha	18	15	25	30	133	137	25	29
496	Kv	15	11	31	39	133	134	28	22
497	Be	18	18	28	30	129	129	26	26
498	Wo	15	15	28	30	136	133	22	21
499	Bj	12	12	30	32	130	130	33	33
500	Be	8	8	32	34	146	146	42	39
502	No	15	15	30	32	132	132	26	24
503	Ul	17	17	29	26	147	149	29	30
504	Fu	15	15	35	32	127	127	20	22
505	Sl	15	18	28	30	120	121	33	32
506	Ha	13	13	33	35	132	132	34	31
507	No	15	15	30	30	137	134	21	19
508	St	18	18	25	28	135	135	33	33
509	He	12	12	35	35	146	146	23	22
510	Sv	10	10	34	34	119	119	23	27
513	Ha	13	13	30	33	130	130	37	32
514	Bu	15	15	31	31	131	131	30	33
515	Go	12	12	30	32	123	125	17	19
516	Pa	17	17	27	27	138	135	36	28
518	Be	19	19	26	30	140	140	47	46
519	Jo	13	13	38	40	128	128	40	40
520	La	12	12	33	33	133	136	30	31
523	Fr	12	12	29	29	132	134	29	30
524	Sn	15	15	29	31	137	143	42	36

APPENDIX (continued).

GROUP C

Case		AC-angle		CE-angle		CCD-angle		AV-angle	
no.	Name	R	L	R	L	R	L	R	L
757	An	15	15	33	33	121	121	29	29
758	Su	12	12	30	35	144	144	50	37
761	An	10	10	36	40	128	128	31	28
762	Re	13	15	37	30	129	130	26	35
763	Pe	12	12	30	35	132	129	26	24
764	Gi	15	15	33	34	129	129	28	34
765	Tø	13	13	31	32	138	142	33	37
766	Bi	12	10	38	38	132	131	29	32
767	Pe	10	7	33	42	127	125	35	31
768	To	22	22	23	23	130	127	36	32
769	Jo	15	15	31	34	126	126	36	30
770	Gå	12	12	36	33	126	128	39	45
771	Re	17	17	29	26	143	141	50	45
773	Ha	18	15	33	35	133	128	43	36
776	He	10	10	35	35	135	132	41	47
777	Gu	20	20	30	34	135	130	26	22
778	Ri	7	7	38	38	136	133	26	19

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